MySQL 5.1 Reference Manual

Including MySQL Cluster NDB 6.X/7.X Reference Guide

Abstract

This is the MySQL™ Reference Manual. It documents MySQL 5.1 through 5.1.73, as well as MySQL Cluster releases based on versions 6.1, 6.2, 6.3, 7.0, and 7.1 of the NDB storage engine through 5.1.15-ndb-6.1.23, 5.1.51-ndb-6.2.19, 5.1.73-ndb-6.3.55, 5.1.73-ndb-7.0.42, and 5.1.77-ndb-7.1.37.

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Preface and Legal Notices

This is the Reference Manual for the MySQL Database System, version 5.1, through release 5.1.73. Differences between minor versions of MySQL 5.1 are noted in the present text with reference to release numbers (5.1.*x*). For license information, see the Legal Notices.

This manual is not intended for use with older versions of the MySQL software due to the many functional and other differences between MySQL 5.1 and previous versions. If you are using an earlier release of the MySQL software, please refer to the appropriate manual. For example, *MySQL 5.0 Reference Manual* covers the 5.0 series of MySQL software releases.

If you are using MySQL 5.5, please refer to the *MySQL 5.5 Reference Manual*.

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Chapter 1 General Information

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The following list describes some sections of particular interest in this manual:

• For a discussion of MySQL Database Server capabilities, see Section 1.3.2, "The Main Features of MySQL".

• For an overview of new MySQL features, see Section 1.4, "What Is New in MySQL 5.1". For information about the changes in each version, see the Release Notes.

- For installation instructions, see Chapter 2, *Installing and Upgrading MySQL*. For information about upgrading MySQL, see Section 2.13.1, "Upgrading MySQL".

- For a tutorial introduction to the MySQL Database Server, see Chapter 3, *Tutorial*.

- For information about configuring and administering MySQL Server, see Chapter 5, *MySQL Server Administration*.

- For information about security in MySQL, see Chapter 6, *Security*.

- For information about setting up replication servers, see Chapter 16, *Replication*.

- For information about MySQL Enterprise, the commercial MySQL release with advanced features and management tools, see Chapter 23, *MySQL Enterprise Edition*.

- For answers to a number of questions that are often asked concerning the MySQL Database Server and its capabilities, see Appendix A, *MySQL 5.1 Frequently Asked Questions*.

- For a history of new features and bug fixes, see the Release Notes.

> **Important**
>
> To report problems or bugs, please use the instructions at Section 1.7, "How to Report Bugs or Problems". If you find a sensitive security bug in MySQL Server, please let us know immediately by sending an email message to `<secalert_us@oracle.com>`. Exception: Support customers should report all problems, including security bugs, to Oracle Support.

1.1 About This Manual

This is the Reference Manual for the MySQL Database System, version 5.1, through release 5.1.73. Differences between minor versions of MySQL 5.1 are noted in the present text with reference to release numbers (5.1.x). For license information, see the Legal Notices.

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If you are using MySQL 5.5, please refer to the *MySQL 5.5 Reference Manual*.

Because this manual serves as a reference, it does not provide general instruction on SQL or relational database concepts. It also does not teach you how to use your operating system or command-line interpreter.

The MySQL Database Software is under constant development, and the Reference Manual is updated frequently as well. The most recent version of the manual is available online in searchable form at http://dev.mysql.com/doc/. Other formats also are available there, including HTML, PDF, and EPUB versions.

The Reference Manual source files are written in DocBook XML format. The HTML version and other formats are produced automatically, primarily using the DocBook XSL stylesheets. For information about DocBook, see http://docbook.org/

If you have questions about using MySQL, you can ask them using our mailing lists or forums. See Section 1.6.1, "MySQL Mailing Lists", and Section 1.6.2, "MySQL Community Support at the MySQL Forums". If you have suggestions concerning additions or corrections to the manual itself, please send them to the http://www.mysql.com/company/contact/.

This manual was originally written by David Axmark and Michael "Monty" Widenius. It is maintained by the MySQL Documentation Team, consisting of Chris Cole, Paul DuBois, Edward Gilmore, Stefan Hinz, David Moss, Philip Olson, Daniel Price, Daniel So, and Jon Stephens.

1.2 Typographical and Syntax Conventions

This manual uses certain typographical conventions:

- `Text in this style` is used for SQL statements; database, table, and column names; program listings and source code; and environment variables. Example: "To reload the grant tables, use the `FLUSH PRIVILEGES` statement."

- **`Text in this style`** indicates input that you type in examples.

- `Text in this style` indicates the names of executable programs and scripts, examples being `mysql` (the MySQL command-line client program) and `mysqld` (the MySQL server executable).

- *`Text in this style`* is used for variable input for which you should substitute a value of your own choosing.

- *Text in this style* is used for emphasis.

- **Text in this style** is used in table headings and to convey especially strong emphasis.

- `Text in this style` is used to indicate a program option that affects how the program is executed, or that supplies information that is needed for the program to function in a certain way. *Example*: "The `--host` option (short form `-h`) tells the `mysql` client program the hostname or IP address of the MySQL server that it should connect to".

- File names and directory names are written like this: "The global `my.cnf` file is located in the `/etc` directory."

- Character sequences are written like this: "To specify a wildcard, use the '`%`' character."

When commands are shown that are meant to be executed from within a particular program, the prompt shown preceding the command indicates which command to use. For example, `shell>` indicates a command that you execute from your login shell, `root-shell>` is similar but should be executed as `root`, and `mysql>` indicates a statement that you execute from the `mysql` client program:

```
shell> type a shell command here
root-shell> type a shell command as root here
mysql> type a mysql statement here
```

In some areas different systems may be distinguished from each other to show that commands should be executed in two different environments. For example, while working with replication the commands might be prefixed with `master` and `slave`:

```
master> type a mysql command on the replication master here
slave> type a mysql command on the replication slave here
```

The "shell" is your command interpreter. On Unix, this is typically a program such as `sh`, `csh`, or `bash`. On Windows, the equivalent program is `command.com` or `cmd.exe`, typically run in a console window.

When you enter a command or statement shown in an example, do not type the prompt shown in the example.

Database, table, and column names must often be substituted into statements. To indicate that such substitution is necessary, this manual uses *db_name*, *tbl_name*, and *col_name*. For example, you might see a statement like this:

```
mysql> SELECT col_name FROM db_name.tbl_name;
```

This means that if you were to enter a similar statement, you would supply your own database, table, and column names, perhaps like this:

```
mysql> SELECT author_name FROM biblio_db.author_list;
```

SQL keywords are not case sensitive and may be written in any lettercase. This manual uses uppercase.

In syntax descriptions, square brackets ("[" and "]") indicate optional words or clauses. For example, in the following statement, IF EXISTS is optional:

```
DROP TABLE [IF EXISTS] tbl_name
```

When a syntax element consists of a number of alternatives, the alternatives are separated by vertical bars ("|"). When one member from a set of choices *may* be chosen, the alternatives are listed within square brackets ("[" and "]"):

```
TRIM([[BOTH | LEADING | TRAILING] [remstr] FROM] str)
```

When one member from a set of choices *must* be chosen, the alternatives are listed within braces ("{" and "}"):

```
{DESCRIBE | DESC} tbl_name [col_name | wild]
```

An ellipsis (...) indicates the omission of a section of a statement, typically to provide a shorter version of more complex syntax. For example, SELECT ... INTO OUTFILE is shorthand for the form of SELECT statement that has an INTO OUTFILE clause following other parts of the statement.

An ellipsis can also indicate that the preceding syntax element of a statement may be repeated. In the following example, multiple *reset_option* values may be given, with each of those after the first preceded by commas:

```
RESET reset_option [,reset_option] ...
```

Commands for setting shell variables are shown using Bourne shell syntax. For example, the sequence to set the CC environment variable and run the configure command looks like this in Bourne shell syntax:

```
shell> CC=gcc ./configure
```

If you are using csh or tcsh, you must issue commands somewhat differently:

```
shell> setenv CC gcc
shell> ./configure
```

1.3 Overview of the MySQL Database Management System

1.3.1 What is MySQL?

MySQL, the most popular Open Source SQL database management system, is developed, distributed, and supported by Oracle Corporation.

The MySQL Web site (http://www.mysql.com/) provides the latest information about MySQL software.

- **MySQL is a database management system.**

  A database is a structured collection of data. It may be anything from a simple shopping list to a picture gallery or the vast amounts of information in a corporate network. To add, access, and process data stored in a computer database, you need a database management system such as MySQL Server. Since computers are very good at handling large amounts of data, database management systems play a central role in computing, as standalone utilities, or as parts of other applications.

- **MySQL databases are relational.**

   A relational database stores data in separate tables rather than putting all the data in one big storeroom. The database structures are organized into physical files optimized for speed. The logical model, with objects such as databases, tables, views, rows, and columns, offers a flexible programming environment. You set up rules governing the relationships between different data fields, such as one-to-one, one-to-many, unique, required or optional, and "pointers" between different tables. The database enforces these rules, so that with a well-designed database, your application never sees inconsistent, duplicate, orphan, out-of-date, or missing data.

  The SQL part of "MySQL" stands for "Structured Query Language". SQL is the most common standardized language used to access databases. Depending on your programming environment, you might enter SQL directly (for example, to generate reports), embed SQL statements into code written in another language, or use a language-specific API that hides the SQL syntax.

  SQL is defined by the ANSI/ISO SQL Standard. The SQL standard has been evolving since 1986 and several versions exist. In this manual, "SQL-92" refers to the standard released in 1992, "SQL:1999" refers to the standard released in 1999, and "SQL:2003" refers to the current version of the standard. We use the phrase "the SQL standard" to mean the current version of the SQL Standard at any time.

- **MySQL software is Open Source.**

   Open Source means that it is possible for anyone to use and modify the software. Anybody can download the MySQL software from the Internet and use it without paying anything. If you wish, you may study the source code and change it to suit your needs. The MySQL software uses the GPL (GNU General Public License), http://www.fsf.org/licenses/, to define what you may and may not do with the software in different situations. If you feel uncomfortable with the GPL or need to embed MySQL code into a commercial application, you can buy a commercially licensed version from us. See the MySQL Licensing Overview for more information (http://www.mysql.com/company/legal/licensing/).

- **The MySQL Database Server is very fast, reliable, scalable, and easy to use.**

  If that is what you are looking for, you should give it a try. MySQL Server can run comfortably on a desktop or laptop, alongside your other applications, web servers, and so on, requiring little or no attention. If you dedicate an entire machine to MySQL, you can adjust the settings to take advantage of all the memory, CPU power, and I/O capacity available. MySQL can also scale up to clusters of machines, networked together.

  MySQL Server was originally developed to handle large databases much faster than existing solutions and has been successfully used in highly demanding production environments for several years. Although under constant development, MySQL Server today offers a rich and useful set of functions. Its connectivity, speed, and security make MySQL Server highly suited for accessing databases on the Internet.

- **MySQL Server works in client/server or embedded systems.**

  The MySQL Database Software is a client/server system that consists of a multi-threaded SQL server that supports different backends, several different client programs and libraries, administrative tools, and a wide range of application programming interfaces (APIs).

  We also provide MySQL Server as an embedded multi-threaded library that you can link into your application to get a smaller, faster, easier-to-manage standalone product.

- **A large amount of contributed MySQL software is available.**

  MySQL Server has a practical set of features developed in close cooperation with our users. It is very likely that your favorite application or language supports the MySQL Database Server.

The official way to pronounce "MySQL" is "My Ess Que Ell" (not "my sequel"), but we do not mind if you pronounce it as "my sequel" or in some other localized way.

1.3.2 The Main Features of MySQL

This section describes some of the important characteristics of the MySQL Database Software. In most respects, the roadmap applies to all versions of MySQL. For information about features as they are introduced into MySQL on a series-specific basis, see the "In a Nutshell" section of the appropriate Manual:

- MySQL 8.0: What Is New in MySQL 8.0

- MySQL 5.7: What Is New in MySQL 5.7

- MySQL 5.6: What Is New in MySQL 5.6

- MySQL 5.5: What Is New in MySQL 5.5

Internals and Portability

- Written in C and C++.

- Tested with a broad range of different compilers.

- Works on many different platforms. See http://www.mysql.com/support/supportedplatforms/database.html.

- For portability, uses `CMake` in MySQL 5.5 and up. Previous series use GNU Automake, Autoconf, and Libtool.

- Tested with Purify (a commercial memory leakage detector) as well as with Valgrind, a GPL tool (http://developer.kde.org/~sewardj/).

- Uses multi-layered server design with independent modules.

- Designed to be fully multi-threaded using kernel threads, to easily use multiple CPUs if they are available.

- Provides transactional and nontransactional storage engines.

- Uses very fast B-tree disk tables (`MyISAM`) with index compression.

- Designed to make it relatively easy to add other storage engines. This is useful if you want to provide an SQL interface for an in-house database.

- Uses a very fast thread-based memory allocation system.

- Executes very fast joins using an optimized nested-loop join.

- Implements in-memory hash tables, which are used as temporary tables.

- Implements SQL functions using a highly optimized class library that should be as fast as possible. Usually there is no memory allocation at all after query initialization.

- Provides the server as a separate program for use in a client/server networked environment, and as a library that can be embedded (linked) into standalone applications. Such applications can be used in isolation or in environments where no network is available.

Data Types

- Many data types: signed/unsigned integers 1, 2, 3, 4, and 8 bytes long, `FLOAT`, `DOUBLE`, `CHAR`, `VARCHAR`, `BINARY`, `VARBINARY`, `TEXT`, `BLOB`, `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, `YEAR`, `SET`, `ENUM`, and OpenGIS spatial types. See Chapter 11, *Data Types*.

- Fixed-length and variable-length string types.

Statements and Functions

- Full operator and function support in the `SELECT` list and `WHERE` clause of queries. For example:

```
mysql> SELECT CONCAT(first_name, ' ', last_name)
    -> FROM citizen
    -> WHERE income/dependents > 10000 AND age > 30;
```

- Full support for SQL `GROUP BY` and `ORDER BY` clauses. Support for group functions (`COUNT()`, `AVG()`, `STD()`, `SUM()`, `MAX()`, `MIN()`, and `GROUP_CONCAT()`).

- Support for `LEFT OUTER JOIN` and `RIGHT OUTER JOIN` with both standard SQL and ODBC syntax.

- Support for aliases on tables and columns as required by standard SQL.

- Support for `DELETE`, `INSERT`, `REPLACE`, and `UPDATE` to return the number of rows that were changed (affected), or to return the number of rows matched instead by setting a flag when connecting to the server.

- Support for MySQL-specific `SHOW` statements that retrieve information about databases, storage engines, tables, and indexes. Support for the `INFORMATION_SCHEMA` database, implemented according to standard SQL.

- An `EXPLAIN` statement to show how the optimizer resolves a query.

- Independence of function names from table or column names. For example, `ABS` is a valid column name. The only restriction is that for a function call, no spaces are permitted between the function name and the "`(`" that follows it. See Section 9.3, "Keywords and Reserved Words".

- You can refer to tables from different databases in the same statement.

Security

- A privilege and password system that is very flexible and secure, and that enables host-based verification.

- Password security by encryption of all password traffic when you connect to a server.

Scalability and Limits

- Support for large databases. We use MySQL Server with databases that contain 50 million records. We also know of users who use MySQL Server with 200,000 tables and about 5,000,000,000 rows.

- Support for up to 64 indexes per table. Each index may consist of 1 to 16 columns or parts of columns. The maximum index width is 767 bytes for `InnoDB` tables, or 1000 for `MyISAM`. An index may use a prefix of a column for `CHAR`, `VARCHAR`, `BLOB`, or `TEXT` column types.

Connectivity

- Clients can connect to MySQL Server using several protocols:

  - Clients can connect using TCP/IP sockets on any platform.

  - On Windows systems, clients can connect using named pipes if the server is started with the `--enable-named-pipe` option. Windows servers also support shared-memory connections if started with the `--shared-memory` option. Clients can connect through shared memory by using the `--protocol=memory` option.

  - On Unix systems, clients can connect using Unix domain socket files.

- MySQL client programs can be written in many languages. A client library written in C is available for clients written in C or C++, or for any language that provides C bindings.

- APIs for C, C++, Eiffel, Java, Perl, PHP, Python, Ruby, and Tcl are available, enabling MySQL clients to be written in many languages. See Chapter 21, *Connectors and APIs*.

- The Connector/ODBC (MyODBC) interface provides MySQL support for client programs that use ODBC (Open Database Connectivity) connections. For example, you can use MS Access to connect to your MySQL server. Clients can be run on Windows or Unix. Connector/ODBC source is available. All ODBC 2.5 functions are supported, as are many others. See MySQL Connector/ODBC Developer Guide.

- The Connector/J interface provides MySQL support for Java client programs that use JDBC connections. Clients can be run on Windows or Unix. Connector/J source is available. See MySQL Connector/J 5.1 Developer Guide.

- MySQL Connector/Net enables developers to easily create .NET applications that require secure, high-performance data connectivity with MySQL. It implements the required ADO.NET interfaces and integrates into ADO.NET aware tools. Developers can build applications using their choice of .NET languages. MySQL Connector/Net is a fully managed ADO.NET driver written in 100% pure C#. See MySQL Connector/Net Developer Guide.

Localization

- The server can provide error messages to clients in many languages. See Section 10.2, "Setting the Error Message Language".

- Full support for several different character sets, including `latin1` (cp1252), `german`, `big5`, `ujis`, several Unicode character sets, and more. For example, the Scandinavian characters "å", "ä" and "ö" are permitted in table and column names.

- All data is saved in the chosen character set.

- Sorting and comparisons are done according to the chosen character set and collation (using `latin1` and Swedish collation by default). It is possible to change this when the MySQL server is started. To see

an example of very advanced sorting, look at the Czech sorting code. MySQL Server supports many different character sets that can be specified at compile time and runtime.

- The server time zone can be changed dynamically, and individual clients can specify their own time zone. See Section 10.6, "MySQL Server Time Zone Support".

Clients and Tools

- MySQL includes several client and utility programs. These include both command-line programs such as `mysqldump` and `mysqladmin`, and graphical programs such as MySQL Workbench.

- MySQL Server has built-in support for SQL statements to check, optimize, and repair tables. These statements are available from the command line through the `mysqlcheck` client. MySQL also includes `myisamchk`, a very fast command-line utility for performing these operations on `MyISAM` tables. See Chapter 4, *MySQL Programs*.

- MySQL programs can be invoked with the `--help` or `-?` option to obtain online assistance.

1.3.3 History of MySQL

We started out with the intention of using the `mSQL` database system to connect to our tables using our own fast low-level (ISAM) routines. However, after some testing, we came to the conclusion that `mSQL` was not fast enough or flexible enough for our needs. This resulted in a new SQL interface to our database but with almost the same API interface as `mSQL`. This API was designed to enable third-party code that was written for use with `mSQL` to be ported easily for use with MySQL.

MySQL is named after co-founder Monty Widenius's daughter, My.

The name of the MySQL Dolphin (our logo) is "Sakila," which was chosen from a huge list of names suggested by users in our "Name the Dolphin" contest. The winning name was submitted by Ambrose Twebaze, an Open Source software developer from Swaziland, Africa. According to Ambrose, the feminine name Sakila has its roots in SiSwati, the local language of Swaziland. Sakila is also the name of a town in Arusha, Tanzania, near Ambrose's country of origin, Uganda.

1.4 What Is New in MySQL 5.1

This section summarizes what has been added to MySQL 5.1 and what has been deprecated for further use.

- Added Features

- Deprecated Features

Added Features

The following features have been added to MySQL 5.1:

- **Partitioning.**   This capability enables distributing portions of individual tables across a file system, according to rules which can be set when the table is created. In effect, different portions of a table are stored as separate tables in different locations, but from the user point of view, the partitioned table is still a single table. Syntactically, this implements a number of new extensions to the `CREATE TABLE`, `ALTER TABLE`, and `EXPLAIN ... SELECT` statements. As of MySQL 5.1.6, queries against partitioned tables can take advantage of *partition pruning*. In some cases, this can result in query execution that is an order of magnitude faster than the same query against a nonpartitioned version of the same table. See Chapter 18, *Partitioning*, for further information on this functionality. (Author: Mikael Ronström)

- **Row-based replication.**   Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called *statement-based replication*. As of MySQL 5.1.5, another basis for replication is available. This is called *row-based replication*. Instead of sending SQL statements to the slave, the master writes events to its binary log that indicate how individual table rows are effected. As of MySQL 5.1.8, a third option is available: *mixed*. This will use statement-based replication by default, and only switch to row-based replication in particular cases. See Section 16.1.2, "Replication Formats". (Authors: Lars Thalmann, Guilhem Bichot, Mats Kindahl)

- **Plugin API.**   MySQL 5.1 adds support for a very flexible plugin API that enables loading and unloading of various components at runtime, without restarting the server. Although the work on this is not finished yet, *plugin full-text parsers* are a first step in this direction. This permits users to implement their own input filter on the indexed text, enabling full-text search capability on arbitrary data such as PDF files or other document formats. A pre-parser full-text plugin performs the actual parsing and extraction of the text and hands it over to the built-in MySQL full-text search. See Section 22.2, "The MySQL Plugin API". (Author: Sergey Vojtovich)

- **Event scheduler.**   MySQL Events are tasks that run according to a schedule. When you create an event, you are creating a named database object containing one or more SQL statements to be executed at one or more regular intervals, beginning and ending at a specific date and time. Conceptually, this is similar to the idea of the Unix `crontab` (also known as a "cron job") or the Windows Task Scheduler. See Section 19.4, "Using the Event Scheduler". (Author: Andrey Hristov)

- **Server log tables.**   Before MySQL 5.1, the server writes general query log and slow query log entries to log files. As of MySQL 5.1, the server's logging capabilities for these logs are more flexible. Log entries can be written to log files (as before) or to the `general_log` and `slow_log` tables in the `mysql` database. If logging is enabled, either or both destinations can be selected. The `--log-output` option controls the destination or destinations of log output. See Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations". (Author: Petr Chardin)

- **Upgrade program.**   The `mysql_upgrade` program (available as of MySQL 5.1.7) checks all existing tables for incompatibilities with the current version of MySQL Server and repairs them if necessary. This program should be run for each MySQL upgrade. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables". (Authors: Alexey Botchkov, Mikael Widenius)

- **MySQL Cluster.**   MySQL Cluster is now released as a separate product, based on MySQL 5.1 but with the addition of the `NDBCLUSTER` storage engine. Clustering support is no longer available in mainline MySQL 5.1 releases. MySQL Cluster releases are identified by a 3-part NDB version number; currently, the MySQL Cluster NDB 6.3, MySQL Cluster NDB 7.0, and MySQL Cluster NDB 7.1 release series are available for production use.

  Some of the changes in MySQL Cluster since MySQL 5.0 are listed here:

  - **MySQL Cluster replication.**   Replication between MySQL Clusters is now supported. It is now also possible to replicate between a MySQL Cluster and a noncluster database. See Section 17.6, "MySQL Cluster Replication".

  - **MySQL Cluster disk data storage.**   Formerly, the `NDBCLUSTER` storage engine was strictly in-memory; now, it is possible to store Cluster data (but not indexes) on disk. This enables MySQL Cluster to scale upward with fewer hardware (RAM) requirements than previously. In addition, the Disk Data implementation includes a new "no-steal" restoration algorithm for fast node restarts when storing very large amounts of data (terabyte range). See Section 17.5.12, "MySQL Cluster Disk Data Tables", for more information.

  - **Improved backups for MySQL Cluster.**   A fault arising in a single data node during a Cluster backup no longer causes the entire backup to be aborted, as occurred in previous versions of MySQL Cluster.

Many other new features and improvements have been made to the `NDBCLUSTER` storage engine in MySQL Cluster NDB 7.0 and MySQL Cluster NDB 7.1; for more information about these, see Section 17.1.4, "MySQL Cluster Development History".

- **Backup of tablespaces.**   The `mysqldump` utility now supports an option for dumping tablespaces. Use `-Y` or `--all-tablespaces` to enable this functionality.

- **Improvements to INFORMATION_SCHEMA.**   MySQL 5.1 provides much more information in its metadata database than was available in MySQL 5.0. New tables in the `INFORMATION_SCHEMA` database include `FILES`, `EVENTS`, `PARTITIONS`, `PROCESSLIST`, `ENGINES`, and `PLUGINS`.

- **XML functions with XPath support.**   `ExtractValue()` returns the content of a fragment of XML matching a given XPath expression. `UpdateXML()` replaces the element selected from a fragment of XML by an XPath expression supplied by the user with a second XML fragment (also user-supplied), and returns the modified XML. See Section 12.11, "XML Functions". (Author: Alexander Barkov)

- **Load emulator.**   The `mysqlslap` program is designed to emulate client load for a MySQL server and report the timing of each stage. It works as if multiple clients were accessing the server. See Section 4.5.7, "`mysqlslap` — Load Emulation Client". (Authors: Patrick Galbraith, Brian Aker)

Deprecated Features

The following constructs are deprecated in MySQL 5.1 and are removed as of MySQL 5.5. Where alternatives are shown, applications should be updated to use them.

- The `log_bin_trust_routine_creators` system variable (use `log_bin_trust_function_creators`).

- The `table_type` system variable (use `storage_engine`).

- The `TYPE` table option to specify the storage engine for `CREATE TABLE` or `ALTER TABLE` (use `ENGINE`).

- The `SHOW TABLE TYPES` SQL statement (use `SHOW ENGINES`).

- The `SHOW INNODB STATUS` and `SHOW MUTEX STATUS` SQL statements (use `SHOW ENGINE INNODB STATUS SHOW ENGINE INNODB MUTEX`).

- The `SHOW PLUGIN` SQL statement (use `SHOW PLUGINS`).

- The `LOAD TABLE ... FROM MASTER` and `LOAD DATA FROM MASTER` SQL statements (use `mysqldump` or `mysqlhotcopy` to dump tables and `mysql` to reload dump files).

- The `BACKUP TABLE` and `RESTORE TABLE` SQL statements (use `mysqldump` or `mysqlhotcopy` to dump tables and `mysql` to reload dump files).

- `TIMESTAMP(N)` data type: The ability to specify a display width of N (use without N).

- The `--master-xxx` server options to set replication parameters (use the `CHANGE MASTER TO` statement instead): `--master-host`, `--master-user`, `--master-password`, `--master-port`, `--master-connect-retry`, `--master-ssl`, `--master-ssl-ca`, `--master-ssl-capath`, `--master-ssl-cert`, `--master-ssl-cipher`, `--master-ssl-key`.

1.5 MySQL Development History

This section describes the general MySQL development history, provides an overview about features that have been implemented in previous series and that are new in MySQL 5.1, the release series covered

in this manual. The maturity level of this release series is general availability. Information about maturity levels can be found in Section 2.1.1.1, "Choosing Which Version of MySQL to Install".

Before upgrading from one release series to the next, please see the notes in Section 2.13.1, "Upgrading MySQL".

The most requested features and the versions in which they were implemented are summarized in the following table.

Feature	MySQL Series
Unions	4.0
Subqueries	4.1
R-trees	4.1 (for the `MyISAM` storage engine)
Stored procedures and functions	5.0
Views	5.0
Cursors	5.0
XA transactions	5.0
Triggers	5.0 and 5.1
Event scheduler	5.1
Partitioning	5.1
Pluggable storage engine API	5.1
Plugin API	5.1
Row-based replication	5.1
Server log tables	5.1
Scalability and performance improvements	5.1 (with InnoDB Plugin)

1.6 MySQL Information Sources

This section lists sources of additional information that you may find helpful, such as the MySQL mailing lists and user forums, and Internet Relay Chat.

1.6.1 MySQL Mailing Lists

This section introduces the MySQL mailing lists and provides guidelines as to how the lists should be used. When you subscribe to a mailing list, you receive all postings to the list as email messages. You can also send your own questions and answers to the list.

To subscribe to or unsubscribe from any of the mailing lists described in this section, visit http://lists.mysql.com/. For most of them, you can select the regular version of the list where you get individual messages, or a digest version where you get one large message per day.

Please *do not* send messages about subscribing or unsubscribing to any of the mailing lists, because such messages are distributed automatically to thousands of other users.

Your local site may have many subscribers to a MySQL mailing list. If so, the site may have a local mailing list, so that messages sent from `lists.mysql.com` to your site are propagated to the local list. In such cases, please contact your system administrator to be added to or dropped from the local MySQL list.

To have traffic for a mailing list go to a separate mailbox in your mail program, set up a filter based on the message headers. You can use either the `List-ID:` or `Delivered-To:` headers to identify list messages.

The MySQL mailing lists are as follows:

- announce

  The list for announcements of new versions of MySQL and related programs. This is a low-volume list to which all MySQL users should subscribe.

- mysql

  The main list for general MySQL discussion. Please note that some topics are better discussed on the more-specialized lists. If you post to the wrong list, you may not get an answer.

- bugs

  The list for people who want to stay informed about issues reported since the last release of MySQL or who want to be actively involved in the process of bug hunting and fixing. See Section 1.7, "How to Report Bugs or Problems".

- internals

  The list for people who work on the MySQL code. This is also the forum for discussions on MySQL development and for posting patches.

- mysqldoc

  The list for people who work on the MySQL documentation.

- benchmarks

  The list for anyone interested in performance issues. Discussions concentrate on database performance (not limited to MySQL), but also include broader categories such as performance of the kernel, file system, disk system, and so on.

- packagers

  The list for discussions on packaging and distributing MySQL. This is the forum used by distribution maintainers to exchange ideas on packaging MySQL and on ensuring that MySQL looks and feels as similar as possible on all supported platforms and operating systems.

- java

  The list for discussions about the MySQL server and Java. It is mostly used to discuss JDBC drivers such as MySQL Connector/J.

- win32

  The list for all topics concerning the MySQL software on Microsoft operating systems, such as Windows 9x, Me, NT, 2000, XP, and 2003.

- myodbc

  The list for all topics concerning connecting to the MySQL server with ODBC.

- gui-tools

The list for all topics concerning MySQL graphical user interface tools such as MySQL Workbench.

- `cluster`

  The list for discussion of MySQL Cluster.

- `dotnet`

  The list for discussion of the MySQL server and the .NET platform. It is mostly related to MySQL Connector/Net.

- `plusplus`

  The list for all topics concerning programming with the C++ API for MySQL.

- `perl`

  The list for all topics concerning Perl support for MySQL with `DBD::mysql`.

If you're unable to get an answer to your questions from a MySQL mailing list or forum, one option is to purchase support from Oracle. This puts you in direct contact with MySQL developers.

The following MySQL mailing lists are in languages other than English. These lists are not operated by Oracle.

- `<mysql-france-subscribe@yahoogroups.com>`

  A French mailing list.

- `<list@tinc.net>`

  A Korean mailing list. To subscribe, email `subscribe mysql your@email.address` to this list.

- `<mysql-de-request@lists.4t2.com>`

  A German mailing list. To subscribe, email `subscribe mysql-de your@email.address` to this list. You can find information about this mailing list at http://www.4t2.com/mysql/.

- `<mysql-br-request@listas.linkway.com.br>`

  A Portuguese mailing list. To subscribe, email `subscribe mysql-br your@email.address` to this list.

- `<mysql-alta@elistas.net>`

  A Spanish mailing list. To subscribe, email `subscribe mysql your@email.address` to this list.

1.6.1.1 Guidelines for Using the Mailing Lists

Please do not post mail messages from your browser with HTML mode turned on. Many users do not read mail with a browser.

When you answer a question sent to a mailing list, if you consider your answer to have broad interest, you may want to post it to the list instead of replying directly to the individual who asked. Try to make your answer general enough that people other than the original poster may benefit from it. When you post to the list, please make sure that your answer is not a duplication of a previous answer.

Try to summarize the essential part of the question in your reply. Do not feel obliged to quote the entire original message.

When answers are sent to you individually and not to the mailing list, it is considered good etiquette to summarize the answers and send the summary to the mailing list so that others may have the benefit of responses you received that helped you solve your problem.

1.6.2 MySQL Community Support at the MySQL Forums

The forums at http://forums.mysql.com are an important community resource. Many forums are available, grouped into these general categories:

- Migration

- MySQL Usage

- MySQL Connectors

- Programming Languages

- Tools

- 3rd-Party Applications

- Storage Engines

- MySQL Technology

- SQL Standards

- Business

1.6.3 MySQL Community Support on Internet Relay Chat (IRC)

In addition to the various MySQL mailing lists and forums, you can find experienced community people on Internet Relay Chat (IRC). These are the best networks/channels currently known to us:

freenode (see http://www.freenode.net/ for servers)

- `#mysql` is primarily for MySQL questions, but other database and general SQL questions are welcome. Questions about PHP, Perl, or C in combination with MySQL are also common.

- `#workbench` is primarily for MySQL Workbench related questions and thoughts, and it is also a good place to meet the MySQL Workbench developers.

If you are looking for IRC client software to connect to an IRC network, take a look at `xChat` (http://www.xchat.org/). X-Chat (GPL licensed) is available for Unix as well as for Windows platforms (a free Windows build of X-Chat is available at http://www.silverex.org/download/).

1.6.4 MySQL Enterprise

Oracle offers technical support in the form of MySQL Enterprise. For organizations that rely on the MySQL DBMS for business-critical production applications, MySQL Enterprise is a commercial subscription offering which includes:

- MySQL Enterprise Server

- MySQL Enterprise Monitor

- Monthly Rapid Updates and Quarterly Service Packs

- MySQL Knowledge Base

- 24x7 Technical and Consultative Support

MySQL Enterprise is available in multiple tiers, giving you the flexibility to choose the level of service that best matches your needs. For more information, see MySQL Enterprise.

1.7 How to Report Bugs or Problems

Before posting a bug report about a problem, please try to verify that it is a bug and that it has not been reported already:

- Start by searching the MySQL online manual at http://dev.mysql.com/doc/. We try to keep the manual up to date by updating it frequently with solutions to newly found problems. In addition, the release notes accompanying the manual can be particularly useful since it is quite possible that a newer version contains a solution to your problem. The release notes are available at the location just given for the manual.

- If you get a parse error for an SQL statement, please check your syntax closely. If you cannot find something wrong with it, it is extremely likely that your current version of MySQL Server doesn't support the syntax you are using. If you are using the current version and the manual doesn't cover the syntax that you are using, MySQL Server doesn't support your statement.

    If the manual covers the syntax you are using, but you have an older version of MySQL Server, you should check the MySQL change history to see when the syntax was implemented. In this case, you have the option of upgrading to a newer version of MySQL Server.

- For solutions to some common problems, see Section B.5, "Problems and Common Errors".

- Search the bugs database at http://bugs.mysql.com/ to see whether the bug has been reported and fixed.

- Search the MySQL mailing list archives at http://lists.mysql.com/. See Section 1.6.1, "MySQL Mailing Lists".

- You can also use http://www.mysql.com/search/ to search all the Web pages (including the manual) that are located at the MySQL Web site.

If you cannot find an answer in the manual, the bugs database, or the mailing list archives, check with your local MySQL expert. If you still cannot find an answer to your question, please use the following guidelines for reporting the bug.

The normal way to report bugs is to visit http://bugs.mysql.com/, which is the address for our bugs database. This database is public and can be browsed and searched by anyone. If you log in to the system, you can enter new reports.

Bugs posted in the bugs database at http://bugs.mysql.com/ that are corrected for a given release are noted in the release notes.

If you find a sensitive security bug in MySQL Server, please let us know immediately by sending an email message to `<secalert_us@oracle.com>`. Exception: Support customers should report all problems, including security bugs, to Oracle Support at http://support.oracle.com/.

To discuss problems with other users, you can use one of the MySQL mailing lists. Section 1.6.1, "MySQL Mailing Lists".

Writing a good bug report takes patience, but doing it right the first time saves time both for us and for yourself. A good bug report, containing a full test case for the bug, makes it very likely that we will fix the bug in the next release. This section helps you write your report correctly so that you do not waste your time doing things that may not help us much or at all. Please read this section carefully and make sure that all the information described here is included in your report.

Preferably, you should test the problem using the latest production or development version of MySQL Server before posting. Anyone should be able to repeat the bug by just using `mysql test < script_file` on your test case or by running the shell or Perl script that you include in the bug report. Any bug that we are able to repeat has a high chance of being fixed in the next MySQL release.

It is most helpful when a good description of the problem is included in the bug report. That is, give a good example of everything you did that led to the problem and describe, in exact detail, the problem itself. The best reports are those that include a full example showing how to reproduce the bug or problem. See Section 22.4, "Debugging and Porting MySQL".

Remember that it is possible for us to respond to a report containing too much information, but not to one containing too little. People often omit facts because they think they know the cause of a problem and assume that some details do not matter. A good principle to follow is that if you are in doubt about stating something, state it. It is faster and less troublesome to write a couple more lines in your report than to wait longer for the answer if we must ask you to provide information that was missing from the initial report.

The most common errors made in bug reports are (a) not including the version number of the MySQL distribution that you use, and (b) not fully describing the platform on which the MySQL server is installed (including the platform type and version number). These are highly relevant pieces of information, and in 99 cases out of 100, the bug report is useless without them. Very often we get questions like, "Why doesn't this work for me?" Then we find that the feature requested wasn't implemented in that MySQL version, or that a bug described in a report has been fixed in newer MySQL versions. Errors often are platform-dependent. In such cases, it is next to impossible for us to fix anything without knowing the operating system and the version number of the platform.

If you compiled MySQL from source, remember also to provide information about your compiler if it is related to the problem. Often people find bugs in compilers and think the problem is MySQL-related. Most compilers are under development all the time and become better version by version. To determine whether your problem depends on your compiler, we need to know what compiler you used. Note that every compiling problem should be regarded as a bug and reported accordingly.

If a program produces an error message, it is very important to include the message in your report. If we try to search for something from the archives, it is better that the error message reported exactly matches the one that the program produces. (Even the lettercase should be observed.) It is best to copy and paste the entire error message into your report. You should never try to reproduce the message from memory.

If you have a problem with Connector/ODBC (MyODBC), please try to generate a trace file and send it with your report. See How to Report Connector/ODBC Problems or Bugs.

If your report includes long query output lines from test cases that you run with the `mysql` command-line tool, you can make the output more readable by using the `--vertical` option or the `\G` statement terminator. The `EXPLAIN SELECT` example later in this section demonstrates the use of `\G`.

Please include the following information in your report:

- The version number of the MySQL distribution you are using (for example, MySQL 5.7.10). You can find out which version you are running by executing `mysqladmin version`. The `mysqladmin` program can be found in the `bin` directory under your MySQL installation directory.

- The manufacturer and model of the machine on which you experience the problem.

- The operating system name and version. If you work with Windows, you can usually get the name and version number by double-clicking your My Computer icon and pulling down the "Help/About Windows" menu. For most Unix-like operating systems, you can get this information by executing the command `uname -a`.

- Sometimes the amount of memory (real and virtual) is relevant. If in doubt, include these values.

- If you are using a source distribution of the MySQL software, include the name and version number of the compiler that you used. If you have a binary distribution, include the distribution name.

- If the problem occurs during compilation, include the exact error messages and also a few lines of context around the offending code in the file where the error occurs.

- If `mysqld` died, you should also report the statement that crashed `mysqld`. You can usually get this information by running `mysqld` with query logging enabled, and then looking in the log after `mysqld` crashes. See Section 22.4, "Debugging and Porting MySQL".

- If a database table is related to the problem, include the output from the `SHOW CREATE TABLE` `db_name.tbl_name` statement in the bug report. This is a very easy way to get the definition of any table in a database. The information helps us create a situation matching the one that you have experienced.

- The SQL mode in effect when the problem occurred can be significant, so please report the value of the `sql_mode` system variable. For stored procedure, stored function, and trigger objects, the relevant `sql_mode` value is the one in effect when the object was created. For a stored procedure or function, the `SHOW CREATE PROCEDURE` or `SHOW CREATE FUNCTION` statement shows the relevant SQL mode, or you can query `INFORMATION_SCHEMA` for the information:

```
SELECT ROUTINE_SCHEMA, ROUTINE_NAME, SQL_MODE
FROM INFORMATION_SCHEMA.ROUTINES;
```

For triggers, you can use this statement:

```
SELECT EVENT_OBJECT_SCHEMA, EVENT_OBJECT_TABLE, TRIGGER_NAME, SQL_MODE
FROM INFORMATION_SCHEMA.TRIGGERS;
```

- For performance-related bugs or problems with `SELECT` statements, you should always include the output of `EXPLAIN SELECT ...`, and at least the number of rows that the `SELECT` statement produces. You should also include the output from `SHOW CREATE TABLE` `tbl_name` for each table that is involved. The more information you provide about your situation, the more likely it is that someone can help you.

The following is an example of a very good bug report. The statements are run using the `mysql` command-line tool. Note the use of the `\G` statement terminator for statements that would otherwise provide very long output lines that are difficult to read.

```
mysql> SHOW VARIABLES;
mysql> SHOW COLUMNS FROM ...\G
       <output from SHOW COLUMNS>
mysql> EXPLAIN SELECT ...\G
       <output from EXPLAIN>
mysql> FLUSH STATUS;
mysql> SELECT ...;
       <A short version of the output from SELECT,
       including the time taken to run the query>
mysql> SHOW STATUS;
       <output from SHOW STATUS>
```

- If a bug or problem occurs while running `mysqld`, try to provide an input script that reproduces the anomaly. This script should include any necessary source files. The more closely the script can reproduce your situation, the better. If you can make a reproducible test case, you should upload it to be attached to the bug report.

  If you cannot provide a script, you should at least include the output from `mysqladmin variables extended-status processlist` in your report to provide some information on how your system is performing.

- If you cannot produce a test case with only a few rows, or if the test table is too big to be included in the bug report (more than 10 rows), you should dump your tables using `mysqldump` and create a `README` file that describes your problem. Create a compressed archive of your files using `tar` and `gzip` or `zip`. After you initiate a bug report for our bugs database at http://bugs.mysql.com/, click the Files tab in the bug report for instructions on uploading the archive to the bugs database.

- If you believe that the MySQL server produces a strange result from a statement, include not only the result, but also your opinion of what the result should be, and an explanation describing the basis for your opinion.

- When you provide an example of the problem, it is better to use the table names, variable names, and so forth that exist in your actual situation than to come up with new names. The problem could be related to the name of a table or variable. These cases are rare, perhaps, but it is better to be safe than sorry. After all, it should be easier for you to provide an example that uses your actual situation, and it is by all means better for us. If you have data that you do not want to be visible to others in the bug report, you can upload it using the Files tab as previously described. If the information is really top secret and you do not want to show it even to us, go ahead and provide an example using other names, but please regard this as the last choice.

- Include all the options given to the relevant programs, if possible. For example, indicate the options that you use when you start the `mysqld` server, as well as the options that you use to run any MySQL client programs. The options to programs such as `mysqld` and `mysql`, and to the `configure` script, are often key to resolving problems and are very relevant. It is never a bad idea to include them. If your problem involves a program written in a language such as Perl or PHP, please include the language processor's version number, as well as the version for any modules that the program uses. For example, if you have a Perl script that uses the `DBI` and `DBD::mysql` modules, include the version numbers for Perl, `DBI`, and `DBD::mysql`.

- If your question is related to the privilege system, please include the output of `mysqladmin reload`, and all the error messages you get when trying to connect. When you test your privileges, you should execute `mysqladmin reload version` and try to connect with the program that gives you trouble.

- If you have a patch for a bug, do include it. But do not assume that the patch is all we need, or that we can use it, if you do not provide some necessary information such as test cases showing the bug that your patch fixes. We might find problems with your patch or we might not understand it at all. If so, we cannot use it.

  If we cannot verify the exact purpose of the patch, we will not use it. Test cases help us here. Show that the patch handles all the situations that may occur. If we find a borderline case (even a rare one) where the patch will not work, it may be useless.

- Guesses about what the bug is, why it occurs, or what it depends on are usually wrong. Even the MySQL team cannot guess such things without first using a debugger to determine the real cause of a bug.

- Indicate in your bug report that you have checked the reference manual and mail archive so that others know you have tried to solve the problem yourself.

- If your data appears corrupt or you get errors when you access a particular table, first check your tables with `CHECK TABLE`. If that statement reports any errors:

  - The `InnoDB` crash recovery mechanism handles cleanup when the server is restarted after being killed, so in typical operation there is no need to "repair" tables. If you encounter an error with `InnoDB` tables, restart the server and see whether the problem persists, or whether the error affected only cached data in memory. If data is corrupted on disk, consider restarting with the `innodb_force_recovery` option enabled so that you can dump the affected tables.

  - For non-transactional tables, try to repair them with `REPAIR TABLE` or with `myisamchk`. See Chapter 5, *MySQL Server Administration*.

  If you are running Windows, please verify the value of `lower_case_table_names` using the `SHOW VARIABLES LIKE 'lower_case_table_names'` statement. This variable affects how the server handles lettercase of database and table names. Its effect for a given value should be as described in Section 9.2.2, "Identifier Case Sensitivity".

- If you often get corrupted tables, you should try to find out when and why this happens. In this case, the error log in the MySQL data directory may contain some information about what happened. (This is the file with the `.err` suffix in the name.) See Section 5.4.2, "The Error Log". Please include any relevant information from this file in your bug report. Normally `mysqld` should *never* crash a table if nothing killed it in the middle of an update. If you can find the cause of `mysqld` dying, it is much easier for us to provide you with a fix for the problem. See Section B.5.1, "How to Determine What Is Causing a Problem".

- If possible, download and install the most recent version of MySQL Server and check whether it solves your problem. All versions of the MySQL software are thoroughly tested and should work without problems. We believe in making everything as backward-compatible as possible, and you should be able to switch MySQL versions without difficulty. See Section 2.1.1, "Choosing Which MySQL Distribution to Install".

1.8 MySQL Standards Compliance

This section describes how MySQL relates to the ANSI/ISO SQL standards. MySQL Server has many extensions to the SQL standard, and here you can find out what they are and how to use them. You can also find information about functionality missing from MySQL Server, and how to work around some of the differences.

The SQL standard has been evolving since 1986 and several versions exist. In this manual, "SQL-92" refers to the standard released in 1992, "SQL:1999" refers to the standard released in 1999, "SQL:2003" refers to the standard released in 2003, and "SQL:2008" refers to the most recent version of the standard, released in 2008. We use the phrase "the SQL standard" or "standard SQL" to mean the current version of the SQL Standard at any time.

One of our main goals with the product is to continue to work toward compliance with the SQL standard, but without sacrificing speed or reliability. We are not afraid to add extensions to SQL or support for non-SQL features if this greatly increases the usability of MySQL Server for a large segment of our user base. The `HANDLER` interface is an example of this strategy. See Section 13.2.4, "HANDLER Syntax".

We continue to support transactional and nontransactional databases to satisfy both mission-critical 24/7 usage and heavy Web or logging usage.

MySQL Server was originally designed to work with medium-sized databases (10-100 million rows, or about 100MB per table) on small computer systems. Today MySQL Server handles terabyte-sized databases, but the code can also be compiled in a reduced version suitable for hand-held and embedded

devices. The compact design of the MySQL server makes development in both directions possible without any conflicts in the source tree.

We are not targeting real-time support, although MySQL replication capabilities offer significant functionality.

MySQL supports ODBC levels 0 to 3.51.

MySQL supports high-availability database clustering using the `NDBCLUSTER` storage engine. See Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*.

We are implementing XML functionality beginning in MySQL 5.1, which supports most of the W3C XPath standard. See Section 12.11, "XML Functions".

Selecting SQL Modes

The MySQL server can operate in different SQL modes, and can apply these modes differently for different clients, depending on the value of the `sql_mode` system variable. DBAs can set the global SQL mode to match site server operating requirements, and each application can set its session SQL mode to its own requirements.

Modes affect the SQL syntax MySQL supports and the data validation checks it performs. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers.

For more information on setting the SQL mode, see Section 5.1.7, "Server SQL Modes".

Running MySQL in ANSI Mode

To run MySQL Server in ANSI mode, start `mysqld` with the `--ansi` option. Running the server in ANSI mode is the same as starting it with the following options:

```
--transaction-isolation=SERIALIZABLE --sql-mode=ANSI
```

To achieve the same effect at runtime, execute these two statements:

```
SET GLOBAL TRANSACTION ISOLATION LEVEL SERIALIZABLE;
SET GLOBAL sql_mode = 'ANSI';
```

You can see that setting the `sql_mode` system variable to `'ANSI'` enables all SQL mode options that are relevant for ANSI mode as follows:

```
mysql> SET GLOBAL sql_mode='ANSI';
mysql> SELECT @@global.sql_mode;
        -> 'REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ANSI'
```

Running the server in ANSI mode with `--ansi` is not quite the same as setting the SQL mode to `'ANSI'` because the `--ansi` option also sets the transaction isolation level.

See Section 5.1.3, "Server Command Options".

1.8.1 MySQL Extensions to Standard SQL

MySQL Server supports some extensions that you probably won't find in other SQL DBMSs. Be warned that if you use them, your code won't be portable to other SQL servers. In some cases, you can write code that includes MySQL extensions, but is still portable, by using comments of the following form:

```
/*! MySQL-specific code */
```

In this case, MySQL Server parses and executes the code within the comment as it would any other SQL statement, but other SQL servers will ignore the extensions. For example, MySQL Server recognizes the STRAIGHT_JOIN keyword in the following statement, but other servers will not:

```
SELECT /*! STRAIGHT_JOIN */ col1 FROM table1,table2 WHERE ...
```

If you add a version number after the "!" character, the syntax within the comment is executed only if the MySQL version is greater than or equal to the specified version number. The TEMPORARY keyword in the following comment is executed only by servers from MySQL 3.23.02 or higher:

```
CREATE /*!32302 TEMPORARY */ TABLE t (a INT);
```

The following descriptions list MySQL extensions, organized by category.

- Organization of data on disk

  MySQL Server maps each database to a directory under the MySQL data directory, and maps tables within a database to file names in the database directory. This has a few implications:

  - Database and table names are case sensitive in MySQL Server on operating systems that have case-sensitive file names (such as most Unix systems). See Section 9.2.2, "Identifier Case Sensitivity".

  - You can use standard system commands to back up, rename, move, delete, and copy tables that are managed by the MyISAM storage engine. For example, it is possible to rename a MyISAM table by renaming the .MYD, .MYI, and .frm files to which the table corresponds. (Nevertheless, it is preferable to use RENAME TABLE or ALTER TABLE ... RENAME and let the server rename the files.)

  Prior to MySQL 5.1.6, database and table names cannot contain path name separator characters ("/", "\").

- General language syntax

  - By default, strings can be enclosed by either """ or "'", not just by "'". (If the ANSI_QUOTES SQL mode is enabled, strings can be enclosed only by "'" and the server interprets strings enclosed by """ as identifiers.)

  - "\" is the escape character in strings.

  - In SQL statements, you can access tables from different databases with the db_name.tbl_name syntax. Some SQL servers provide the same functionality but call this User space. MySQL Server doesn't support tablespaces such as used in statements like this: CREATE TABLE ralph.my_table ... IN my_tablespace.

- SQL statement syntax

  - The ANALYZE TABLE, CHECK TABLE, OPTIMIZE TABLE, and REPAIR TABLE statements.

  - The CREATE DATABASE, DROP DATABASE, and ALTER DATABASE statements. See Section 13.1.10, "CREATE DATABASE Syntax", Section 13.1.21, "DROP DATABASE Syntax", and Section 13.1.1, "ALTER DATABASE Syntax".

  - The DO statement.

- `EXPLAIN SELECT` to obtain a description of how tables are processed by the query optimizer.

- The `FLUSH` and `RESET` statements.

- The `SET` statement. See Section 13.7.4.1, "SET Syntax for Variable Assignment".

- The `SHOW` statement. See Section 13.7.5, "SHOW Syntax". The information produced by many of the MySQL-specific `SHOW` statements can be obtained in more standard fashion by using `SELECT` to query `INFORMATION_SCHEMA`. See Chapter 20, *INFORMATION_SCHEMA Tables*.

- Use of `LOAD DATA INFILE`. In many cases, this syntax is compatible with Oracle's `LOAD DATA INFILE`. See Section 13.2.6, "LOAD DATA INFILE Syntax".

- Use of `RENAME TABLE`. See Section 13.1.33, "RENAME TABLE Syntax".

- Use of `REPLACE` instead of `DELETE` plus `INSERT`. See Section 13.2.7, "REPLACE Syntax".

- Use of `CHANGE` *col_name*, `DROP` *col_name*, or `DROP INDEX`, `IGNORE` or `RENAME` in `ALTER TABLE` statements. Use of multiple `ADD`, `ALTER`, `DROP`, or `CHANGE` clauses in an `ALTER TABLE` statement. See Section 13.1.7, "ALTER TABLE Syntax".

- Use of index names, indexes on a prefix of a column, and use of `INDEX` or `KEY` in `CREATE TABLE` statements. See Section 13.1.17, "CREATE TABLE Syntax".

- Use of `TEMPORARY` or `IF NOT EXISTS` with `CREATE TABLE`.

- Use of `IF EXISTS` with `DROP TABLE` and `DROP DATABASE`.

- The capability of dropping multiple tables with a single `DROP TABLE` statement.

- The `ORDER BY` and `LIMIT` clauses of the `UPDATE` and `DELETE` statements.

- `INSERT INTO` *tbl_name* `SET` *col_name* `= ...` syntax.

- The `DELAYED` clause of the `INSERT` and `REPLACE` statements.

- The `LOW_PRIORITY` clause of the `INSERT`, `REPLACE`, `DELETE`, and `UPDATE` statements.

- Use of `INTO OUTFILE` or `INTO DUMPFILE` in `SELECT` statements. See Section 13.2.8, "SELECT Syntax".

- Options such as `STRAIGHT_JOIN` or `SQL_SMALL_RESULT` in `SELECT` statements.

- You don't need to name all selected columns in the `GROUP BY` clause. This gives better performance for some very specific, but quite normal queries. See Section 12.17, "Aggregate (GROUP BY) Functions".

- You can specify `ASC` and `DESC` with `GROUP BY`, not just with `ORDER BY`.

- The ability to set variables in a statement with the `:=` assignment operator. See Section 9.4, "User-Defined Variables".

- Data types

  - The `MEDIUMINT`, `SET`, and `ENUM` data types, and the various `BLOB` and `TEXT` data types.

  - The `AUTO_INCREMENT`, `BINARY`, `NULL`, `UNSIGNED`, and `ZEROFILL` data type attributes.

- Functions and operators

  - To make it easier for users who migrate from other SQL environments, MySQL Server supports aliases for many functions. For example, all string functions support both standard SQL syntax and ODBC syntax.

  - MySQL Server understands the `||` and `&&` operators to mean logical OR and AND, as in the C programming language. In MySQL Server, `||` and `OR` are synonyms, as are `&&` and `AND`. Because of this nice syntax, MySQL Server doesn't support the standard SQL `||` operator for string concatenation; use `CONCAT()` instead. Because `CONCAT()` takes any number of arguments, it is easy to convert use of the `||` operator to MySQL Server.

  - Use of `COUNT(DISTINCT value_list)` where `value_list` has more than one element.

  - String comparisons are case-insensitive by default, with sort ordering determined by the collation of the current character set, which is `latin1` (cp1252 West European) by default. If you don't like this, you should declare your columns with the `BINARY` attribute or use the `BINARY` cast, which causes comparisons to be done using the underlying character code values rather than a lexical ordering.

  - The `%` operator is a synonym for `MOD()`. That is, `N % M` is equivalent to `MOD(N,M)`. `%` is supported for C programmers and for compatibility with PostgreSQL.

  - The `=`, `<>`, `<=`, `<`, `>=`, `>`, `<<`, `>>`, `<=>`, `AND`, `OR`, or `LIKE` operators may be used in expressions in the output column list (to the left of the `FROM`) in `SELECT` statements. For example:

    ```
    mysql> SELECT col1=1 AND col2=2 FROM my_table;
    ```

  - The `LAST_INSERT_ID()` function returns the most recent `AUTO_INCREMENT` value. See Section 12.14, "Information Functions".

  - `LIKE` is permitted on numeric values.

  - The `REGEXP` and `NOT REGEXP` extended regular expression operators.

  - `CONCAT()` or `CHAR()` with one argument or more than two arguments. (In MySQL Server, these functions can take a variable number of arguments.)

  - The `BIT_COUNT()`, `CASE`, `ELT()`, `FROM_DAYS()`, `FORMAT()`, `IF()`, `PASSWORD()`, `ENCRYPT()`, `MD5()`, `ENCODE()`, `DECODE()`, `PERIOD_ADD()`, `PERIOD_DIFF()`, `TO_DAYS()`, and `WEEKDAY()` functions.

  - Use of `TRIM()` to trim substrings. Standard SQL supports removal of single characters only.

  - The `GROUP BY` functions `STD()`, `BIT_OR()`, `BIT_AND()`, `BIT_XOR()`, and `GROUP_CONCAT()`. See Section 12.17, "Aggregate (GROUP BY) Functions".

1.8.2 MySQL Differences from Standard SQL

We try to make MySQL Server follow the ANSI SQL standard and the ODBC SQL standard, but MySQL Server performs operations differently in some cases:

- There are several differences between the MySQL and standard SQL privilege systems. For example, in MySQL, privileges for a table are not automatically revoked when you delete a table. You must explicitly issue a `REVOKE` statement to revoke privileges for a table. For more information, see Section 13.7.1.5, "REVOKE Syntax".

- The `CAST()` function does not support cast to `REAL` or `BIGINT`. See Section 12.10, "Cast Functions and Operators".

1.8.2.1 SELECT INTO TABLE

MySQL Server doesn't support the `SELECT ... INTO TABLE` Sybase SQL extension. Instead, MySQL Server supports the `INSERT INTO ... SELECT` standard SQL syntax, which is basically the same thing. See Section 13.2.5.1, "INSERT ... SELECT Syntax". For example:

```
INSERT INTO tbl_temp2 (fld_id)
    SELECT tbl_temp1.fld_order_id
    FROM tbl_temp1 WHERE tbl_temp1.fld_order_id > 100;
```

Alternatively, you can use `SELECT ... INTO OUTFILE` or `CREATE TABLE ... SELECT`.

You can use `SELECT ... INTO` with user-defined variables. The same syntax can also be used inside stored routines using cursors and local variables. See Section 13.2.8.1, "SELECT ... INTO Syntax".

1.8.2.2 UPDATE

If you access a column from the table to be updated in an expression, `UPDATE` uses the current value of the column. The second assignment in the following statement sets `col2` to the current (updated) `col1` value, not the original `col1` value. The result is that `col1` and `col2` have the same value. This behavior differs from standard SQL.

```
UPDATE t1 SET col1 = col1 + 1, col2 = col1;
```

1.8.2.3 Transactions and Atomic Operations

MySQL Server (version 3.23-max and all versions 4.0 and above) supports transactions with the `InnoDB` transactional storage engine. `InnoDB` provides *full* ACID compliance. See Chapter 14, *Storage Engines*. For information about `InnoDB` differences from standard SQL with regard to treatment of transaction errors, see Section 14.6.12.4, "InnoDB Error Handling".

The other nontransactional storage engines in MySQL Server (such as `MyISAM`) follow a different paradigm for data integrity called "atomic operations." In transactional terms, `MyISAM` tables effectively always operate in `autocommit = 1` mode. Atomic operations often offer comparable integrity with higher performance.

Because MySQL Server supports both paradigms, you can decide whether your applications are best served by the speed of atomic operations or the use of transactional features. This choice can be made on a per-table basis.

As noted, the tradeoff for transactional versus nontransactional storage engines lies mostly in performance. Transactional tables have significantly higher memory and disk space requirements, and more CPU overhead. On the other hand, transactional storage engines such as `InnoDB` also offer many significant features. MySQL Server's modular design enables the concurrent use of different storage engines to suit different requirements and deliver optimum performance in all situations.

But how do you use the features of MySQL Server to maintain rigorous integrity even with the nontransactional `MyISAM` tables, and how do these features compare with the transactional storage engines?

- If your applications are written in a way that is dependent on being able to call `ROLLBACK` rather than `COMMIT` in critical situations, transactions are more convenient. Transactions also ensure that unfinished updates or corrupting activities are not committed to the database; the server is given the opportunity to do an automatic rollback and your database is saved.

If you use nontransactional tables, you must resolve potential problems at the application level by including simple checks before updates and by running simple scripts that check the databases for inconsistencies and automatically repair or warn if such an inconsistency occurs. You can normally fix tables perfectly with no data integrity loss just by using the MySQL log or even adding one extra log.

- More often than not, critical transactional updates can be rewritten to be atomic. Generally speaking, all integrity problems that transactions solve can be done with `LOCK TABLES` or atomic updates, ensuring that there are no automatic aborts from the server, which is a common problem with transactional database systems.

- To be safe with MySQL Server, regardless of whether you use transactional tables, you only need to have backups and have binary logging turned on. When that is true, you can recover from any situation that you could with any other transactional database system. It is always good to have backups, regardless of which database system you use.

The transactional paradigm has its advantages and disadvantages. Many users and application developers depend on the ease with which they can code around problems where an abort appears to be necessary, or is necessary. However, even if you are new to the atomic operations paradigm, or more familiar with transactions, do consider the speed benefit that nontransactional tables can offer on the order of three to five times the speed of the fastest and most optimally tuned transactional tables.

In situations where integrity is of highest importance, MySQL Server offers transaction-level reliability and integrity even for nontransactional tables. If you lock tables with `LOCK TABLES`, all updates stall until integrity checks are made. If you obtain a `READ LOCAL` lock (as opposed to a write lock) for a table that enables concurrent inserts at the end of the table, reads are permitted, as are inserts by other clients. The newly inserted records are not be seen by the client that has the read lock until it releases the lock. With `INSERT DELAYED`, you can write inserts that go into a local queue until the locks are released, without having the client wait for the insert to complete. See Section 8.11.3, "Concurrent Inserts", and Section 13.2.5.2, "INSERT DELAYED Syntax".

"Atomic," in the sense that we mean it, is nothing magical. It only means that you can be sure that while each specific update is running, no other user can interfere with it, and there can never be an automatic rollback (which can happen with transactional tables if you are not very careful). MySQL Server also guarantees that there are no dirty reads.

Following are some techniques for working with nontransactional tables:

- Loops that need transactions normally can be coded with the help of `LOCK TABLES`, and you don't need cursors to update records on the fly.

- To avoid using `ROLLBACK`, you can employ the following strategy:

  1. Use `LOCK TABLES` to lock all the tables you want to access.

  2. Test the conditions that must be true before performing the update.

  3. Update if the conditions are satisfied.

  4. Use `UNLOCK TABLES` to release your locks.

  This is usually a much faster method than using transactions with possible rollbacks, although not always. The only situation this solution doesn't handle is when someone kills the threads in the middle of an update. In that case, all locks are released but some of the updates may not have been executed.

- You can also use functions to update records in a single operation. You can get a very efficient application by using the following techniques:

- Modify columns relative to their current value.

- Update only those columns that actually have changed.

For example, when we are updating customer information, we update only the customer data that has changed and test only that none of the changed data, or data that depends on the changed data, has changed compared to the original row. The test for changed data is done with the `WHERE` clause in the `UPDATE` statement. If the record wasn't updated, we give the client a message: "Some of the data you have changed has been changed by another user." Then we show the old row versus the new row in a window so that the user can decide which version of the customer record to use.

This gives us something that is similar to column locking but is actually even better because we only update some of the columns, using values that are relative to their current values. This means that typical `UPDATE` statements look something like these:

```
UPDATE tablename SET pay_back=pay_back+125;

UPDATE customer
  SET
    customer_date='current_date',
    address='new address',
    phone='new phone',
    money_owed_to_us=money_owed_to_us-125
  WHERE
    customer_id=id AND address='old address' AND phone='old phone';
```

This is very efficient and works even if another client has changed the values in the `pay_back` or `money_owed_to_us` columns.

- When managing unique identifiers, you can avoid statements such as `LOCK TABLES` or `ROLLBACK` by using an `AUTO_INCREMENT` column and either the `LAST_INSERT_ID()` SQL function or the `mysql_insert_id()` C API function. See Section 12.14, "Information Functions", and Section 21.8.7.37, "mysql_insert_id()".

  For situations that require row-level locking, use `InnoDB` tables. Otherwise, with `MyISAM` tables, you can use a flag column in the table and do something like the following:

```
UPDATE tbl_name SET row_flag=1 WHERE id=ID;
```

  MySQL returns `1` for the number of affected rows if the row was found and `row_flag` wasn't `1` in the original row. You can think of this as though MySQL Server changed the preceding statement to:

```
UPDATE tbl_name SET row_flag=1 WHERE id=ID AND row_flag <> 1;
```

1.8.2.4 Foreign Key Differences

MySQL's implementation of foreign keys differs from the SQL standard in the following key respects:

- If there are several rows in the parent table that have the same referenced key value, `InnoDB` acts in foreign key checks as if the other parent rows with the same key value do not exist. For example, if you have defined a `RESTRICT` type constraint, and there is a child row with several parent rows, `InnoDB` does not permit the deletion of any of those parent rows.

  `InnoDB` performs cascading operations through a depth-first algorithm, based on records in the indexes corresponding to the foreign key constraints.

- A `FOREIGN KEY` constraint that references a non-`UNIQUE` key is not standard SQL but rather an `InnoDB` extension.

- If `ON UPDATE CASCADE` or `ON UPDATE SET NULL` recurses to update the *same table* it has previously updated during the same cascade, it acts like `RESTRICT`. This means that you cannot use self-referential `ON UPDATE CASCADE` or `ON UPDATE SET NULL` operations. This is to prevent infinite loops resulting from cascaded updates. A self-referential `ON DELETE SET NULL`, on the other hand, is possible, as is a self-referential `ON DELETE CASCADE`. Cascading operations may not be nested more than 15 levels deep.

- In an SQL statement that inserts, deletes, or updates many rows, foreign key constraints (like unique constraints) are checked row-by-row. When performing foreign key checks, `InnoDB` sets shared row-level locks on child or parent records that it must examine. MySQL checks foreign key constraints immediately; the check is not deferred to transaction commit. According to the SQL standard, the default behavior should be deferred checking. That is, constraints are only checked after the *entire SQL statement* has been processed. This means that it is not possible to delete a row that refers to itself using a foreign key.

For information about how the `InnoDB` storage engine handles foreign keys, see Section 14.6.6.6, "InnoDB and FOREIGN KEY Constraints".

1.8.2.5 '--' as the Start of a Comment

Standard SQL uses the C syntax `/* this is a comment */` for comments, and MySQL Server supports this syntax as well. MySQL also support extensions to this syntax that enable MySQL-specific SQL to be embedded in the comment, as described in Section 9.6, "Comment Syntax".

Standard SQL uses "`--`" as a start-comment sequence. MySQL Server uses "`#`" as the start comment character. MySQL Server 3.23.3 and up also supports a variant of the "`--`" comment style. That is, the "`--`" start-comment sequence must be followed by a space (or by a control character such as a newline). The space is required to prevent problems with automatically generated SQL queries that use constructs such as the following, where we automatically insert the value of the payment for `payment`:

```
UPDATE account SET credit=credit-payment
```

Consider about what happens if `payment` has a negative value such as `-1`:

```
UPDATE account SET credit=credit--1
```

`credit--1` is a valid expression in SQL, but "`--`" is interpreted as the start of a comment, part of the expression is discarded. The result is a statement that has a completely different meaning than intended:

```
UPDATE account SET credit=credit
```

The statement produces no change in value at all. This illustrates that permitting comments to start with "`--`" can have serious consequences.

Using our implementation requires a space following the "`--`" for it to be recognized as a start-comment sequence in MySQL Server 3.23.3 and newer. Therefore, `credit--1` is safe to use.

Another safe feature is that the `mysql` command-line client ignores lines that start with "`--`".

The following information is relevant only if you are running a MySQL version earlier than 3.23.3:

If you have an SQL script in a text file that contains "`--`" comments, you should use the `replace` utility as follows to convert the comments to use "`#`" characters before executing the script:

```
shell> replace " --" " #" < text-file-with-funny-comments.sql \
       | mysql db_name
```

That is safer than executing the script in the usual way:

```
shell> mysql db_name < text-file-with-funny-comments.sql
```

You can also edit the script file "in place" to change the "`--`" comments to "`#`" comments:

```
shell> replace " --" " #" -- text-file-with-funny-comments.sql
```

Change them back with this command:

```
shell> replace " #" " --" -- text-file-with-funny-comments.sql
```

See Section 4.8.2, "`replace` — A String-Replacement Utility".

1.8.3 How MySQL Deals with Constraints

MySQL enables you to work both with transactional tables that permit rollback and with nontransactional tables that do not. Because of this, constraint handling is a bit different in MySQL than in other DBMSs. We must handle the case when you have inserted or updated a lot of rows in a nontransactional table for which changes cannot be rolled back when an error occurs.

The basic philosophy is that MySQL Server tries to produce an error for anything that it can detect while parsing a statement to be executed, and tries to recover from any errors that occur while executing the statement. We do this in most cases, but not yet for all.

The options MySQL has when an error occurs are to stop the statement in the middle or to recover as well as possible from the problem and continue. By default, the server follows the latter course. This means, for example, that the server may coerce invalid values to the closest valid values.

Several SQL mode options are available to provide greater control over handling of bad data values and whether to continue statement execution or abort when errors occur. Using these options, you can configure MySQL Server to act in a more traditional fashion that is like other DBMSs that reject improper input. The SQL mode can be set globally at server startup to affect all clients. Individual clients can set the SQL mode at runtime, which enables each client to select the behavior most appropriate for its requirements. See Section 5.1.7, "Server SQL Modes".

The following sections describe how MySQL Server handles different types of constraints.

1.8.3.1 PRIMARY KEY and UNIQUE Index Constraints

Normally, errors occur for data-change statements (such as `INSERT` or `UPDATE`) that would violate primary-key, unique-key, or foreign-key constraints. If you are using a transactional storage engine such as `InnoDB`, MySQL automatically rolls back the statement. If you are using a nontransactional storage engine, MySQL stops processing the statement at the row for which the error occurred and leaves any remaining rows unprocessed.

MySQL supports an `IGNORE` keyword for `INSERT`, `UPDATE`, and so forth. If you use it, MySQL ignores primary-key or unique-key violations and continues processing with the next row. See the section for the

statement that you are using (Section 13.2.5, "INSERT Syntax", Section 13.2.10, "UPDATE Syntax", and so forth).

You can get information about the number of rows actually inserted or updated with the `mysql_info()` C API function. You can also use the `SHOW WARNINGS` statement. See Section 21.8.7.35, "mysql_info()", and Section 13.7.5.42, "SHOW WARNINGS Syntax".

Only `InnoDB` tables support foreign keys. See Section 14.6.6.6, "InnoDB and FOREIGN KEY Constraints".

1.8.3.2 FOREIGN KEY Constraints

Foreign keys let you cross-reference related data across tables, and foreign key constraints help keep this spread-out data consistent.

MySQL supports `ON UPDATE` and `ON DELETE` foreign key references in `CREATE TABLE` and `ALTER TABLE` statements. The available referential actions are `RESTRICT` (the default), `CASCADE`, `SET NULL`, and `NO ACTION`.

`SET DEFAULT` is also supported by the MySQL Server but is currently rejected as invalid by `InnoDB`. Since MySQL does not support deferred constraint checking, `NO ACTION` is treated as `RESTRICT`. For the exact syntax supported by MySQL for foreign keys, see Section 13.1.17.3, "Using FOREIGN KEY Constraints".

`MATCH FULL`, `MATCH PARTIAL`, and `MATCH SIMPLE` are allowed, but their use should be avoided, as they cause the MySQL Server to ignore any `ON DELETE` or `ON UPDATE` clause used in the same statement. `MATCH` options do not have any other effect in MySQL, which in effect enforces `MATCH SIMPLE` semantics full-time.

MySQL requires that foreign key columns be indexed; if you create a table with a foreign key constraint but no index on a given column, an index is created.

You can obtain information about foreign keys from the `INFORMATION_SCHEMA.KEY_COLUMN_USAGE` table. An example of a query against this table is shown here:

```
mysql> SELECT TABLE_SCHEMA, TABLE_NAME, COLUMN_NAME, CONSTRAINT_NAME
    > FROM INFORMATION_SCHEMA.KEY_COLUMN_USAGE
    > WHERE REFERENCED_TABLE_SCHEMA IS NOT NULL;
+--------------+---------------+-------------+-----------------+
| TABLE_SCHEMA | TABLE_NAME    | COLUMN_NAME | CONSTRAINT_NAME |
+--------------+---------------+-------------+-----------------+
| fk1          | myuser        | myuser_id   | f               |
| fk1          | product_order | customer_id | f2              |
| fk1          | product_order | product_id  | f1              |
+--------------+---------------+-------------+-----------------+
3 rows in set (0.01 sec)
```

Only `InnoDB` tables support foreign keys. See Section 14.6.6.6, "InnoDB and FOREIGN KEY Constraints", for information specific to foreign key support in `InnoDB`.

1.8.3.3 Constraints on Invalid Data

By default, MySQL is forgiving of invalid or improper data values and coerces them to valid values for data entry. However, you can enable strict SQL mode to select more traditional treatment of bad values such that the server rejects them and aborts the statement in which they occur. See Section 5.1.7, "Server SQL Modes".

This section describes the default (forgiving) behavior of MySQL, as well as the strict SQL mode and how it differs.

If you are not using strict mode, then whenever you insert an "incorrect" value into a column, such as a `NULL` into a `NOT NULL` column or a too-large numeric value into a numeric column, MySQL sets the column to the "best possible value" instead of producing an error: The following rules describe in more detail how this works:

- If you try to store an out of range value into a numeric column, MySQL Server instead stores zero, the smallest possible value, or the largest possible value, whichever is closest to the invalid value.

- For strings, MySQL stores either the empty string or as much of the string as can be stored in the column.

- If you try to store a string that does not start with a number into a numeric column, MySQL Server stores 0.

- Invalid values for `ENUM` and `SET` columns are handled as described in Section 1.8.3.4, "ENUM and SET Constraints".

- MySQL permits you to store certain incorrect date values into `DATE` and `DATETIME` columns (such as `'2000-02-31'` or `'2000-02-00'`). In this case, when an application has not enabled strict SQL mode, it up to the application to validate the dates before storing them. If MySQL can store a date value and retrieve exactly the same value, MySQL stores it as given. If the date is totally wrong (outside the server's ability to store it), the special "zero" date value `'0000-00-00'` is stored in the column instead.

- If you try to store `NULL` into a column that doesn't take `NULL` values, an error occurs for single-row `INSERT` statements. For multiple-row `INSERT` statements or for `INSERT INTO ... SELECT` statements, MySQL Server stores the implicit default value for the column data type. In general, this is `0` for numeric types, the empty string (`''`) for string types, and the "zero" value for date and time types. Implicit default values are discussed in Section 11.6, "Data Type Default Values".

- If an `INSERT` statement specifies no value for a column, MySQL inserts its default value if the column definition includes an explicit `DEFAULT` clause. If the definition has no such `DEFAULT` clause, MySQL inserts the implicit default value for the column data type.

The reason for using the preceding rules in nonstrict mode is that we can't check these conditions until the statement has begun executing. We can't just roll back if we encounter a problem after updating a few rows, because the storage engine may not support rollback. The option of terminating the statement is not that good; in this case, the update would be "half done," which is probably the worst possible scenario. In this case, it is better to "do the best you can" and then continue as if nothing happened.

You can select stricter treatment of input values by using the `STRICT_TRANS_TABLES` or `STRICT_ALL_TABLES` SQL modes:

```
SET sql_mode = 'STRICT_TRANS_TABLES';
SET sql_mode = 'STRICT_ALL_TABLES';
```

`STRICT_TRANS_TABLES` enables strict mode for transactional storage engines, and also to some extent for nontransactional engines. It works like this:

- For transactional storage engines, bad data values occurring anywhere in a statement cause the statement to abort and roll back.

- For nontransactional storage engines, a statement aborts if the error occurs in the first row to be inserted or updated. (When the error occurs in the first row, the statement can be aborted to leave the table unchanged, just as for a transactional table.) Errors in rows after the first do not abort the statement, because the table has already been changed by the first row. Instead, bad data values are adjusted and result in warnings rather than errors. In other words, with `STRICT_TRANS_TABLES`, a wrong value

causes MySQL to roll back all updates done so far, if that can be done without changing the table. But once the table has been changed, further errors result in adjustments and warnings.

For even stricter checking, enable `STRICT_ALL_TABLES`. This is the same as `STRICT_TRANS_TABLES` except that for nontransactional storage engines, errors abort the statement even for bad data in rows following the first row. This means that if an error occurs partway through a multiple-row insert or update for a nontransactional table, a partial update results. Earlier rows are inserted or updated, but those from the point of the error on are not. To avoid this for nontransactional tables, either use single-row statements or else use `STRICT_TRANS_TABLES` if conversion warnings rather than errors are acceptable. To avoid problems in the first place, do not use MySQL to check column content. It is safest (and often faster) to let the application ensure that it passes only valid values to the database.

With either of the strict mode options, you can cause errors to be treated as warnings by using `INSERT IGNORE` or `UPDATE IGNORE` rather than `INSERT` or `UPDATE` without `IGNORE`.

1.8.3.4 ENUM and SET Constraints

`ENUM` and `SET` columns provide an efficient way to define columns that can contain only a given set of values. See Section 11.4.4, "The ENUM Type", and Section 11.4.5, "The SET Type".

With strict mode enabled (see Section 5.1.7, "Server SQL Modes"), the definition of a `ENUM` or `SET` column acts as a constraint on values entered into the column. An error occurs for values that do not satisfy these conditions:

- An `ENUM` value must be one of those listed in the column definition, or the internal numeric equivalent thereof. The value cannot be the error value (that is, 0 or the empty string). For a column defined as `ENUM('a','b','c')`, values such as `''`, `'d'`, or `'ax'` are invalid and are rejected.

- A `SET` value must be the empty string or a value consisting only of the values listed in the column definition separated by commas. For a column defined as `SET('a','b','c')`, values such as `'d'` or `'a,b,c,d'` are invalid and are rejected.

Errors for invalid values can be suppressed in strict mode if you use `INSERT IGNORE` or `UPDATE IGNORE`. In this case, a warning is generated rather than an error. For `ENUM`, the value is inserted as the error member (`0`). For `SET`, the value is inserted as given except that any invalid substrings are deleted. For example, `'a,x,b,y'` results in a value of `'a,b'`.

1.9 Credits

The following sections list developers, contributors, and supporters that have helped to make MySQL what it is today.

1.9.1 Contributors to MySQL

Although Oracle Corporation and/or its affiliates own all copyrights in the `MySQL server` and the `MySQL manual`, we wish to recognize those who have made contributions of one kind or another to the `MySQL distribution`. Contributors are listed here, in somewhat random order:

- Gianmassimo Vigazzola `<qwerg@mbox.vol.it>` or `<qwerg@tin.it>`

  The initial port to Win32/NT.

- Per Eric Olsson

  For constructive criticism and real testing of the dynamic record format.

- Irena Pancirov `<irena@mail.yacc.it>`

  Win32 port with Borland compiler. `mysqlshutdown.exe` and `mysqlwatch.exe`.

- David J. Hughes

  For the effort to make a shareware SQL database. At TcX, the predecessor of MySQL AB, we started with `mSQL`, but found that it couldn't satisfy our purposes so instead we wrote an SQL interface to our application builder Unireg. `mysqladmin` and `mysql` client are programs that were largely influenced by their `mSQL` counterparts. We have put a lot of effort into making the MySQL syntax a superset of `mSQL`. Many of the API's ideas are borrowed from `mSQL` to make it easy to port free `mSQL` programs to the MySQL API. The MySQL software doesn't contain any code from `mSQL`. Two files in the distribution (`client/insert_test.c` and `client/select_test.c`) are based on the corresponding (noncopyrighted) files in the `mSQL` distribution, but are modified as examples showing the changes necessary to convert code from `mSQL` to MySQL Server. (`mSQL` is copyrighted David J. Hughes.)

- Patrick Lynch

  For helping us acquire http://www.mysql.com/.

- Fred Lindberg

  For setting up qmail to handle the MySQL mailing list and for the incredible help we got in managing the MySQL mailing lists.

- Igor Romanenko `<igor@frog.kiev.ua>`

  `mysqldump` (previously `msqldump`, but ported and enhanced by Monty).

- Yuri Dario

  For keeping up and extending the MySQL OS/2 port.

- Tim Bunce

  Author of `mysqlhotcopy`.

- Zarko Mocnik `<zarko.mocnik@dem.si>`

  Sorting for Slovenian language.

- "TAMITO" `<tommy@valley.ne.jp>`

  The `_MB` character set macros and the ujis and sjis character sets.

- Joshua Chamas `<joshua@chamas.com>`

  Base for concurrent insert, extended date syntax, debugging on NT, and answering on the MySQL mailing list.

- Yves Carlier `<Yves.Carlier@rug.ac.be>`

  `mysqlaccess`, a program to show the access rights for a user.

- Rhys Jones `<rhys@wales.com>` (And GWE Technologies Limited)

  For one of the early JDBC drivers.

- Dr Xiaokun Kelvin ZHU `<X.Zhu@brad.ac.uk>`

Further development of one of the early JDBC drivers and other MySQL-related Java tools.

- James Cooper `<pixel@organic.com>`

  For setting up a searchable mailing list archive at his site.

- Rick Mehalick `<Rick_Mehalick@i-o.com>`

  For `xmysql`, a graphical X client for MySQL Server.

- Doug Sisk `<sisk@wix.com>`

  For providing RPM packages of MySQL for Red Hat Linux.

- Diemand Alexander V. `<axeld@vial.ethz.ch>`

  For providing RPM packages of MySQL for Red Hat Linux-Alpha.

- Antoni Pamies Olive `<toni@readysoft.es>`

  For providing RPM versions of a lot of MySQL clients for Intel and SPARC.

- Jay Bloodworth `<jay@pathways.sde.state.sc.us>`

  For providing RPM versions for MySQL 3.21.

- David Sacerdote `<davids@secnet.com>`

  Ideas for secure checking of DNS host names.

- Wei-Jou Chen `<jou@nematic.ieo.nctu.edu.tw>`

  Some support for Chinese(BIG5) characters.

- Wei He `<hewei@mail.ied.ac.cn>`

  A lot of functionality for the Chinese(GBK) character set.

- Jan Pazdziora `<adelton@fi.muni.cz>`

  Czech sorting order.

- Zeev Suraski `<bourbon@netvision.net.il>`

  `FROM_UNIXTIME()` time formatting, `ENCRYPT()` functions, and `bison` advisor. Active mailing list member.

- Luuk de Boer `<luuk@wxs.nl>`

  Ported (and extended) the benchmark suite to `DBI`/`DBD`. Have been of great help with `crash-me` and running benchmarks. Some new date functions. The `mysql_setpermission` script.

- Alexis Mikhailov `<root@medinf.chuvashia.su>`

  User-defined functions (UDFs); `CREATE FUNCTION` and `DROP FUNCTION`.

- Andreas F. Bobak `<bobak@relog.ch>`

  The `AGGREGATE` extension to user-defined functions.

- Ross Wakelin `<R.Wakelin@march.co.uk>`

  Help to set up InstallShield for MySQL-Win32.

- Jethro Wright III `<jetman@li.net>`

  The `libmysql.dll` library.

- James Pereria `<jpereira@iafrica.com>`

  Mysqlmanager, a Win32 GUI tool for administering MySQL Servers.

- Curt Sampson `<cjs@portal.ca>`

  Porting of MIT-pthreads to NetBSD/Alpha and NetBSD 1.3/i386.

- Martin Ramsch `<m.ramsch@computer.org>`

  Examples in the MySQL Tutorial.

- Steve Harvey

  For making `mysqlaccess` more secure.

- Konark IA-64 Centre of Persistent Systems Private Limited

  Help with the Win64 port of the MySQL server.

- Albert Chin-A-Young.

  Configure updates for Tru64, large file support and better TCP wrappers support.

- John Birrell

  Emulation of `pthread_mutex()` for OS/2.

- Benjamin Pflugmann

  Extended `MERGE` tables to handle `INSERTS`. Active member on the MySQL mailing lists.

- Jocelyn Fournier

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- Marc Liyanage

  Maintaining the OS X packages and providing invaluable feedback on how to create OS X packages.

- Robert Rutherford

  Providing invaluable information and feedback about the QNX port.

- Previous developers of NDB Cluster

  Lots of people were involved in various ways summer students, master thesis students, employees. In total more than 100 people so too many to mention here. Notable name is Ataullah Dabaghi who up until 1999 contributed around a third of the code base. A special thanks also to developers of the AXE system which provided much of the architectural foundations for NDB Cluster with blocks, signals and crash tracing functionality. Also credit should be given to those who believed in the ideas enough to allocate of their budgets for its development from 1992 to present time.

- Google Inc.

  We wish to recognize Google Inc. for contributions to the MySQL distribution: Mark Callaghan's SMP Performance patches and other patches.

Other contributors, bugfinders, and testers: James H. Thompson, Maurizio Menghini, Wojciech Tryc, Luca Berra, Zarko Mocnik, Wim Bonis, Elmar Haneke, `<jehamby@lightside>`, `<psmith@BayNetworks.com>`, `<duane@connect.com.au>`, Ted Deppner `<ted@psyber.com>`, Mike Simons, Jaakko Hyvatti.

And lots of bug report/patches from the folks on the mailing list.

A big tribute goes to those that help us answer questions on the MySQL mailing lists:

- Daniel Koch `<dkoch@amcity.com>`

  Irix setup.

- Luuk de Boer `<luuk@wxs.nl>`

  Benchmark questions.

- Tim Sailer `<tps@users.buoy.com>`

  `DBD::mysql` questions.

- Boyd Lynn Gerber `<gerberb@zenez.com>`

  SCO-related questions.

- Richard Mehalick `<RM186061@shellus.com>`

  `xmysql`-related questions and basic installation questions.

- Zeev Suraski `<bourbon@netvision.net.il>`

  Apache module configuration questions (log & auth), PHP-related questions, SQL syntax-related questions and other general questions.

- Francesc Guasch `<frankie@citel.upc.es>`

  General questions.

- Jonathan J Smith `<jsmith@wtp.net>`

  Questions pertaining to OS-specifics with Linux, SQL syntax, and other things that might need some work.

- David Sklar `<sklar@student.net>`

  Using MySQL from PHP and Perl.

- Alistair MacDonald `<A.MacDonald@uel.ac.uk>`

  Is flexible and can handle Linux and perhaps HP-UX.

- John Lyon `<jlyon@imag.net>`

  Questions about installing MySQL on Linux systems, using either `.rpm` files or compiling from source.

- Lorvid Ltd. `<lorvid@WOLFENET.com>`

  Simple billing/license/support/copyright issues.

- Patrick Sherrill `<patrick@coconet.com>`

  ODBC and VisualC++ interface questions.

- Randy Harmon `<rjharmon@uptimecomputers.com>`

  `DBD`, Linux, some SQL syntax questions.

1.9.2 Documenters and translators

The following people have helped us with writing the MySQL documentation and translating the documentation or error messages in MySQL.

- Paul DuBois

  Ongoing help with making this manual correct and understandable. That includes rewriting Monty's and David's attempts at English into English as other people know it.

- Kim Aldale

  Helped to rewrite Monty's and David's early attempts at English into English.

- Michael J. Miller Jr. `<mke@terrapin.turbolift.com>`

  For the first MySQL manual. And a lot of spelling/language fixes for the FAQ (that turned into the MySQL manual a long time ago).

- Yan Cailin

  First translator of the MySQL Reference Manual into simplified Chinese in early 2000 on which the Big5 and HK coded versions were based.

- Jay Flaherty `<fty@mediapulse.com>`

  Big parts of the Perl `DBI`/`DBD` section in the manual.

- Paul Southworth `<pauls@etext.org>`, Ray Loyzaga `<yar@cs.su.oz.au>`

  Proof-reading of the Reference Manual.

- Therrien Gilbert `<gilbert@ican.net>`, Jean-Marc Pouyot `<jmp@scalaire.fr>`

  French error messages.

- Petr Snajdr, `<snajdr@pvt.net>`

  Czech error messages.

- Jaroslaw Lewandowski `<jotel@itnet.com.pl>`

  Polish error messages.

- Miguel Angel Fernandez Roiz

  Spanish error messages.

- Roy-Magne Mo `<rmo@www.hivolda.no>`

  Norwegian error messages and testing of MySQL 3.21.xx.

- Timur I. Bakeyev `<root@timur.tatarstan.ru>`

  Russian error messages.

- `<brenno@dewinter.com>` & Filippo Grassilli `<phil@hyppo.com>`

  Italian error messages.

- Dirk Munzinger `<dirk@trinity.saar.de>`

  German error messages.

- Billik Stefan `<billik@sun.uniag.sk>`

  Slovak error messages.

- Stefan Saroiu `<tzoompy@cs.washington.edu>`

  Romanian error messages.

- Peter Feher

  Hungarian error messages.

- Roberto M. Serqueira

  Portuguese error messages.

- Carsten H. Pedersen

  Danish error messages.

- Arjen Lentz

  Dutch error messages, completing earlier partial translation (also work on consistency and spelling).

1.9.3 Packages that support MySQL

The following is a list of creators/maintainers of some of the most important API/packages/applications that a lot of people use with MySQL.

We cannot list every possible package here because the list would then be way to hard to maintain. For other packages, please refer to the software portal at http://solutions.mysql.com/software/.

- Tim Bunce, Alligator Descartes

  For the `DBD` (Perl) interface.

- Andreas Koenig `<a.koenig@mind.de>`

  For the Perl interface for MySQL Server.

- Jochen Wiedmann `<wiedmann@neckar-alb.de>`

  For maintaining the Perl `DBD::mysql` module.

- Eugene Chan `<eugene@acenet.com.sg>`

  For porting PHP for MySQL Server.

- Georg Richter

  MySQL 4.1 testing and bug hunting. New PHP 5.0 `mysqli` extension (API) for use with MySQL 4.1 and up.

- Giovanni Maruzzelli `<maruzz@matrice.it>`

  For porting iODBC (Unix ODBC).

- Xavier Leroy `<Xavier.Leroy@inria.fr>`

  The author of LinuxThreads (used by the MySQL Server on Linux).

1.9.4 Tools that were used to create MySQL

The following is a list of some of the tools we have used to create MySQL. We use this to express our thanks to those that has created them as without these we could not have made MySQL what it is today.

- Free Software Foundation

  From whom we got an excellent compiler (`gcc`), an excellent debugger (`gdb` and the `libc` library (from which we have borrowed `strto.c` to get some code working in Linux).

- Free Software Foundation & The XEmacs development team

  For a really great editor/environment.

- Julian Seward

  Author of `valgrind`, an excellent memory checker tool that has helped us find a lot of otherwise hard to find bugs in MySQL.

- Dorothea Lütkehaus and Andreas Zeller

  For `DDD` (The Data Display Debugger) which is an excellent graphical front end to `gdb`).

1.9.5 Supporters of MySQL

Although Oracle Corporation and/or its affiliates own all copyrights in the `MySQL server` and the `MySQL manual`, we wish to recognize the following companies, which helped us finance the development of the `MySQL server`, such as by paying us for developing a new feature or giving us hardware for development of the `MySQL server`.

- VA Linux / Andover.net

  Funded replication.

- NuSphere

  Editing of the MySQL manual.

- Stork Design studio

  The MySQL Web site in use between 1998-2000.

- Intel

  Contributed to development on Windows and Linux platforms.

- Compaq

  Contributed to Development on Linux/Alpha.

- SWSoft

  Development on the embedded `mysqld` version.

- FutureQuest

  The `--skip-show-database` option.

Chapter 2 Installing and Upgrading MySQL

Table of Contents

End of Product Lifecycle.   Active development for MySQL Database Server version 5.1 has ended. Oracle offers various support offerings which may be of interest. For details and more information, see the MySQL section of the Lifetime Support Policy for Oracle Technology Products (http://www.oracle.com/us/support/lifetime-support/index.html). Please consider upgrading to a recent version.

This chapter describes how to obtain and install MySQL. A summary of the procedure follows and later sections provide the details. If you plan to upgrade an existing version of MySQL to a newer version rather than install MySQL for the first time, see Section 2.13.1, "Upgrading MySQL", for information about upgrade procedures and about issues that you should consider before upgrading.

If you are interested in migrating to MySQL from another database system, see Section A.8, "MySQL 5.1 FAQ: Migration", which contains answers to some common questions concerning migration issues.

If you are migrating from MySQL Enterprise Edition to MySQL Community Server, see Section 2.13.2.2, "Downgrading from MySQL Enterprise Edition to MySQL Community Server".

Installation of MySQL generally follows the steps outlined here:

1. **Determine whether MySQL runs and is supported on your platform.**

   Please note that not all platforms are equally suitable for running MySQL, and that not all platforms on which MySQL is known to run are officially supported by Oracle Corporation.

2. **Choose which distribution to install.**

   Several versions of MySQL are available, and most are available in several distribution formats. You can choose from pre-packaged distributions containing binary (precompiled) programs or source code. When in doubt, use a binary distribution. Oracle also provides access to the MySQL source code for those who want to see recent developments and test new code. To determine which version and type of distribution you should use, see Section 2.1.1, "Choosing Which MySQL Distribution to Install".

3. **Download the distribution that you want to install.**

   For instructions, see Section 2.1.2, "How to Get MySQL". To verify the integrity of the distribution, use the instructions in Section 2.1.3, "Verifying Package Integrity Using MD5 Checksums or GnuPG".

4. **Install the distribution.**

   To install MySQL from a binary distribution, use the instructions in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

   To install MySQL from a source distribution or from the current development source tree, use the instructions in Section 2.11, "Installing MySQL from Source".

5. **Perform any necessary postinstallation setup.**

   After installing MySQL, see Section 2.12, "Postinstallation Setup and Testing" for information about making sure the MySQL server is working properly. Also refer to the information provided in Section 2.12.4, "Securing the Initial MySQL Accounts". This section describes how to secure the initial MySQL user accounts, *which have no passwords* until you assign passwords. The section applies whether you install MySQL using a binary or source distribution.

6. If you want to run the MySQL benchmark scripts, Perl support for MySQL must be available. See Section 2.15, "Perl Installation Notes".

Instructions for installing MySQL on different platforms and environments is available on a platform by platform basis:

- **Unix, Linux, FreeBSD**

  For instructions on installing MySQL on most Linux and Unix platforms using a generic binary (for example, a `.tar.gz` package), see Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

  For information on building MySQL entirely from the source code distributions or the source code repositories, see Section 2.11, "Installing MySQL from Source"

  For specific platform help on installation, configuration, and building from source see the corresponding platform section:

  - Linux, including notes on distribution specific methods, see Section 2.5, "Installing MySQL on Linux".

  - Solaris and OpenSolaris, including PKG and IPS formats, see Section 2.6, "Installing MySQL on Solaris and OpenSolaris".

  - IBM AIX, see Section 2.6, "Installing MySQL on Solaris and OpenSolaris".

  - Hewlett-Packard HP-UX, including the DEPOT package format, see Section 2.8, "Installing MySQL on HP-UX".

  - FreeBSD, see Section 2.9, "Installing MySQL on FreeBSD".

- **Microsoft Windows**

  For instructions on installing MySQL on Microsoft Windows, using either a Zipped binary or an MSI package, see Section 2.3, "Installing MySQL on Microsoft Windows".

  For information on using the MySQL Server Instance Config Wizard, see Section 2.3.5, "Using the MySQL Server Instance Config Wizard".

  For details and instructions on building MySQL from source code using Microsoft Visual Studio, see Section 2.11.7, "Installing MySQL from Source on Windows".

- **OS X**

For installation on OS X, including using both the binary package and native PKG formats, see Section 2.4, "Installing MySQL on OS X".

For information on making use of the MySQL Startup Item to automatically start and stop MySQL, see Section 2.4.4, "Installing the MySQL Startup Item".

For information on the MySQL Preference Pane, see Section 2.4.5, "Installing and Using the MySQL Preference Pane".

- **IBM i5/OS**

  For instructions on installing, starting, and stopping MySQL on i5/OS, see Section 2.10, "Installing MySQL on i5/OS".

2.1 General Installation Guidance

The immediately following sections contain the information necessary to choose, download, and verify your distribution. The instructions in later sections of the chapter describe how to install the distribution that you choose. For binary distributions, see the instructions at Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries" or the corresponding section for your platform if available. To build MySQL from source, use the instructions in Section 2.11, "Installing MySQL from Source".

2.1.1 Choosing Which MySQL Distribution to Install

MySQL is available on a number of operating systems and platforms. For information about those platforms that are officially supported, see http://www.mysql.com/support/supportedplatforms/database.html on the MySQL Web site.

When preparing to install MySQL, you should decide which version to use. MySQL development occurs in several release series, and you can pick the one that best fits your needs. After deciding which version to install, you can choose a distribution format. Releases are available in binary or source format.

2.1.1.1 Choosing Which Version of MySQL to Install

The first decision to make is whether you want to use a production (stable) release or a development release. In the MySQL development process, multiple release series co-exist, each at a different stage of maturity.

Production Releases

- MySQL 5.7: Latest General Availability (Production) release

- MySQL 5.6: Previous General Availability (Production) release

- MySQL 5.5: Older General Availability (Production) release

- MySQL 5.1, 5.0: Older Production releases for which active development has ended

MySQL 4.1, 4.0, and 3.23 are old releases that are no longer supported.

See http://www.mysql.com/about/legal/lifecycle/ for information about support policies and schedules. For supported platform information, see http://www.mysql.com/support/supportedplatforms/database.html.

Normally, if you are beginning to use MySQL for the first time or trying to port it to some system for which there is no binary distribution, use the most recent General Availability series listed in the preceding

descriptions. All MySQL releases, even those from development series, are checked with the MySQL benchmarks and an extensive test suite before being issued.

If you are running an older system and want to upgrade, but do not want to take the chance of having a nonseamless upgrade, you should upgrade to the latest version in the same release series you are using (where only the last part of the version number is newer than yours). We have tried to fix only fatal bugs and make only small, relatively "safe" changes to that version.

If you want to use new features not present in the production release series, you can use a version from a development series. Be aware that development releases are not as stable as production releases.

We do not use a complete code freeze because this prevents us from making bugfixes and other fixes that must be done. We may add small things that should not affect anything that currently works in a production release. Naturally, relevant bugfixes from an earlier series propagate to later series.

If you want to use the very latest sources containing all current patches and bugfixes, you can use one of our source code repositories (see Section 2.11.3, "Installing MySQL Using a Development Source Tree"). These are not "releases" as such, but are available as previews of the code on which future releases are to be based.

The naming scheme in MySQL 5.1 uses release names that consist of three numbers and a suffix; for example, **mysql-5.1.29-rc**. The numbers within the release name are interpreted as follows:

- The first number (**5**) is the major version and describes the file format. All MySQL 5 releases have the same file format.

- The second number (**1**) is the release level. Taken together, the major version and release level constitute the release series number.

- The third number (**29**) is the version number within the release series. This is incremented for each new release. Usually you want the latest version for the series you have chosen.

For each minor update, the last number in the version string is incremented. When there are major new features or minor incompatibilities with previous versions, the second number in the version string is incremented. When the file format changes, the first number is increased.

Release names also include a suffix that indicates the stability level of the release. Releases within a series progress through a set of suffixes to indicate how the stability level improves. The possible suffixes are:

- **alpha** indicates that the release is for preview purposes only. Known bugs should be documented in the Release Notes. Most alpha releases implement new commands and extensions. Active development that may involve major code changes can occur in an alpha release. However, we do conduct testing before issuing a release.

- **beta** indicates that the release is appropriate for use with new development. Within beta releases, the features and compatibility should remain consistent. However, beta releases may contain numerous and major unaddressed bugs.

  All APIs, externally visible structures, and columns for SQL statements will not change during future beta, release candidate, or production releases.

- **rc** indicates a Release Candidate. Release candidates are believed to be stable, having passed all of MySQL's internal testing, and with all known fatal runtime bugs fixed. However, the release has not been in widespread use long enough to know for sure that all bugs have been identified. Only minor fixes are added. (A release candidate is what formerly was known as a gamma release.)

- If there is no suffix, it indicates that the release is a General Availability (GA) or Production release. GA releases are stable, having successfully passed through all earlier release stages and are believed to be reliable, free of serious bugs, and suitable for use in production systems. Only critical bugfixes are applied to the release.

All releases of MySQL are run through our standard tests and benchmarks to ensure that they are relatively safe to use. Because the standard tests are extended over time to check for all previously found bugs, the test suite keeps getting better.

All releases have been tested at least with these tools:

- **An internal test suite.**   The `mysql-test` directory contains an extensive set of test cases. We run these tests for every server binary. See Section 22.1.2, "The MySQL Test Suite", for more information about this test suite.

- **The MySQL benchmark suite.**   This suite runs a range of common queries. It is also a test to determine whether the latest batch of optimizations actually made the code faster. See Section 8.13.2, "The MySQL Benchmark Suite".

We also perform additional integration and nonfunctional testing of the latest MySQL version in our internal production environment. Integration testing is done with different connectors, storage engines, replication modes, backup, partitioning, stored programs, and so forth in various combinations. Additional nonfunctional testing is done in areas of performance, concurrency, stress, high volume, upgrade and downgrade.

2.1.1.2 Choosing a Distribution Format

After choosing which version of MySQL to install, you should decide whether to use a binary distribution or a source distribution. In most cases, you should probably use a binary distribution, if one exists for your platform. Binary distributions are available in native format for many platforms, such as RPM packages for Linux, DMG packages for OS X, and PKG packages for Solaris. Distributions are also available in more generic formats such as Zip archives or compressed `tar` files.

Reasons to choose a binary distribution include the following:

- Binary distributions generally are easier to install than source distributions.

- To satisfy different user requirements, we provide several servers in binary distributions. `mysqld` is an optimized server that is a smaller, faster binary. `mysqld-debug` is compiled with debugging support.

  Each of these servers is compiled from the same source distribution, though with different configuration options. All native MySQL clients can connect to servers from either MySQL version.

Under some circumstances, you may be better off installing MySQL from a source distribution:

- You want to install MySQL at some explicit location. The standard binary distributions are ready to run at any installation location, but you might require even more flexibility to place MySQL components where you want.

- You want to configure `mysqld` to ensure that features are available that might not be included in the standard binary distributions. Here is a list of the most common extra options that you may want to use to ensure feature availability:

  - `--with-libwrap`

  - `--with-named-z-libs` (this is done for some of the binaries)

  - `--with-debug[=full]`

For additional information, see Section 2.11.4, "MySQL Source-Configuration Options".

- You want to configure `mysqld` without some features that are included in the standard binary distributions. For example, distributions normally are compiled with support for all character sets. If you want a smaller MySQL server, you can recompile it with support for only the character sets you need.

- You want to use the latest sources from one of the Bazaar repositories to have access to all current bugfixes. For example, if you have found a bug and reported it to the MySQL development team, the bugfix is committed to the source repository and you can access it there. The bugfix does not appear in a release until a release actually is issued.

- You want to read (or modify) the C and C++ code that makes up MySQL. For this purpose, you should get a source distribution, because the source code is always the ultimate manual.

- Source distributions contain more tests and examples than binary distributions.

2.1.1.3 How and When Updates Are Released

MySQL is evolving quite rapidly and we want to share new developments with other MySQL users. We try to produce a new release whenever we have new and useful features that others also seem to have a need for.

We also try to help users who request features that are easy to implement. We take note of what our licensed users want, and we especially take note of what our support customers want and try to help them in this regard.

No one is *required* to download a new release. The Release Notes help you determine whether the new release has something you really want.

We use the following policy when updating MySQL:

- Enterprise Server releases are meant to appear every 18 months, supplemented by quarterly service packs and monthly rapid updates. Community Server releases are meant to appear 2 to 3 times per year.

- Releases are issued within each series. For each release, the last number in the version is one more than the previous release within the same series.

- Binary distributions for some platforms are made by us for major releases. Other people may make binary distributions for other systems, but probably less frequently.

- We make fixes available as soon as we have identified and corrected small or noncritical but annoying bugs. The fixes are available in source form immediately from our public Bazaar repositories, and are included in the next release.

- If by any chance a security vulnerability or critical bug is found in a release, our policy is to fix it in a new release as soon as possible. (We would like other companies to do this, too!)

2.1.2 How to Get MySQL

Check our downloads page at http://dev.mysql.com/downloads/ for information about the current version of MySQL and for downloading instructions. For a complete up-to-date list of MySQL download mirror sites, see http://dev.mysql.com/downloads/mirrors.html. You can also find information there about becoming a MySQL mirror site and how to report a bad or out-of-date mirror.

To obtain the latest development source, see Section 2.11.3, "Installing MySQL Using a Development Source Tree".

2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG

After downloading the MySQL package that suits your needs and before attempting to install it, make sure that it is intact and has not been tampered with. There are three means of integrity checking:

- MD5 checksums

- Cryptographic signatures using `GnuPG`, the GNU Privacy Guard

- For RPM packages, the built-in RPM integrity verification mechanism

The following sections describe how to use these methods.

If you notice that the MD5 checksum or GPG signatures do not match, first try to download the respective package one more time, perhaps from another mirror site.

2.1.3.1 Verifying the MD5 Checksum

After you have downloaded a MySQL package, you should make sure that its MD5 checksum matches the one provided on the MySQL download pages. Each package has an individual checksum that you can verify against the package that you downloaded. The correct MD5 checksum is listed on the downloads page for each MySQL product, and you will compare it against the MD5 checksum of the file (product) that you download.

Each operating system and setup offers its own version of tools for checking the MD5 checksum. Typically the command is named `md5sum`, or it may be named `md5`, and some operating systems do not ship it at all. On Linux, it is part of the **GNU Text Utilities** package, which is available for a wide range of platforms. You can also download the source code from http://www.gnu.org/software/textutils/. If you have OpenSSL installed, you can use the command `openssl md5` `package_name` instead. A Windows implementation of the `md5` command line utility is available from http://www.fourmilab.ch/md5/. `winMd5Sum` is a graphical MD5 checking tool that can be obtained from http://www.nullriver.com/index/products/winmd5sum. Our Microsoft Windows examples will assume the name `md5.exe`.

Linux and Microsoft Windows examples:

```
shell> md5sum mysql-standard-5.1.73-linux-i686.tar.gz
aaab65abbec64d5e907dcd41b8699945  mysql-standard-5.1.73-linux-i686.tar.gz
```

```
shell> md5.exe mysql-installer-community-5.1.73.msi
aaab65abbec64d5e907dcd41b8699945  mysql-installer-community-5.1.73.msi
```

You should verify that the resulting checksum (the string of hexadecimal digits) matches the one displayed on the download page immediately below the respective package.

Note

Make sure to verify the checksum of the *archive file* (for example, the `.zip`, `.tar.gz`, or `.msi` file) and not of the files that are contained inside of the archive. In other words, verify the file before extracting its contents.

2.1.3.2 Signature Checking Using GnuPG

Another method of verifying the integrity and authenticity of a package is to use cryptographic signatures. This is more reliable than using MD5 checksums, but requires more work.

We sign MySQL downloadable packages with `GnuPG` (GNU Privacy Guard). `GnuPG` is an Open Source alternative to the well-known Pretty Good Privacy (`PGP`) by Phil Zimmermann. See http://www.gnupg.org/

for more information about `GnuPG` and how to obtain and install it on your system. Most Linux distributions ship with `GnuPG` installed by default. For more information about `GnuPG`, see http://www.openpgp.org/.

To verify the signature for a specific package, you first need to obtain a copy of our public GPG build key, which you can download from http://pgp.mit.edu/. The key that you want to obtain is named `mysql-build@oss.oracle.com`. Alternatively, you can cut and paste the key directly from the following text:

```
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.4.9 (SunOS)

mQGiBD4+owwRBAC14GIfUfCyEDSIePvEW3SAFUdJBtoQHH/nJKZyQT7h9bPlUWC3
RODjQReyCITRrdwyrKUGku2FmeVGwn2u2WmDMNABLnpprWPkBdCk96+OmSLN9brZ
fw2vOUgCmYv2hW0hyDHuvYlQA/BThQoADgj8AW6/0Lo7V1W9/8VuHP0gQwCgvzV3
BqOxRznNCRCRxAuAuVztHRcEAJooQK1+iSiunZMYD1WufeXfshc57S/+yeJkegNW
hxwR9pRWVArNYJdDRT+rf2RUe3vpquKNQU/hnEIUHJRQqYHo8gTxvxXNQc7fJYLV
K2HtkrPbP72vwsEKMYhhr0eKCbtLGfls9krjJ6sBgACyP/Vb7hiPwxh6rDZ7ITnE
kYpXBACmWpP8NJTkamEnPCia2ZoOHODANwpUkP43I7jsDmgtobZX9qnrAXw+uNDI
QJEXM6FSbi0LLtZciNlYsafwAPEOMDKpMqAK6IyisNtPvaLd8lH0bPAnWqcyefep
rv0sxxqUEMcM3o7wwgfN83POkDasDbs3pjwPhxvhz6//62zQJ7Q2TXlTUUwgUmVs
ZWFzZSBEFbmdpbmVlcmluZyA8bXlzcWwtYnVpbGRAb3NzLm9yYWNsZS5jb20+iGkE
ExECACkCGyMGCwkIBwMCBBUCCAMEFgIDAQIeAQIXgAIZAQUCUwHUZgUJGGmbLywAK
CRCMcY07UHLh9V+DAKCjS1gGwgVI/eut+5L+l2v3ybl+ZgCcD7ZoA341HtoroV3U
6xRD09fUgeq0O015U1FMIFBhY2thZ2Ugc2lnbmluZyBrZXkgKHd3dy5teXNxbC5j
b20pIDxidWlsZEBteXNxbC5jb20+iG8EMBECAC8FAk53Pa0oHSBidWlsZEBteXNx
bC5jb20gd2lsbCBzdG9wIHdvcmtpbmcgc29vbgAKCRCMcY07UHLh9bU9AJ9x9DK0o
xJFL9vTl9OSZC4lX0K9AzwCcCrS9cnJyz79eaRjL0s2r/CcljdyIZQQTEQIAHQUC
R6yUtAUJDTBYqAULBwoDBAMVAwIDFgIBAheAABIJEIxxjTtQcuH1B2VHUEcAAQGu
kgCffz4GUEjzXOi71VcwgCxASTgbe0An34LPr1j9fCbrXWXO14msIADfb5piEwE
ExECAAwFAj4+o9EFgwlmALsACgkQSVDhKrJykfIk4QCfWbEeKN+3TRspe+5xKj+k
QJSammIAnjUz0xFWPlVx0f8o38qNG1bq0cU9iEwEExECAAwFAj5CggMFgwliIokA
CgkQtvXNTca6JD+WkQCgiGmnoGjMojynp5ppvMXkyUkfnykAoK79E6h8rwkSDZou
iz7nMRisH8uyiEYEEBECAAYFAj+s468ACgkQr8UjSHiDdA/2lgCg21IhIMMABTYd
p/IBiUsP/JQLiEoAnRzMywEtujQz/E9ono7H1DkebDa4iEYEEBECAAYFAj+0Q3cA
CgkQhZavqzBzTmbGwwCdFqDlfrViC7WRt8GKoOS7hzNN32kAnirlbwpnT7a6NOsQ
83nk11a2dePhiEYEEBECAAYFAkNbs+oACgkQi9gubzC5Slx/dACdELKoXQKkwJN0
gZztsM7kjsIgyFMAnRRMbHQ7V39XC90OIpaPjk3a0ltgiEYEEKECAAYFAkTxMyYA
CgkQ9knE9GCTUwwKcQCgibak/SwhxWH1ijRhgYCo5GtM4vcAnAhtzL57wcw1Kg1X
m7nVGetUqJ7fiEwEEBECAAwFAkGBywEFgwYi2YsACgkQGFnQH2d7oexCjQCcD8sJ
NDc/mS8m8OGDUOx9VMWcnGkAnj1YWOD+Qhxo3mI/Ul9oEAhNkjcfiEwEEBECAAwF
AkGByzQFgwYi2VgACgkQgcL36+ITtpIiIwCdFVNVUB8xe8mFXoPm4d9Z54PTjpMA
niSPA/ZsfJ3oOMLKar4F0QPPrdrGiEwEEBECAAwFAkGBy2IFgwYi2SoACgkQa3Ds
2V3D9HMJqgCbBYzr5GPXOXgP88jKzmdbjweqXeEAnRss4G2G/3qD7uhTL1SPT1SH
jWUXiEwEEBECAAwFAkHQkyQFgwXUEWgACgkQfSXKCsEpp8JiVQCghvWvkPqowsw8
w7WSseTcw1tflvkAni+vLH1/DqIly0LkZYn5jzK1dpvfiEwEEBECAAwFAkIrW7oF
gwV5SNIACgkQ5hukiRXruavzEwCgkzL5QkLSypcw9LGHcFSx1ya0VL4An35nXkum
g6cCJ1NP8r2I4NcZWIrqiEwEEhECAAwFAkAqWToFgwd6S1IACgkQPKEfNJT6+GEm
XACcD+A53A50GM7w750W11ukq4iZ9ckAnRMvndAqn3YTOxxlLPj2UPZiSgSqiEwE
EhECAAwFAkA9+roFgwdmqdIACgkQ8tdcY+OcZZyy3wCgtDcwlaq20w0cNuXFLLNe
EUaFFTwAni6RHN80moSVAdDTRkzZacJU3M5QiEwEEhECAAwFAkEOCoQFgwaWmggA
CgkQOcor9D1qil/83QCeITZ9wIo7XAMjC6y4ZWUL4m+edZsAoMOhRIRi42fmrNFu
vNZbnMGej81viEwEEhECAAwFAkKApTQFgwUj/1gACgkQBA3AhXyDn6jjJACcD1A4
UtXk84J13JQyoH9+dy24714Aniwlsso/9ndICJOkqs2j5dlHFq6oiEwEExECAAwF
Aj5NTYQFgwlXVwgACgkQLbt2v63UyTMFDACglT5G5NVKf5Mj65bFSlPzb92zk2QA
n1uc2h19/IwwrsbIyK/9POJ+JMP7iEwEExECAAwFAkHXgHYFgwXNJBYACgkQZu/b
yM2C/T4/vACfXe67xiSHB80wkmFZ2krb+oz/gBAAnjR2ucpbaonkQQgnC3GnBqmC
vNaJiEwEExECAAwFAkIYgQ4FgwWMI34ACgkQdsEDHKIxbqGg7gCfQi2HcrHn+yLF
uNlH1oSOh48ZM0oAn3hKV0uIRJphonHaUYiUP1ttWgdBiGUEExECAB0FCwcKAwQD
FQMCAxYCAQIXgAUCS3AvygUJEPPzpwASB2VHUEcAAQEJEIxxjTtQcuH1sNsAniYp
YBGqy/HhMnw3WE8kXahOOR5KAJ4xUmWPGYP4l3hKxyNK9OAUbpDVYIh7BDARAgA7
BQJCdzX1NB0AT29wcy4uLiBzaG91bGQgaGF2ZSBiZWVuIGxvY2FsISBJJ20gKnNv
KiBzdHVwaWQuLi4ACgkQOcor9D1qil/vRwCdFo08f66oKLiuEAqzlf9iDlPozEEA
n2EgvCYLCCHjfGosrkrU3WK5NFVgiI8EMBECAE8FAkVvAL9IHQBTaG91bGQgaGF2
ZSBiZWVuIGEgbG9jYWwgc2lnbmF0dXJlLCBvciBzb211dGhpbmcgLSBYVEYgd2Fz
IEkgdGhpbmtpbmc/AAoJEDnKK/Q9aopfoPsAn3BVqKOalJeF0xPSvLR90PsRlnmG
AJ44oisY7Tl3NJbPgZal8W32fbqqbIkCIgQQAQIADAUCQYHLhQWDBiLZBwAKCRCq
```

```
4+bOZqFEaKgvEACCErnaHGyUYa0wETjj6DLEXsqeOiXad4i9aBQxnD35GUgcFofC
/nCY4XcnCMMEnmdQ9ofUuU3OBJ6BNJIbEusAabgLooebP/3KEaiCIiyhHYU5jarp
ZAh+Zopgs3Oc11mQ1tIaS69iJxrGTLodkAsAJAeEUwTPq9fHFFzCleGBysoyFWg4
bIjz/zClI+qyTbFA5g6tRoiXTo8ko7QhY2AA5UGEg+83Hdb6akC04Z2QRErxKAqr
phHzj8XpjVOsQAdAi/qVKQeNKROlJ+iq6+YesmcWGfzeb87dGNweVFDJIGA0qY27
pTb2lExYjsRFN4Cb13NfodAbMTOxcAWZ7jAPCxAPlHUG++mHMrhQXEToZnBFE4nb
nC7vOBNgWdjUgXcpkUCkop4b17BFpR+k8ZtYLSS8p2LLz4uAeCcSm2/msJxT7rC/
FvoH8428oHincqs2ICo9zO/Ud4HmmO0O+SsZdVKIIjinGyOVWb4OOzkAlnnhEZ3o
6hAHcREIsBgPwEYVTj/9ZdC0AO44Nj9cU7awaqgtrnwwfr/o4V2gl8bLSkltZU27
/29HeuOeFGjlFe0YrDd/aRNsxbyb2O28H4sG1CVZmC5uKliQBDiSyA7Q0bbdofCW
oQzm5twlpKWnY8Oe0ub9XP5p/sVfck4FceWFHwv+/PC9RzSl33lQ6vM2wIkCIgQT
AQIADAUCQp8KHAWDBQWacAAKCRDYwgoJWiRXzyE+D/9uc7z6fIsalfOYoLN60ajA
bQbI/uRKBFugyZ5RoaItusn9Z2rAtn61WrFhu4uCSJtFN1ny2RERg40f56pTghKr
D+YEt+Nze6+FKQ5AbGIdFsR/2bUk+ZZRSt83e14Lcb6ii/fJfzkoIox9ltkifQxq
Y7Tvk4noKu4oLSc8O1Wsfc/y0B9sYUUCmUfcnq58DEmGie9ovUslmyt5NPnveXxp
5UeaRc5Rqt9tK2B4A+7/cqENrdZJbAMSunt2+2fkYiRunAFPKPBdJBsY1sxeL/A9
aKe0viKEXQdAWqdNZKNCi8rd/oOP99/9lMbFudAbX6nL2DSb1OG2Z7NWEqgIAzjm
pwYYPCKeVz5Q8R+if9/fe5+STY/55OaI33fJ2H3v+U435VjYqbrerWe36xJItcJe
qUzW71fQtXi1CTEl3w2ch7VF5oj/QyjabLnAlHgSlkSi6p7By5C2MnbCHlCfPnIi
nPhFoRcRGPjJe9nFwGs+QblvS/Chzc2WX3s/2SWm4gEUKRX4zsAJ5ocyfa/vkxCk
SxK/erWlCPf/J1T70+i5waXDN/E3enSet/WL7h94pQKpjz8OdGL4JSBHuAVGA+a+
dknqnPF0KMKLhjrgV+L7O84FhbmAP7PXm3xmiMPriXf+el5fZZequQoIagf8rdRH
HhRJxQgI0HNknkaOqs8dtrkCDQQ+PqMdEAgA7+GJfxbMdY4wslPnjH9rF4N2qfWs
EN/lxaZoJYc3a6M02WCnHl6ahT2/tBK2w1QI4YFteR47gCvtgb6OlJHffOo2HfLm
RDRiRjd1DTCHqeyX7CHhcghj/dNRlW2ZOl5QFEcmV9U0Vhp3aFfWC4Ujfs3LU+hk
AWzE7zaD5cH9J7yv/6xuZVw4l1x0h4UqsTcWMu0iM1BzELqX1DY7LwoPEb/O9Rkb
f4fmLe11EzIaCa4PqARXQZc4dhSinMt6K3X4BrRsKTfozBu74F47D8Ilbf5vSYHb
uE5p/1oIDznkg/p8kW+3FxuWrycciqFTcNz2l5yyX39LXFnlLzKUb/F5GwADBQf+
Lwqqa8CGrRfsOAJxim63CHfty5mUc5rUSnTslGYEIOCR1BeQauyPZbPDsDD9MZ1Z
aSafanFvwFG6Llx9xkU7tzq+vKLoWkm4u5xf3vn55VjnSd1aQ9eQnUcXiL4cnBGo
TbOWI39EcyzgslzBdC++MPjcQTcA7p6JUVsP6oAB3FQWg54tuUo0Ec8bsM8b3Ev4
2LmuQT5NdKHGwHsXTPtl0klk4bQk4OajHsiy1BMahpT27jWjJlMiJc+IWJ0mghkK
Ht926s/ymfdf5HkdQlcyvsz5tryVI3Fx78XeSYfQvuuwqp2H139pXGEkg0n6KdUO
etdZWhe70YGNPw1yjWJT1IhUBBgRAgAMBQJOdz3tBQkT+wG4ABIHZUdQRwABAQkQ
jHGNOlBy4fUUmwCbBYr2+bBEn/L2BOcnw9Z/QFWuhRMAoKVgCFm5fadQ3Afi+UQl
AcOphrnJ
=443I
-----END PGP PUBLIC KEY BLOCK-----
```

To import the build key into your personal public GPG keyring, use `gpg --import`. For example, if you have saved the key in a file named `mysql_pubkey.asc`, the import command looks like this:

```
shell> gpg --import mysql_pubkey.asc
gpg: key 5072E1F5: public key "MySQL Release Engineering
<mysql-build@oss.oracle.com>" imported
gpg: Total number processed: 1
gpg:               imported: 1
gpg: no ultimately trusted keys found
```

You can also download the key from the public keyserver using the public key id, `5072E1F5`:

```
shell> gpg --recv-keys 5072E1F5
gpg: requesting key 5072E1F5 from hkp server keys.gnupg.net
gpg: key 5072E1F5: "MySQL Release Engineering <mysql-build@oss.oracle.com>"
1 new user ID
gpg: key 5072E1F5: "MySQL Release Engineering <mysql-build@oss.oracle.com>"
53 new signatures
gpg: no ultimately trusted keys found
gpg: Total number processed: 1
gpg:           new user IDs: 1
gpg:        new signatures: 53
```

If you want to import the key into your RPM configuration to validate RPM install packages, you should be able to import the key directly:

```
shell> rpm --import mysql_pubkey.asc
```

If you experience problems or require RPM specific information, see Section 2.1.3.4, "Signature Checking Using RPM".

After you have downloaded and imported the public build key, download your desired MySQL package and the corresponding signature, which also is available from the download page. The signature file has the same name as the distribution file with an `.asc` extension, as shown by the examples in the following table.

Table 2.1 MySQL Package and Signature Files for Source files

File Type	File Name
Distribution file	`mysql-standard-5.1.73-linux-i686.tar.gz`
Signature file	`mysql-standard-5.1.73-linux-i686.tar.gz.asc`

Make sure that both files are stored in the same directory and then run the following command to verify the signature for the distribution file:

```
shell> gpg --verify package_name.asc
```

If the downloaded package is valid, you will see a "Good signature" similar to:

```
shell> gpg --verify mysql-standard-5.1.73-linux-i686.tar.gz.asc
gpg: Signature made Tue 01 Feb 2011 02:38:30 AM CST using DSA key ID 5072E1F5
gpg: Good signature from "MySQL Release Engineering <mysql-build@oss.oracle.com>"
```

The `Good signature` message indicates that the file signature is valid, when compared to the signature listed on our site. But you might also see warnings, like so:

```
shell> gpg --verify mysql-standard-5.1.73-linux-i686.tar.gz.asc
gpg: Signature made Wed 23 Jan 2013 02:25:45 AM PST using DSA key ID 5072E1F5
gpg: checking the trustdb
gpg: no ultimately trusted keys found
gpg: Good signature from "MySQL Release Engineering <mysql-build@oss.oracle.com>"
gpg: WARNING: This key is not certified with a trusted signature!
gpg:          There is no indication that the signature belongs to the owner.
Primary key fingerprint: A4A9 4068 76FC BD3C 4567  70C8 8C71 8D3B 5072 E1F5
```

That is normal, as they depend on your setup and configuration. Here are explanations for these warnings:

* *gpg: no ultimately trusted keys found*: This means that the specific key is not "ultimately trusted" by you or your web of trust, which is okay for the purposes of verifying file signatures.

* *WARNING: This key is not certified with a trusted signature! There is no indication that the signature belongs to the owner.*: This refers to your level of trust in your belief that you possess our real public key. This is a personal decision. Ideally, a MySQL developer would hand you the key in person, but more commonly, you downloaded it. Was the download tampered with? Probably not, but this decision is up to you. Setting up a web of trust is one method for trusting them.

See the GPG documentation for more information on how to work with public keys.

2.1.3.3 Signature Checking Using Gpg4win for Windows

The Section 2.1.3.2, "Signature Checking Using GnuPG" section describes how to verify MySQL downloads using GPG. That guide also applies to Microsoft Windows, but another option is to use a GUI

tool like Gpg4win. You may use a different tool but our examples are based on Gpg4win, and utilize its bundled `Kleopatra` GUI.

Download and install Gpg4win, and then load Kleopatra. The dialog should look similar to:

Figure 2.1 Initial screen after loading Kleopatra
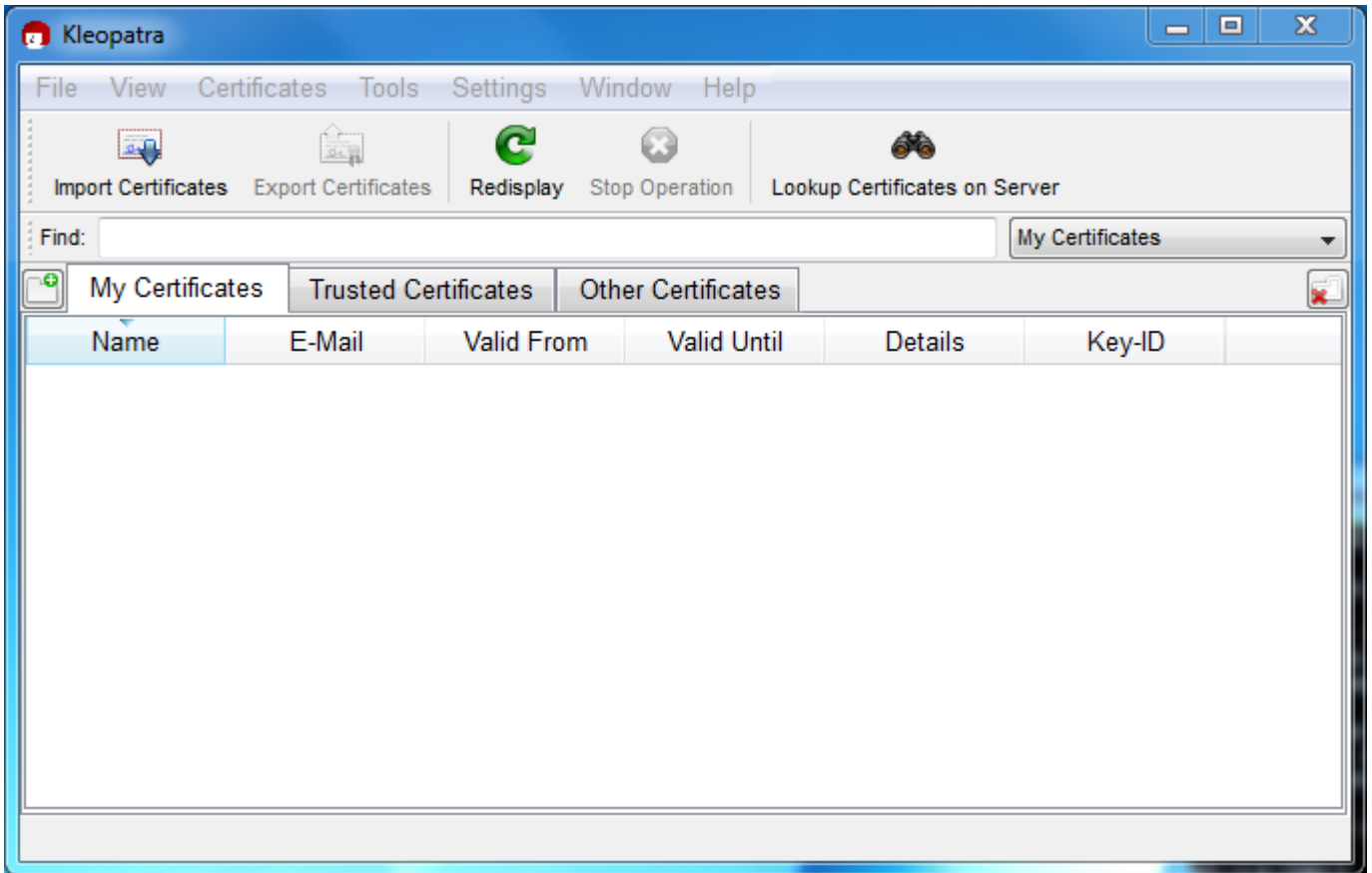
Next, add the MySQL Release Engineering certificate. Do this by clicking **File**, **Lookup Certificates on Server**. Type "Mysql Release Engineering" into the search box and press **Search**.

Figure 2.2 Finding the MySQL Release Engineering certificate
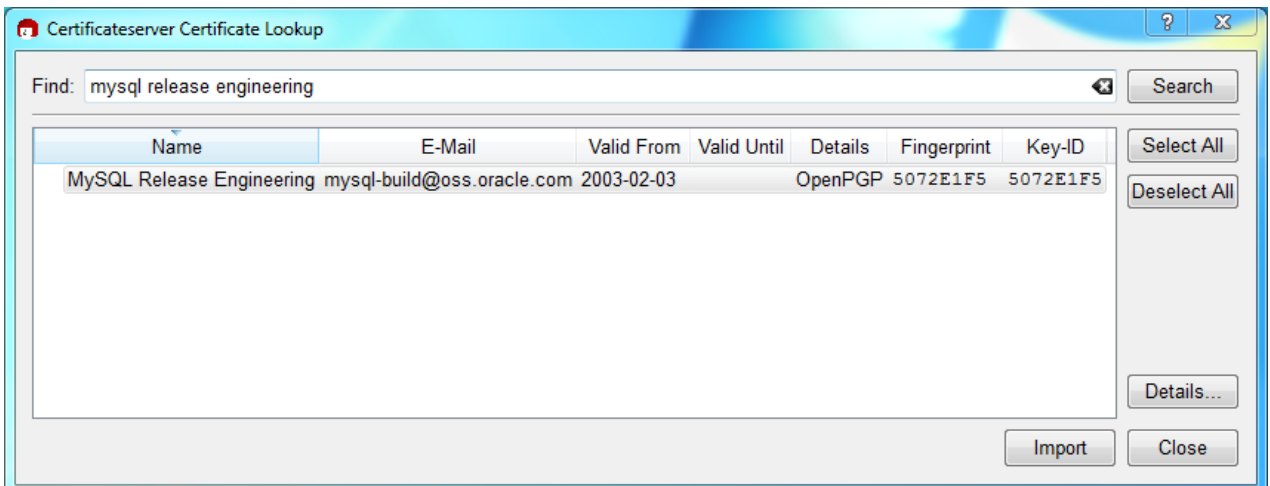
Select the "MySQL Release Engineering" certificate. The Fingerprint and Key-ID must be "5072E1F5", or choose **Details...** to confirm the certificate is valid. Now, import it by clicking **Import**. An import dialog will be displayed, choose **Okay**, and this certificate will now be listed under the **Imported Certificates** tab.

Next, configure the trust level for our certificate. Select our certificate, then from the main menu select **Certificates**, **Change Owner Trust...**. We suggest choosing **I believe checks are very accurate** for our certificate, as otherwise you might not be able to verify our signature. Select **I believe checks are very accurate** and then press **OK**.

Figure 2.3 Changing the Trust level
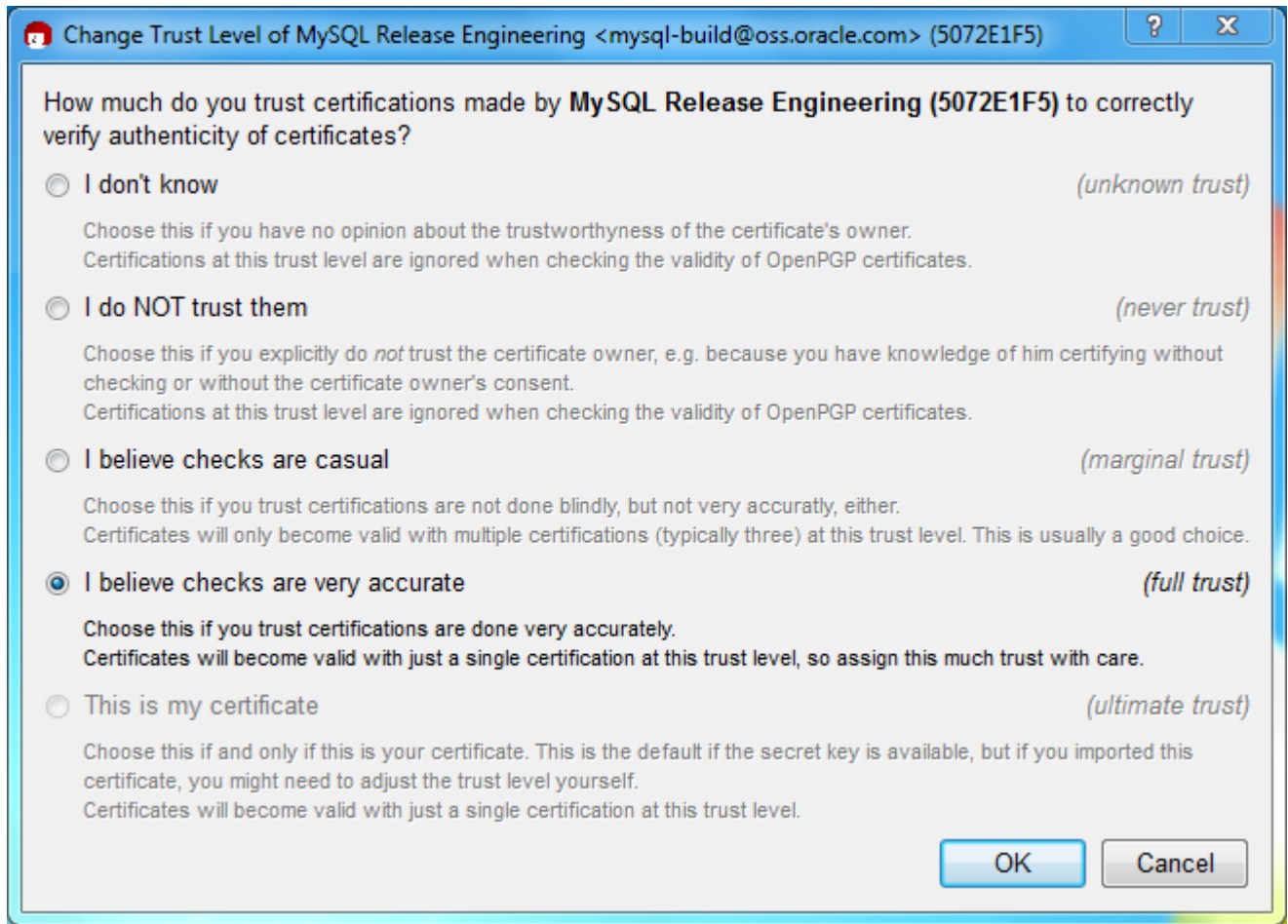
Next, verify the downloaded MySQL package file. This requires files for both the packaged file, and the signature. The signature file must have the same name as the packaged file but with an appended `.asc` extension, as shown by the example in the following table. The signature is linked to on the downloads page for each MySQL product. You must create the `.asc` file with this signature.

Table 2.2 MySQL Package and Signature Files for MySQL Installer for Microsoft Windows

File Type	File Name
Distribution file	`mysql-installer-community-5.1.73.msi`
Signature file	`mysql-installer-community-5.1.73.msi.asc`

Make sure that both files are stored in the same directory and then run the following command to verify the signature for the distribution file. Either drag and drop the signature (`.asc`) file into Kleopatra, or load the dialog from **File**, **Decrypt/Verify Files...**, and then choose either the `.msi` or `.asc` file.

Figure 2.4 The Decrypt/Verify Files dialog
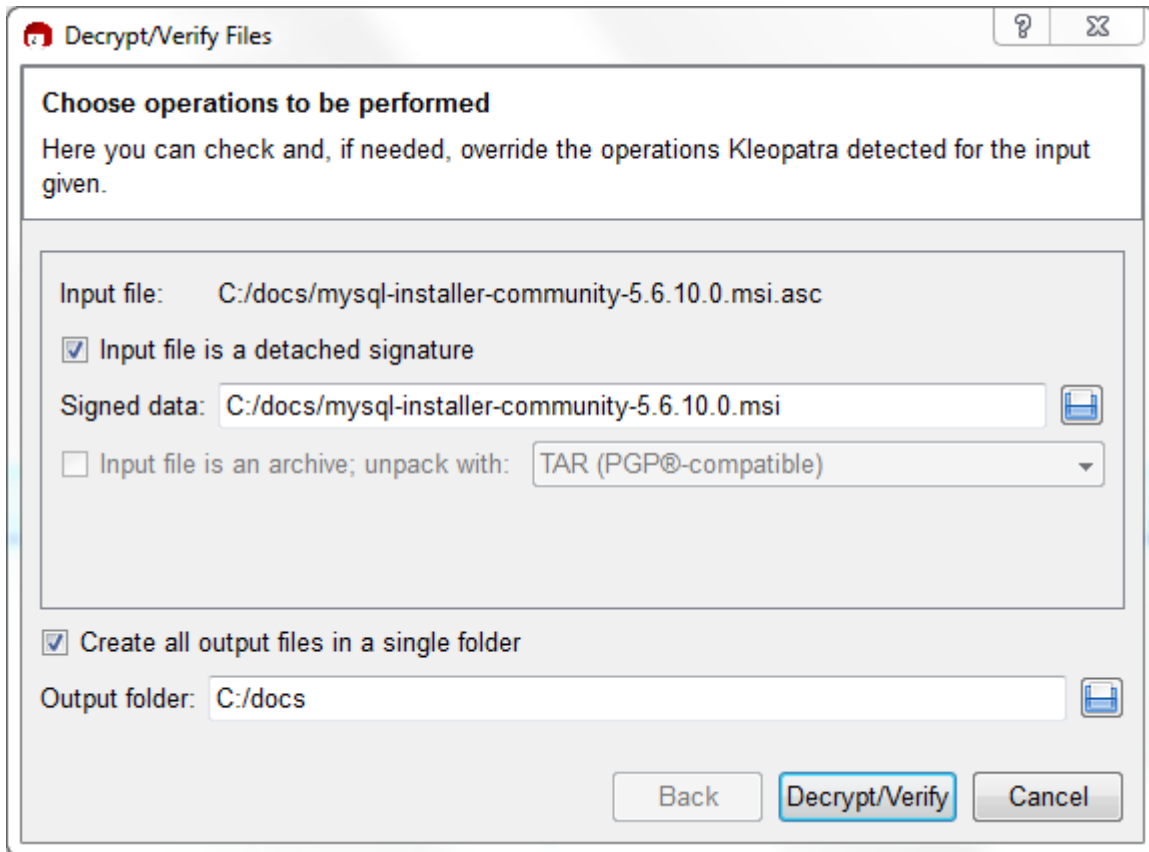
Click **Decrypt/Verify** to check the file. The two most common results will look like the following, and although the yellow warning looks problematic, the following means that the file check passed with success. You may now run this installer.

Figure 2.5 The Decrypt/Verify Results: Good
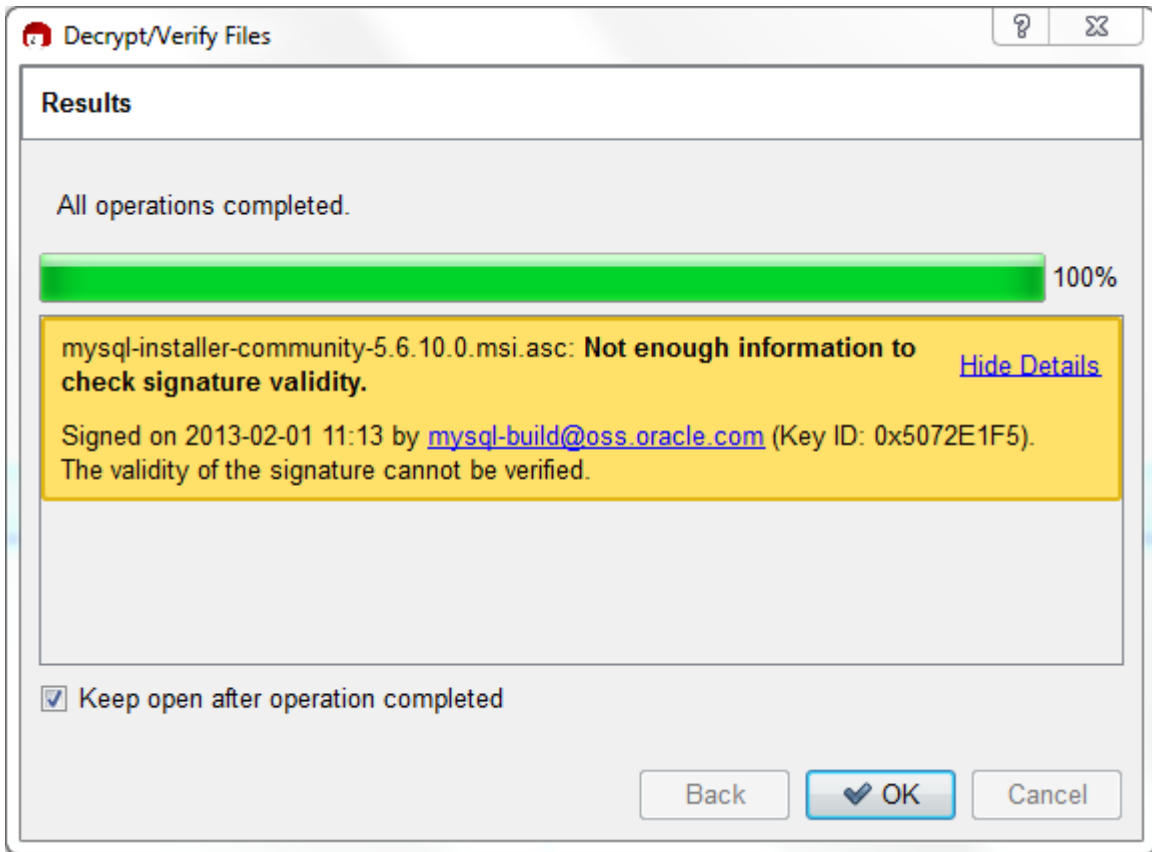
Seeing a red "The signature is bad" error means the file is invalid. Do not execute the MSI file if you see this error.

Figure 2.6 The Decrypt/Verify Results: Bad
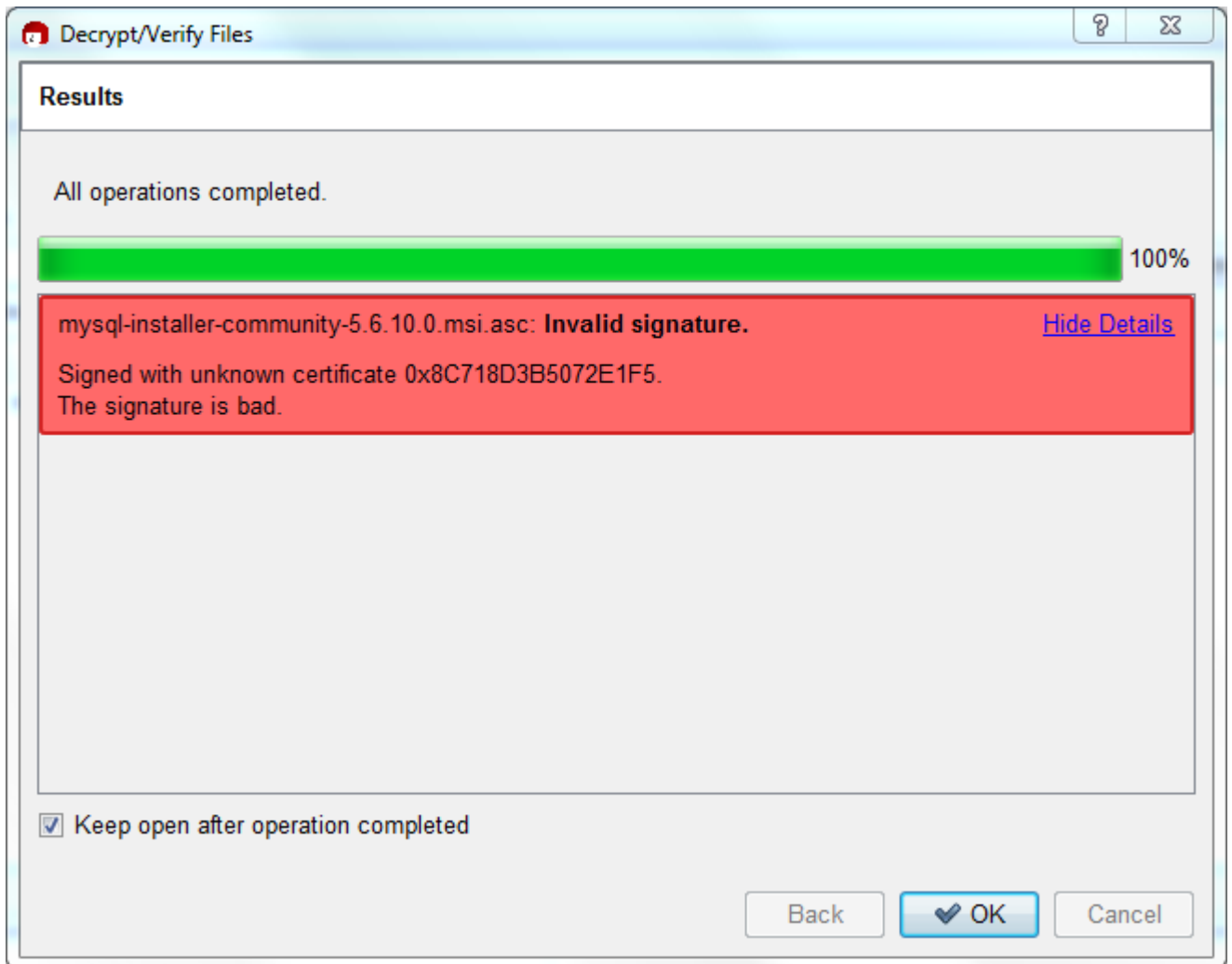
The Section 2.1.3.2, "Signature Checking Using GnuPG" section explains why you probably don't see a green `Good signature` result.

2.1.3.4 Signature Checking Using RPM

For RPM packages, there is no separate signature. RPM packages have a built-in GPG signature and MD5 checksum. You can verify a package by running the following command:

```
shell> rpm --checksig package_name.rpm
```

Example:

```
shell> rpm --checksig MySQL-server-5.1.73-0.glibc23.i386.rpm
MySQL-server-5.1.73-0.glibc23.i386.rpm: md5 gpg OK
```

> **Note**
>
> If you are using RPM 4.1 and it complains about `(GPG) NOT OK (MISSING KEYS: GPG#5072e1f5)`, even though you have imported the MySQL public build

> key into your own GPG keyring, you need to import the key into the RPM keyring
> first. RPM 4.1 no longer uses your personal GPG keyring (or GPG itself). Rather,
> RPM maintains a separate keyring because it is a system-wide application and a
> user's GPG public keyring is a user-specific file. To import the MySQL public key
> into the RPM keyring, first obtain the key, then use `rpm --import` to import the
> key. For example:

```
shell> gpg --export -a 5072e1f5 > 5072e1f5.asc
shell> rpm --import 5072e1f5.asc
```

Alternatively, `rpm` also supports loading the key directly from a URL, and you can use this manual page:

```
shell> rpm --import http://dev.mysql.com/doc/refman/5.1/en/checking-gpg-signature.html
```

If you need to obtain the MySQL public key, see Section 2.1.3.2, "Signature Checking Using GnuPG".

2.1.4 Installation Layouts

The installation layout differs for different installation types (for example, native packages, binary tarballs, and source tarballs), which can lead to confusion when managing different systems or using different installation sources. The individual layouts are given in the corresponding installation type or platform chapter, as described following. Note that the layout of installations from vendors other than Oracle may differ from these layouts.

- Section 2.3.1, "MySQL Installation Layout on Microsoft Windows"

- Section 2.11.1, "MySQL Layout for Source Installation"

- Table 2.3, "MySQL Installation Layout for Generic Unix/Linux Binary Package"

- Table 2.15, "MySQL Installation Layout for Linux RPM Packages"

- Table 2.12, "MySQL Installation Layout on OS X"

2.1.5 Compiler-Specific Build Characteristics

In some cases, the compiler used to build MySQL affects the features available for use. The notes in this section apply for binary distributions provided by Oracle Corporation or that you compile yourself from source.

`icc` (Intel C++ Compiler) Builds

A server built with `icc` has these characteristics:

- SSL support is not included.

- `InnoDB Plugin` is not included.

2.2 Installing MySQL on Unix/Linux Using Generic Binaries

Oracle provides a set of binary distributions of MySQL. These include generic binary distributions in the form of compressed `tar` files (files with a `.tar.gz` extension) for a number of platforms, and binaries in platform-specific package formats for selected platforms.

This section covers the installation of MySQL from a compressed `tar` file binary distribution. For other platform-specific package formats, see the other platform-specific sections. For example, for Windows distributions, see Section 2.3, "Installing MySQL on Microsoft Windows".

To obtain MySQL, see Section 2.1.2, "How to Get MySQL".

MySQL compressed `tar` file binary distributions have names of the form `mysql-VERSION-OS.tar.gz`, where *VERSION* is a number (for example, `5.1.73`), and *OS* indicates the type of operating system for which the distribution is intended (for example, `pc-linux-i686` or `winx64`).

> **Warning**
>
> If you have previously installed MySQL using your operating system native package management system, such as `yum` or `apt-get`, you may experience problems installing using a native binary. Make sure your previous MySQL installation has been removed entirely (using your package management system), and that any additional files, such as old versions of your data files, have also been removed. You should also check for configuration files such as `/etc/my.cnf` or the `/etc/mysql` directory and delete them.

If you run into problems and need to file a bug report, please use the instructions in Section 1.7, "How to Report Bugs or Problems".

On Unix, to install a compressed `tar` file binary distribution, unpack it at the installation location you choose (typically `/usr/local/mysql`). This creates the directories shown in the following table.

Table 2.3 MySQL Installation Layout for Generic Unix/Linux Binary Package

Directory	Contents of Directory
`bin`, `scripts`	`mysqld` server, client and utility programs
`data`	Log files, databases
`docs`	MySQL manual in Info format
`man`	Unix manual pages
`include`	Include (header) files
`lib`	Libraries
`share`	Miscellaneous support files, including error messages, sample configuration files, SQL for database installation
`sql-bench`	Benchmarks

Debug versions of the `mysqld` binary are available as `mysqld-debug`. To compile your own debug version of MySQL from a source distribution, use the appropriate configuration options to enable debugging support. See Section 2.11, "Installing MySQL from Source".

To install and use a MySQL binary distribution, the command sequence looks like this:

```
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
shell> cd /usr/local
shell> tar zxvf /path/to/mysql-VERSION-OS.tar.gz
shell> ln -s full-path-to-mysql-VERSION-OS mysql
shell> cd mysql
shell> chown -R mysql .
shell> chgrp -R mysql .
shell> scripts/mysql_install_db --user=mysql
shell> chown -R root .
shell> chown -R mysql data
# Next command is optional
shell> cp support-files/my-medium.cnf /etc/my.cnf
shell> bin/mysqld_safe --user=mysql &
```

```
# Next command is optional
shell> cp support-files/mysql.server /etc/init.d/mysql.server
```

Note

This procedure assumes that you have `root` (administrator) access to your system. Alternatively, you can prefix each command using the `sudo` (Linux) or `pfexec` (OpenSolaris) command.

Note

The procedure does not assign passwords to MySQL accounts. To do so, use the instructions in Section 2.12.4, "Securing the Initial MySQL Accounts".

A more detailed version of the preceding description for installing a binary distribution follows.

Create a mysql User and Group

If your system does not already have a user and group to use for running `mysqld`, you may need to create one. The following commands add the `mysql` group and the `mysql` user. You might want to call the user and group something else instead of `mysql`. If so, substitute the appropriate name in the following instructions. The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix, or they may have different names such as `adduser` and `addgroup`.

```
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
```

Note

Because the user is required only for ownership purposes, not login purposes, the `useradd` command uses the `-r` and `-s /bin/false` options to create a user that does not have login permissions to your server host. Omit these options if your `useradd` does not support them.

Obtain and Unpack the Distribution

Pick the directory under which you want to unpack the distribution and change location into it. The example here unpacks the distribution under `/usr/local`. The instructions, therefore, assume that you have permission to create files and directories in `/usr/local`. If that directory is protected, you must perform the installation as `root`.

```
shell> cd /usr/local
```

Obtain a distribution file using the instructions in Section 2.1.2, "How to Get MySQL". For a given release, binary distributions for all platforms are built from the same MySQL source distribution.

Unpack the distribution, which creates the installation directory. Then create a symbolic link to that directory. `tar` can uncompress and unpack the distribution if it has `z` option support:

```
shell> tar zxvf /path/to/mysql-VERSION-OS.tar.gz
shell> ln -s full-path-to-mysql-VERSION-OS mysql
```

The `tar` command creates a directory named `mysql-VERSION-OS`. The `ln` command makes a symbolic link to that directory. This enables you to refer more easily to the installation directory as `/usr/local/mysql`.

To install MySQL from a compressed `tar` file binary distribution, your system must have GNU `gunzip` to uncompress the distribution and a reasonable `tar` to unpack it. If your `tar` program supports the `z` option, it can both uncompress and unpack the file.

GNU `tar` is known to work. The standard `tar` provided with some operating systems is not able to unpack the long file names in the MySQL distribution. You should download and install GNU `tar`, or if available, use a preinstalled version of GNU tar. Usually this is available as `gnutar`, `gtar`, or as `tar` within a GNU or Free Software directory, such as `/usr/sfw/bin` or `/usr/local/bin`. GNU `tar` is available from http://www.gnu.org/software/tar/.

If your `tar` does not have `z` option support, use `gunzip` to unpack the distribution and `tar` to unpack it. Replace the preceding `tar` command with the following alternative command to uncompress and extract the distribution:

```
shell> gunzip < /path/to/mysql-VERSION-OS.tar.gz | tar xvf -
```

Perform Postinstallation Setup

The remainder of the installation process involves setting distribution ownership and access permissions, initializing the data directory, starting the MySQL server, and setting up the configuration file. For instructions, see Section 2.12, "Postinstallation Setup and Testing".

2.3 Installing MySQL on Microsoft Windows

Important

The MySQL server 5.1 branch is old and not recommended for new installations. Consider installing the latest stable branch, which today is MySQL server 5.7.

MySQL is available for Microsoft Windows, for both 32-bit and 64-bit versions. For supported Windows platform information, see http://www.mysql.com/support/supportedplatforms/database.html.

It is possible to run MySQL as a standard application or as a Windows service. By using a service, you can monitor and control the operation of the server through the standard Windows service management tools. For more information, see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

Generally, you should install MySQL on Windows using an account that has administrator rights. Otherwise, you may encounter problems with certain operations such as editing the `PATH` environment variable or accessing the `Service Control Manager`. Once installed, MySQL does not need to be executed using a user with Administrator privileges.

For a list of limitations on the use of MySQL on the Windows platform, see Section C.7.6, "Windows Platform Limitations".

In addition to the MySQL Server package, you may need or want additional components to use MySQL with your application or development environment. These include, but are not limited to:

- To connect to the MySQL server using ODBC, you must have a Connector/ODBC driver. For more information, including installation and configuration instructions, see MySQL Connector/ODBC Developer Guide.

- To use MySQL server with .NET applications, you must have the Connector/Net driver. For more information, including installation and configuration instructions, see MySQL Connector/Net Developer Guide.

MySQL distributions for Windows can be downloaded from http://dev.mysql.com/downloads/. See Section 2.1.2, "How to Get MySQL".

MySQL for Windows is available in several distribution formats, detailed here. Generally speaking, you should use a binary distribution that includes an installer. It is simpler to use than the others, and you need no additional tools to get MySQL up and running. The installer for the Windows version of MySQL, combined with a GUI Config Wizard, automatically installs MySQL, creates an option file, starts the server, and secures the default user accounts.

- Binary installer distribution. The installable distribution comes packaged as a Microsoft Windows Installer (MSI) package that you can install manually or automatically on your systems. Two formats are available, an essentials package that contains all the files you need to install and configure MySQL, but no additional components, and a complete package that includes MySQL, configuration tools, benchmarks and other components. For more information on the specific differences, see Section 2.3.2, "Choosing the Installation Package for Microsoft Windows"

  For instructions on installing MySQL using one of the MSI installation packages, see Section 2.3.4, "Installing MySQL on Microsoft Windows Using an MSI Package".

- The standard binary distribution (packaged as a Zip file) contains all of the necessary files that you unpack into your chosen location. This package contains all of the files in the full Windows MSI Installer package, but does not include an installation program.

  For instructions on installing MySQL using the Zip file, see Section 2.3.6, "Installing MySQL on Microsoft Windows Using a noinstall Zip Archive".

- The source distribution format contains all the code and support files for building the executables using the Visual Studio compiler system.

  For instructions on building MySQL from source on Windows, see Section 2.11.7, "Installing MySQL from Source on Windows".

MySQL on Windows considerations:

- **Large Table Support**

  If you need tables with a size larger than 4GB, install MySQL on an NTFS or newer file system. Do not forget to use `MAX_ROWS` and `AVG_ROW_LENGTH` when you create tables. See Section 13.1.17, "CREATE TABLE Syntax".

- **MySQL and Virus Checking Software**

  Virus-scanning software such as Norton/Symantec Anti-Virus on directories containing MySQL data and temporary tables can cause issues, both in terms of the performance of MySQL and the virus-scanning software misidentifying the contents of the files as containing spam. This is due to the fingerprinting mechanism used by the virus-scanning software, and the way in which MySQL rapidly updates different files, which may be identified as a potential security risk.

  After installing MySQL Server, it is recommended that you disable virus scanning on the main directory (`datadir`) used to store your MySQL table data. There is usually a system built into the virus-scanning software to enable specific directories to be ignored.

  In addition, by default, MySQL creates temporary files in the standard Windows temporary directory. To prevent the temporary files also being scanned, configure a separate temporary directory for MySQL temporary files and add this directory to the virus scanning exclusion list. To do this, add a configuration option for the `tmpdir` parameter to your `my.ini` configuration file. For more information, see Section 2.3.6.2, "Creating an Option File".

2.3.1 MySQL Installation Layout on Microsoft Windows

For MySQL 5.1 on Windows, the default installation directory is `C:\Program Files\MySQL\MySQL Server 5.1`. Some Windows users prefer to install in `C:\mysql`, the directory that formerly was used as the default. However, the layout of the subdirectories remains the same.

For MySQL 5.1.23 and earlier, all of the files are located within the parent directory, using the structure shown in the following table.

Table 2.4 Installation Layout for Windows Using MySQL 5.1.23 and Earlier

Directory	Contents of Directory
`bin`	Client programs and the `mysqld` server
`data`	Log files, databases
`examples`	Example programs and scripts
`include`	Include (header) files
`lib`	Libraries
`scripts`	Utility scripts
`share`	Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation

For MySQL 5.1.24 and later, the default location of data directory was changed. The remainder of the directory structure remains the same.

Table 2.5 Installation Layout for Microsoft Windows using MySQL 5.1.24 and later

Directory	Contents of Directory	Notes
`bin`, `scripts`	`mysqld` server, client and utility programs	
`%ALLUSERSPROFILE%\MySQL\MySQL Server 5.1\`	Log files, databases (Windows XP, Windows Server 2003)	The Windows system variable `%ALLUSERSPROFILE%` defaults to `C:\Documents and Settings\All Users\Application Data`
`%PROGRAMDATA%\MySQL\MySQL Server 5.1\`	Log files, databases (Vista, Windows 7, Windows Server 2008, and newer)	The Windows system variable `%PROGRAMDATA%` defaults to `C:\ProgramData`
`examples`	Example programs and scripts	
`include`	Include (header) files	
`lib`	Libraries	
`share`	Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation	

2.3.2 Choosing the Installation Package for Microsoft Windows

For MySQL 5.1, there are multiple installation package formats to choose from when installing MySQL on Windows.

> **Note**
>
> Using MySQL Installer is the recommended installation method for Microsoft
> Windows users. The MySQL Server 5.1 release does not include its own MySQL
> Installer release, but a MySQL Installer version 5.5 and above can optionally install
> MySQL Server 5.1. Follow the standard Installing MySQL on Microsoft Windows
> Using MySQL Installer documentation but choose **Custom Install** after executing
> it. A MySQL Server 5.1 option will be available, and choosing it will cause MySQL
> Installer to download it for you.

Table 2.6 Microsoft Windows MySQL Installation package comparison

	Packaging		
Feature	**Essentials**	**Complete**	**Zip (No-install)**
Installer	Yes	Yes	No
Directory-only			
MySQL Server Instance Config Wizard	Yes	Yes	No
Test Suite	No	Yes	Yes
MySQL Server	Yes	Yes	Yes
MySQL Client Programs	Yes	Yes	Yes
C Headers/Libraries	Yes	Yes	Yes
Embedded Server	No	Optional	Yes
Scripts and Examples	No	Optional	Yes

In the above table:

- *Yes* indicates that the component is installed by default.

- *No* indicates that the component is not installed or included.

- *Optional* indicates that the component is included with the package, but not installed unless explicitly
  requested using the Custom installation mode.

The workflow for installing using the MSI installer is shown here:

Figure 2.7 Installation Workflow for Windows Using MSI
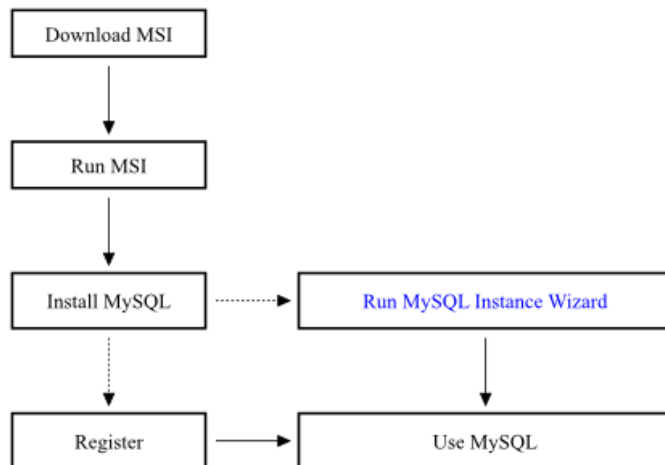
The workflow for installing using the Zip package is shown here:

Figure 2.8 Installation Workflow for Windows Using Zip
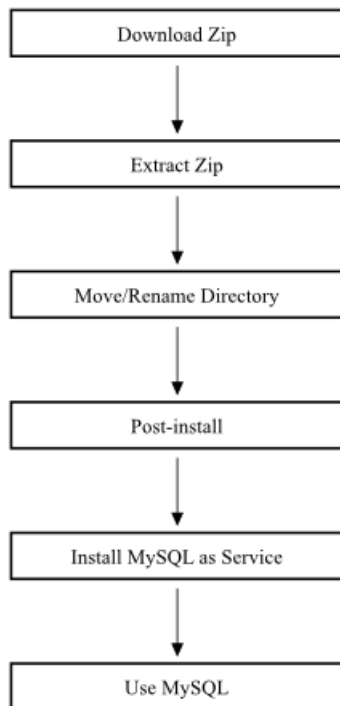
> **Note**
>
> For the Essentials and Complete packages in the MSI installer, you can select individual components to be installed by using the Custom mode, including disable the components confiurated for installation by default.

Full details on the components are suggested uses are provided here for reference:

- **Windows Essentials**: This package has a file name similar to `mysql-essential-5.1.73-win32.msi` and is supplied as a Microsoft Installer (MSI) package. The package includes the minimum set of files needed to install MySQL on Windows, including the MySQL Server Instance Config Wizard. This package does not include optional components such as the embedded server, developer headers and libraries or benchmark suite.

  To install using this package, see Section 2.3.4, "Installing MySQL on Microsoft Windows Using an MSI Package".

- **Windows MSI Installer (Complete)**: This package has a file name similar to `mysql-5.1.73-win32.msi` and contains all files needed for a complete Windows installation, including the MySQL Server Instance Config Wizard. This package includes optional components such as the embedded server and benchmark suite.

  To install using this package, see Section 2.3.4, "Installing MySQL on Microsoft Windows Using an MSI Package".

- **Without installer**: This package has a file name similar to `mysql-noinstall-5.1.73-win32.zip` and contains all the files found in the Complete install package, with the exception of the MySQL Server

Instance Config Wizard. This package does not include an automated installer, and must be manually installed and configured.

The Essentials package is recommended for most users. Both the Essentials and Complete distributions are available as an `.msi` file for use with the Windows Installer. The Noinstall distribution is packaged as a Zip archive. To use a Zip archive, you must have a tool that can unpack `.zip` files.

When using the MSI installers you can automate the installation process. For more information, see Section 2.3.4.2, "Automating MySQL Installation on Microsoft Windows Using the MSI Package". To automate the creation of a MySQL instance, see Section 2.3.5.13, "MySQL Server Instance Config Wizard: Creating an Instance from the Command Line".

Your choice of install package affects the installation process you must follow. If you choose to install either an Essentials or Complete install package, see Section 2.3.4, "Installing MySQL on Microsoft Windows Using an MSI Package". If you choose to install a Noinstall archive, see Section 2.3.6, "Installing MySQL on Microsoft Windows Using a noinstall Zip Archive".

2.3.3 MySQL Notifier

MySQL Notifier is a tool that enables you to monitor and adjust the status of your local and remote MySQL server instances through an indicator that resides in the system tray. MySQL Notifier also gives quick access to MySQL Workbench through its context menu.

The MySQL Notifier is installed by MySQL Installer, and (by default) will start-up when Microsoft Windows is started.

To install, download and execute the MySQL Installer, be sure the MySQL Notifier product is selected, then proceed with the installation. See the MySQL Installer manual for additional details.

For notes detailing the changes in each release of MySQL Notifier, see the MySQL Notifier Release Notes.

Visit the MySQL Notifier forum for additional MySQL Notifier help and support.

Features include:

- Start, Stop, and Restart instances of the MySQL Server.

- Automatically detects (and adds) new MySQL Server services. These are listed under **Manage Monitored Items**, and may also be configured.

- The Tray icon changes, depending on the status. It's green if all monitored MySQL Server instances are running, or red if at least one service is stopped. The **Update MySQL Notifier tray icon based on service status** option, which dictates this behavior, is enabled by default for each service.

- Links to other applications like MySQL Workbench, MySQL Installer, and the MySQL Utilities. For example, choosing **Manage Instance** will load the MySQL Workbench Server Administration window for that particular instance.

- If MySQL Workbench is also installed, then the **Manage Instance** and **SQL Editor** options are available for local (but not remote) MySQL instances.

- Monitors both local and remote MySQL instances.

2.3.3.1 MySQL Notifier Usage

MySQL Notifier resides in the system tray and provides visual status information for your MySQL server instances. A green icon is displayed at the top left corner of the tray icon if the current MySQL server is running, or a red icon if the service is stopped.

MySQL Notifier automatically adds discovered MySQL services on the local machine, and each service is saved and configurable. By default, the **Automatically add new services whose name contains** option is enabled and set to `mysql`. Related **Notifications Options** include being notified when new services are either discovered or experience status changes, and are also enabled by default. And uninstalling a service will also remove the service from MySQL Notifier.

Clicking the system tray icon will reveal several options, as the follow figures show:

The Service Instance menu is the main MySQL Notifier window, and enables you to Stop, Start, and Restart the MySQL server.

Figure 2.9 MySQL Notifier Service Instance menu
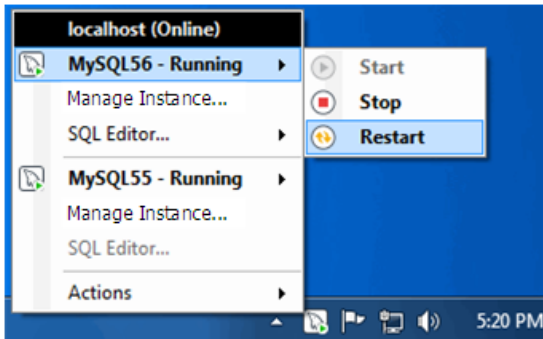
The **Actions** menu includes several links to external applications (if they are installed), and a **Refresh Status** option to manually refresh the status of all monitored services (in both local and remote computers) and MySQL instances.

> **Note**
>
> The main menu will not show the **Actions** menu when there are no services being monitored by MySQL Notifier.

Figure 2.10 MySQL Notifier Actions menu
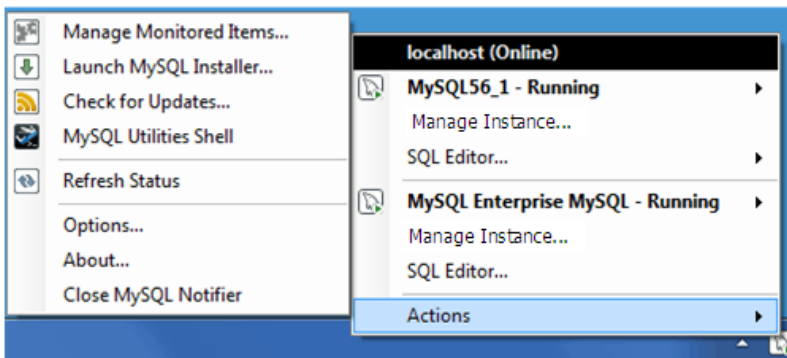
The **Actions**, **Options** menu configures MySQL Notifier and includes options to:

- **Use colorful status icons**: Enables a colorful style of icons for the tray of MySQL Notifier.

- **Run at Windows Startup**: Allows the application to be loaded when Microsoft Windows starts.

- **Automatically Check For Updates Every # Weeks**: Checks for a new version of MySQL Notifier, and runs this check every # weeks.

- **Automatically add new services whose name contains:** The text used to filter services and add them automatically to the monitored list of the local computer running MySQL Notifier, and on remote computers already monitoring Windows services.

- **Ping monitored MySQL Server instances every # seconds**: The interval (in seconds) to ping monitored MySQL Server instances for status changes. Longer intervals might be necessary if the list of monitored remote instances is large.

- **Notify me when a service is automatically added**: Will display a balloon notification from the taskbar when a newly discovered service is added to the monitored services list.

- **Notify me when a service changes status**: Will display a balloon notification from the taskbar when a monitored service changes its status.

- **Automatic connections migration delayed until:** When there are connections to migrate, postpone the migration by one hour, one day, one week, one month, or indefinitely.

Figure 2.11 MySQL Notifier Options menu
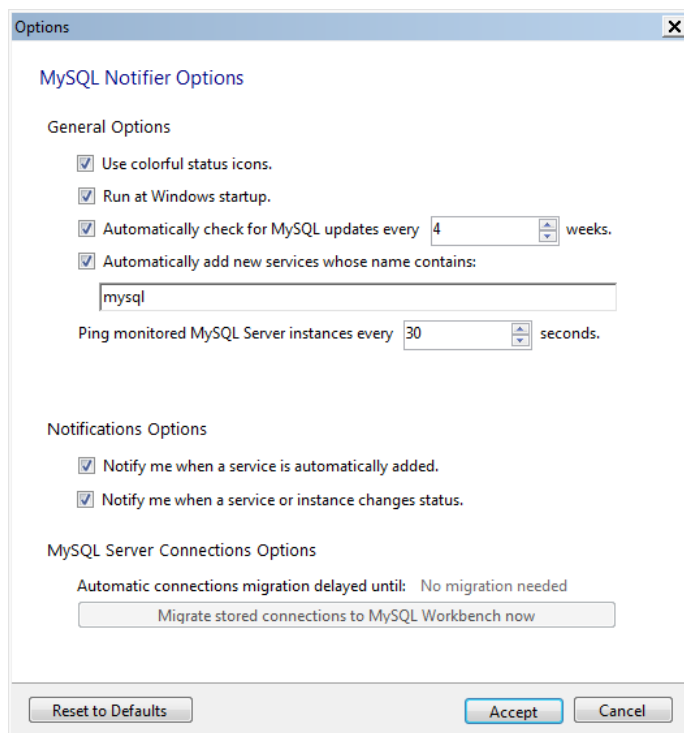
The **Actions**, **Manage Monitored Items** menu enables you to configure the monitored services and MySQL instances. First, with the **Services** tab open:

Figure 2.12 MySQL Notifier Manage Services menu
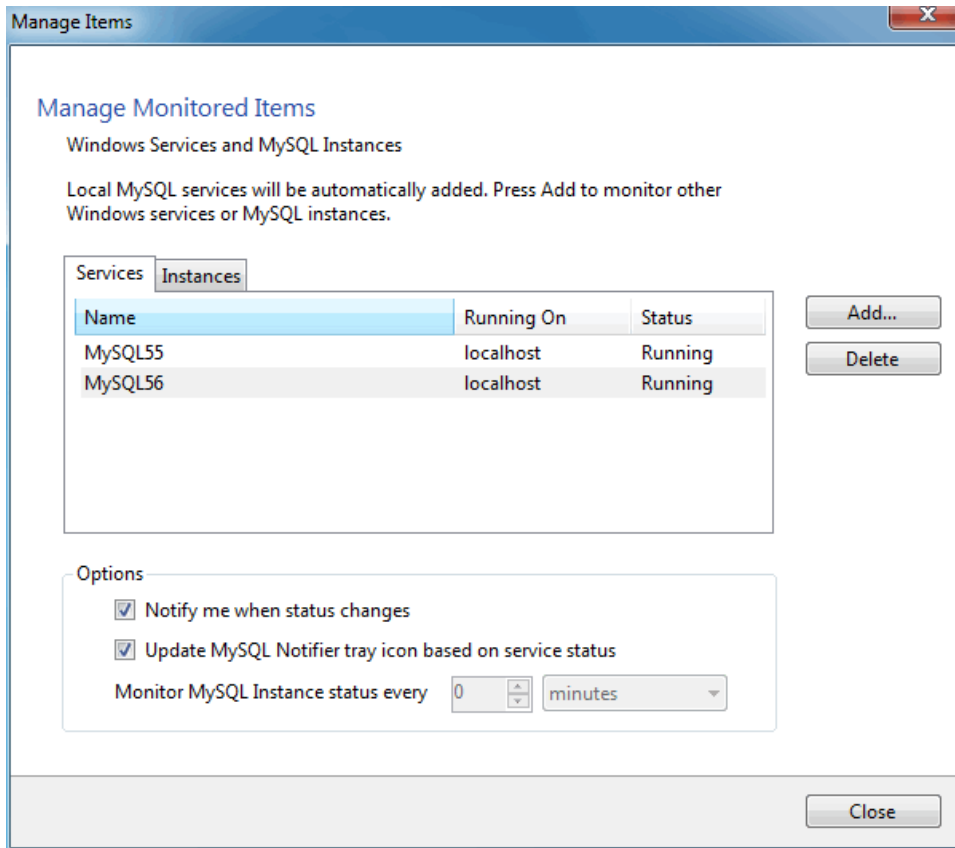
The **Instances** tab is similar:

Figure 2.13 MySQL Notifier Manage Instances menu
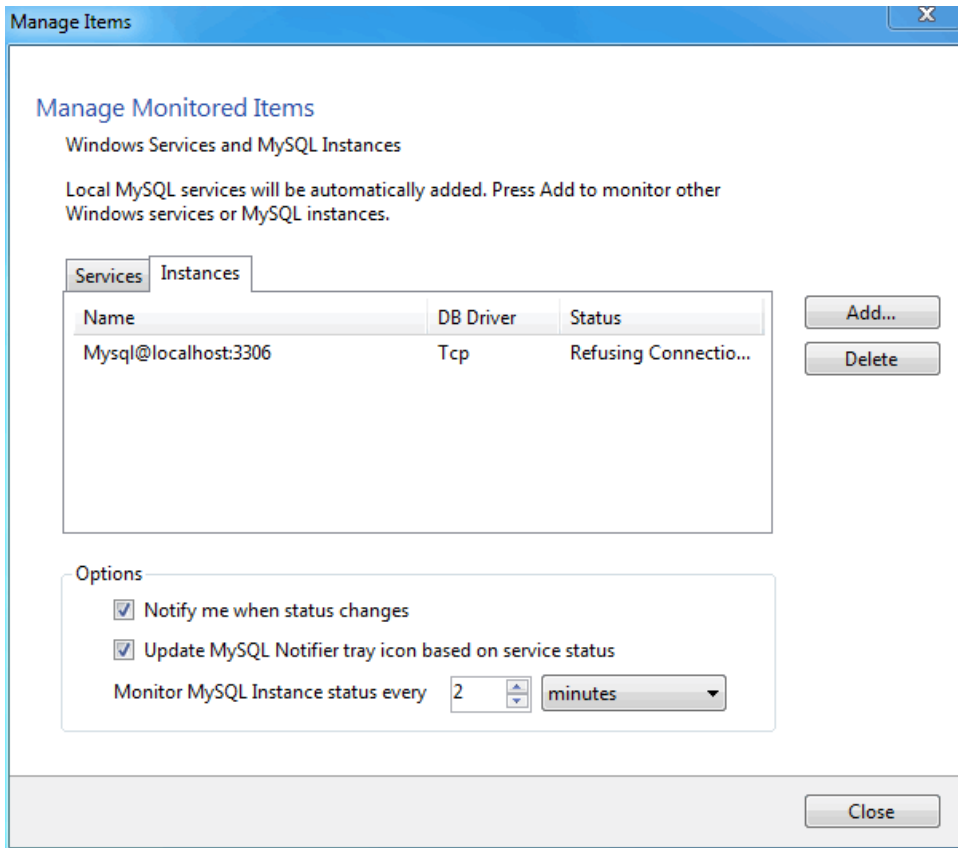
Adding a service or instance (after clicking **Add** in the **Manage Monitored Items** window) enables you to select a running Microsoft Windows service or instance connection, and configure MySQL Notifier to monitor it. Add a new service or instance by clicking service name from the list, then **OK** to accept. Multiple services and instances may be selected.

Figure 2.14 MySQL Notifier Adding new services
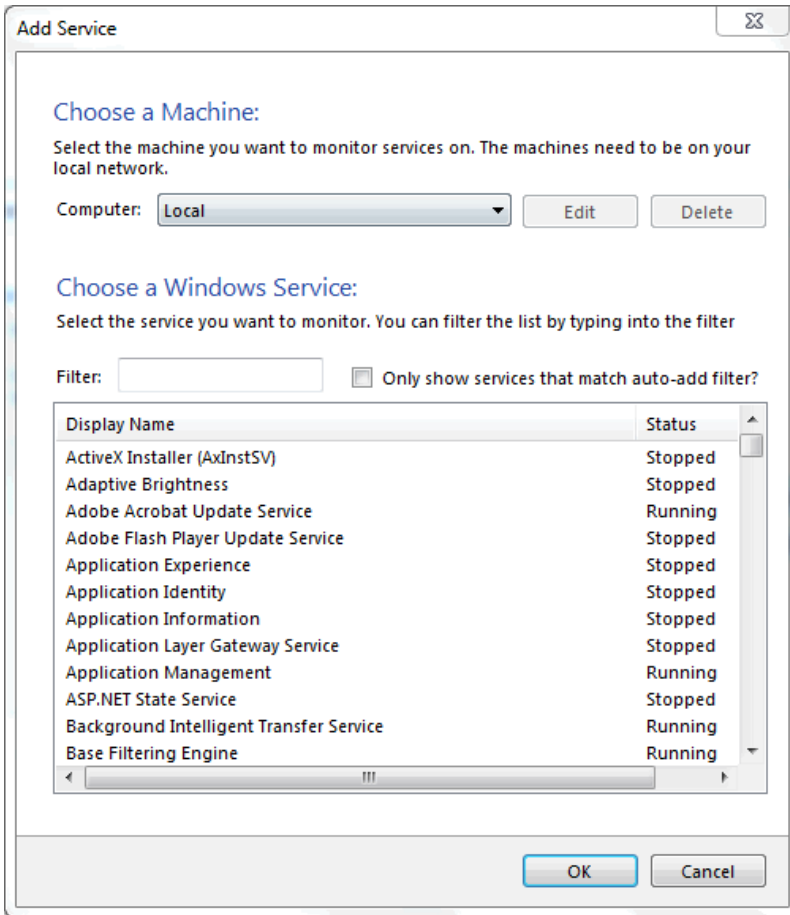
Add instances:

Figure 2.15 MySQL Notifier Adding new instances
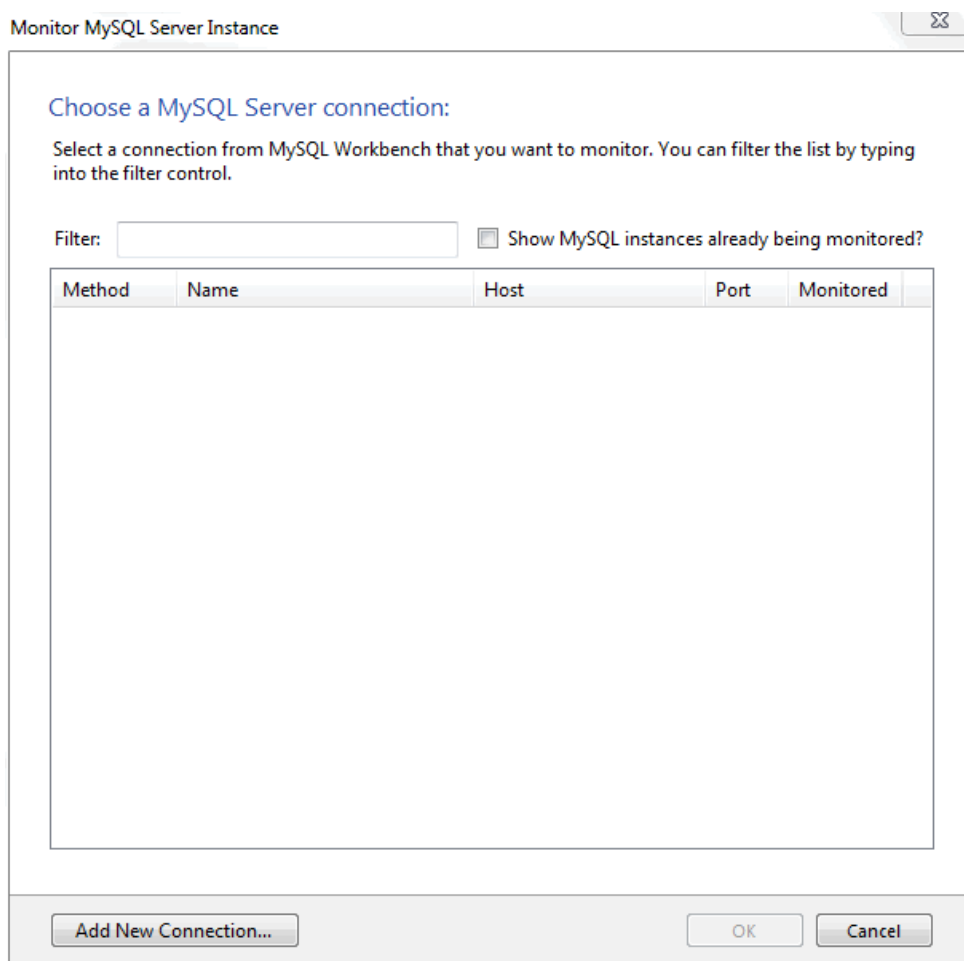
Troubleshooting

For issues that are not documented here, visit the MySQL Notifier Support Forum for MySQL Notifier help and support.

- *Problem*: attempting to start/stop/restart a MySQL service might generate an error similar to "The Service **MySQL_VERSION** failed the most recent status change request with the message "The service **mysql_VERSION** was not found in the Windows Services".

  Explanation: this is a case-sensitivity issue, in that the service name is **MySQL_VERSION** compared to having **mysql_VERSION** in the configuration file.

  Solution: either update your MySQL Notifier configuration file with the correct information, or stop MySQL Notifier and delete this configuration file. The MySQL Notifier configuration file is located at `%APPDATA%\Oracle\MySQL Notifier\settings.config` where `%APPDATA%` is a variable and depends on your system. A typical location is "C:\Users*YourUsername*\AppData\Running\Oracle\MySQL Notifier\settings.config" where *YourUsername* is your system's user name. In this file, and within the ServerList section, change the ServerName values from lowercase to the actual service names. For example, change **mysql_VERSION** to **MySQL_VERSION**, save, and then restart MySQL Notifier. Alternatively, stop MySQL Notifier, delete this file, then restart MySQL Notifier.

- *Problem*: when connecting to a remote computer for the purpose of monitoring a remote Windows service, the **Add Service** dialog does not always show all the services shown in the Windows Services console.

  Explanation: this behavior is governed by the operating system and the outcome is expected when working with nondomain user accounts. For a complete description of the behavior, see the User Account Control and WMI article from Microsoft.

  Solution: when the remote computer is in a compatible domain, it is recommended that domain user accounts are used to connect through WMI to a remote computer. For detailed setup instructions using WMI, see Section 2.3.3.2, "Setting Up Remote Monitoring in MySQL Notifier".

  Alternatively, when domain user accounts are not available, Microsoft provides a less secure workaround that should only be implemented with caution. For more information, see the Description of User Account Control and remote restrictions in Windows Vista KB article from Microsoft.

2.3.3.2 Setting Up Remote Monitoring in MySQL Notifier

MySQL Notifier uses Windows Management Instrumentation (WMI) to manage and monitor services on remote computers. This section explains how it works and how to set up your system to monitor remote MySQL instances.

In order to configure WMI, it is important to understand that the underlying Distributed Component Object Model (DCOM) architecture is doing the WMI work. Specifically, MySQL Notifier is using asynchronous notification queries on remote Microsoft Windows hosts as .NET events. These events send an asynchronous callback to the computer running MySQL Notifier so it knows when a service status has changed on the remote computer. Asynchronous notifications offer the best performance compared to semisynchronous notifications or synchronous notifications that use timers.

Asynchronous notification requires the remote computer to send a callback to the client computer (thus opening a reverse connection), so the Windows Firewall and DCOM settings must be properly configured for the communication to function properly.

Figure 2.16 MySQL Notifier Distributed Component Object Model (DCOM)
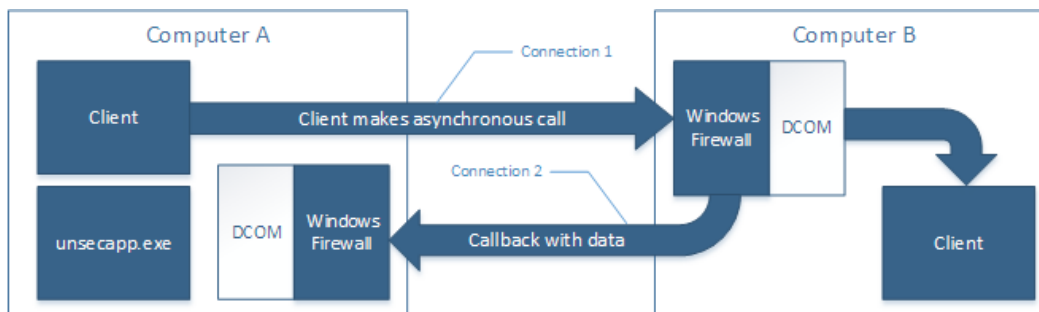
Most of the common errors thrown by asynchronous WMI notifications are related to Windows Firewall blocking the communication, or to DCOM / WMI settings not being set up properly. For a list of common errors with solutions, see Common Errors.

The following steps are required to make WMI function. These steps are divided between two machines. A single host computer that runs MySQL Notifier (Computer A), and multiple remote machines that are being monitored (Computer B).

Computer running MySQL Notifier (Computer A)

1. Enable remote administration by either editing the **Group Policy Editor**, or using `NETSH`:

Using the **Group Policy Editor**:

a. Click **Start**, click **Run**, type `GPEDIT.MSC`, and then click **OK**.

b. Under the **Local Computer Policy** heading, expand **Computer Configuration**.

c. Expand **Administrative Templates**, then **Network**, **Network Connections**, and then **Windows Firewall**.

d. If the computer is in the domain, then double-click **Domain Profile**; otherwise, double-click **Standard Profile**.

e. Double-click **Windows Firewall: Allow inbound remote administration exception** to open a configuration window.

f. Check the **Enabled** option button and then click **OK**.

Using the `NETSH` command:

> **Note**
>
> The "netsh firewall" command is deprecated as of Microsoft Server 2008 and Vista, and replaced with "netsh advfirewall firewall".

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and select **Run as Administrator**).

b. Execute the following command:

```
NETSH advfirewall firewall set service RemoteAdmin enable
```

2. Open the DCOM port TCP 135:

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and select **Run as Administrator**).

b. Execute the following command:

```
NETSH advfirewall firewall add rule name=DCOM_TCP135 protocol=TCP localport=135 dir=in action=allow
```

3. Add the client application that contains the sink for the callback (`MySqlNotifier.exe`) to the Windows Firewall Exceptions List (use either the Windows Firewall configuration or `NETSH`):

Using the Windows Firewall configuration:

a. In the Control Panel, double-click **Windows Firewall**.

b. In the Windows Firewall window's left panel, click **Allow a program or feature through Windows Firewall**.

c. In the Allowed Programs window, click **Change Settings** and do one of the following:

- If `MySqlNotifier.exe` is in the Allowed programs and features list, make sure it is checked for the type of networks the computer connects to (Private, Public or both).

- If `MySqlNotifier.exe` is not in the list, click **Allow another program...**.

     i.   In the **Add a Program** window, select the `MySqlNotifier.exe` if it exists in the Programs list, otherwise click Browse... and go to the directory where `MySqlNotifier.exe` was installed to select it, then click **Add**.

    ii.   Make sure `MySqlNotifier.exe` is checked for the type of networks the computer connects to (Private, Public or both).

Using the `NETSH` command:

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and click **Run as Administrator**).

b. Execute the following command, where you change "*[YOUR_INSTALL_DIRECTORY]*":

```
NETSH advfirewall firewall add rule name=MySqlNotifier program=[YOUR_INSTALL_DIRECTORY]\MySqlNotifier.e
```

4. If Computer B is either a member of `WORKGROUP` or is in a different domain that is untrusted by Computer A, then the callback connection (Connection 2) is created as an Anonymous connection. To grant Anonymous connections DCOM Remote Access permissions:

a. Click **Start**, click **Run**, type `DCOMCNFG`, and then click **OK**.

b. In the Component Services dialog box, expand Component Services, expand Computers, and then right-click **My Computer** and click **Properties**.

c. In the My Computer Properties dialog box, click the **COM Security** tab.

d. Under Access Permissions, click **Edit Limits**.

e. In the Access Permission dialog box, select **ANONYMOUS LOGON name** in the Group or user names box. In the Allow column under Permissions for User, select **Remote Access**, and then click **OK**.

Monitored Remote Computer (Computer B)

If the user account that is logged on to the computer running the MySQL Notifier (Computer A) is a local administrator on the remote computer (Computer B), such that the same account is an administrator on Computer B, you can skip to the "Allow for remote administration" step.

Setting DCOM security to allow a non-administrator user to access a computer remotely:

1. Grant "DCOM remote launch" and activation permissions for a user or group:

a. Click **Start**, click **Run**, type `DCOMCNFG`, and then click **OK**.

b. In the Component Services dialog box, expand Component Services, expand Computers, and then right-click **My Computer** and click **Properties**.

c. In the My Computer Properties dialog box, click the **COM Security** tab.

d. Under Launch and Activation Permission, click **Edit Limits**.

e. In the **Launch and Activation Permission** dialog box, follow these steps if your name or your group does not appear in the Groups or user names list:

    i.   In the **Launch and Activation Permission** dialog box, click **Add**.

      ii. In the Select Users or Groups dialog box, add your name and the group in the **Enter the object names to select** box, and then click **OK**.

f.   In the **Launch and Activation Permission** dialog box, select your user and group in the Group or user names box. In the Allow column under Permissions for User, select **Remote Launch**, select **Remote Activation**, and then click **OK**.

Grant DCOM remote access permissions:

a.   Click **Start**, click **Run**, type DCOMCNFG, and then click **OK**.

b.   In the Component Services dialog box, expand Component Services, expand Computers, and then right-click **My Computer** and click **Properties**.

c.   In the My Computer Properties dialog box, click the **COM Security** tab.

d.   Under Access Permissions, click **Edit Limits**.

e.   In the Access Permission dialog box, select **ANONYMOUS LOGON name** in the Group or user names box. In the Allow column under Permissions for User, select **Remote Access**, and then click **OK**.

2. Allowing non-administrator users access to a specific WMI namespace:

   a.   In the Control Panel, double-click **Administrative Tools**.

   b.   In the Administrative Tools window, double-click **Computer Management**.

   c.   In the Computer Management window, expand the **Services and Applications** tree.

   d.   Right-click the WMI Control icon and select **Properties**.

   e.   In the WMI Control Properties window, click the **Security** tab.

   f.   In the Security tab, select the namespace and click **Security**. Root/CIMV2 is a commonly used namespace.

   g.   Locate the appropriate account and check **Remote Enable** in the Permissions list.

3. Allow for remote administration by either editing the **Group Policy Editor** or using NETSH:

Using the **Group Policy Editor**:

   a.   Click **Start**, click **Run**, type GPEDIT.MSC, and then click **OK**.

   b.   Under the Local Computer Policy heading, double-click **Computer Configuration**.

   c.   Double-click **Administrative Templates**, then **Network**, **Network Connections**, and then **Windows Firewall**.

   d.   If the computer is in the domain, then double-click **Domain Profile**; otherwise, double-click **Standard Profile**.

   e.   Click **Windows Firewall: Allow inbound remote administration exception**.

   f.   On the Action menu either select **Edit**, or double-click the selection from the previous step.

g. Check the **Enabled** radio button, and then click **OK**.

Using the `NETSH` command:

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and click Run as Administrator).

b. Execute the following command:

```
NETSH advfirewall firewall set service RemoteAdmin enable
```

4. Confirm that the user account you are logging in with uses the `Name` value and not the `Full Name` value:

a. In the **Control Panel**, double-click **Administrative Tools**.

b. In the **Administrative Tools** window, double-click **Computer Management**.

c. In the **Computer Management** window, expand the **System Tools** then **Local Users and Groups**.

d. Click the **Users** node, and on the right side panel locate your user and make sure it uses the **Name** value to connect, and not the **Full Name** value.

Common Errors

- `0x80070005`

  - DCOM Security was not configured properly (see Computer B, the `Setting DCOM security...` step).

  - The remote computer (Computer B) is a member of WORKGROUP or is in a domain that is untrusted by the client computer (Computer A) (see Computer A, the `Grant Anonymous connections DCOM Remote Access permissions` step).

- `0x8007000E`

  - The remote computer (Computer B) is a member of WORKGROUP or is in a domain that is untrusted by the client computer (Computer A) (see Computer A, the `Grant Anonymous connections DCOM Remote Access permissions` step).

- `0x80041003`

  - Access to the remote WMI namespace was not configured properly (see Computer B, the `Allowing non-administrator users access to a specific WMI namespace` step).

- `0x800706BA`

  - The DCOM port is not open on the client computers (Computer A) firewall. See the `Open the DCOM port TCP 135` step for Computer A.

  - The remote computer (Computer B) is inaccessible because its network location is set to Public. Make sure you can access it through the Windows Explorer.

2.3.4 Installing MySQL on Microsoft Windows Using an MSI Package

The MSI package is designed to install and configure MySQL in such a way that you can immediately get started using MySQL.

The MySQL Installation Wizard and MySQL Configuration Wizard are available in the Essentials and Complete install packages. They are recommended for most standard MySQL installations. Exceptions include users who need to install multiple instances of MySQL on a single server host and advanced users who want complete control of server configuration.

- For information on installing using the GUI MSI installer process, see Section 2.3.4.1, "Using the MySQL Installation Wizard for Microsoft Windows".

- For information on installing using the command line using the MSI package, see Section 2.3.4.2, "Automating MySQL Installation on Microsoft Windows Using the MSI Package".

- If you have previously installed MySQL using the MSI package and want to remove MySQL, see Section 2.3.4.3, "Removing MySQL When Installed from the MSI Package".

The workflow sequence for using the installer is shown in the figure below:

Figure 2.17 Installation Workflow for Windows Using MSI Installer
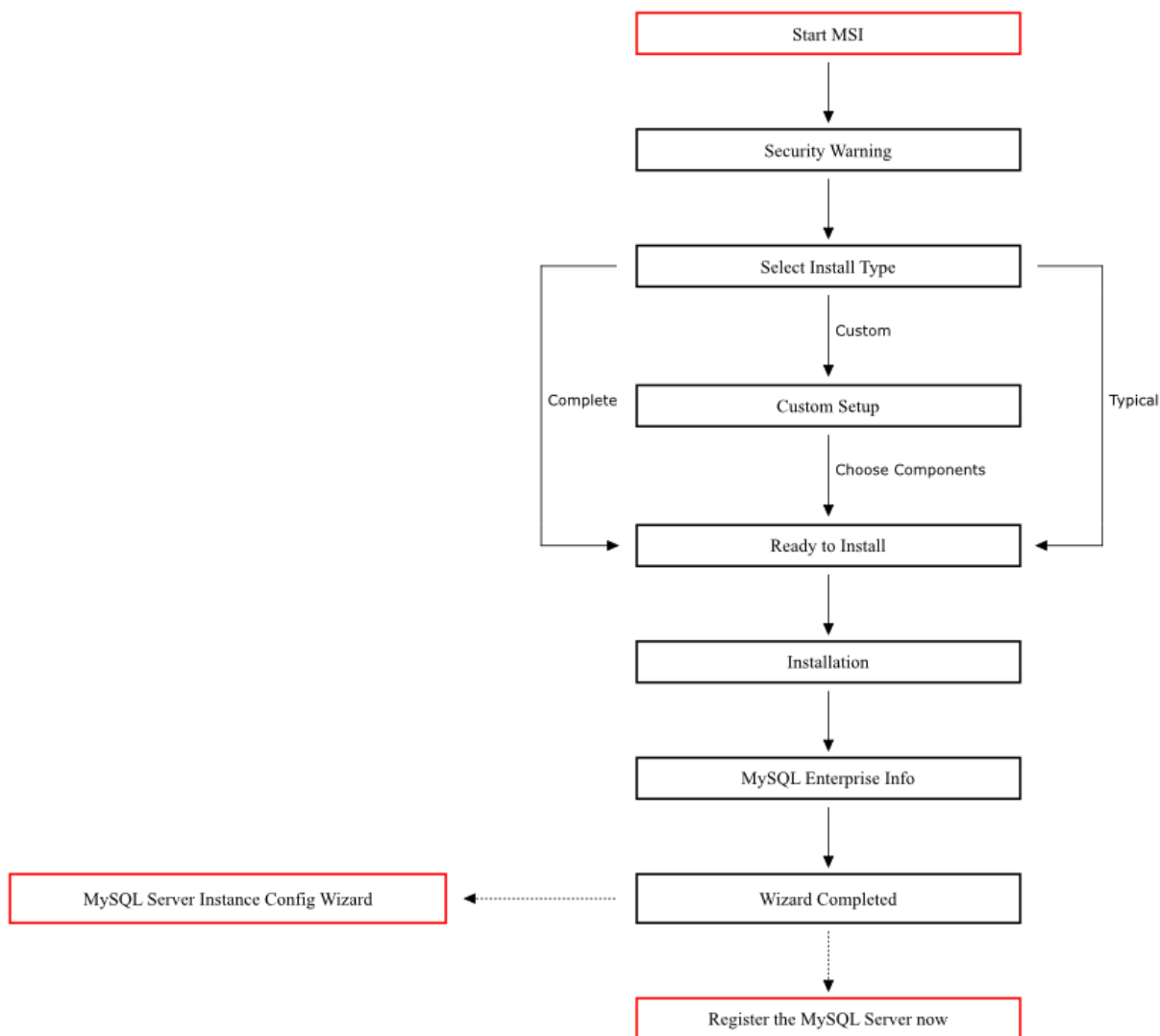
Note

Microsoft Windows XP and later include a firewall which specifically blocks ports. If you plan on using MySQL through a network port then you should open and create an exception for this port before performing the installation. To check and if necessary add an exception to the firewall settings:

1. First ensure that you are logged in as an Administrator or a user with Administrator privileges.

2. Go to the **Control Panel**, and double click the **Windows Firewall** icon.

3. Choose the **Allow a program through Windows Firewall** option and click the **Add port** button.

4. Enter `MySQL` into the **Name** text box and `3306` (or the port of your choice) into the **Port number** text box.

5. Also ensure that the **TCP** protocol radio button is selected.

6. If you wish, you can also limit access to the MySQL server by choosing the **Change scope** button.

7. Confirm your choices by clicking the **OK** button.

Additionally, when running the MySQL Installation Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.

Note

When using Windows Vista or newer, you may want to disable User Account Control (UAC) before performing the installation. If you do not do so, then MySQL may be identified as a security risk, which will mean that you need to enable MySQL. You can disable the security checking by following these instructions:

1. Open **Control Panel**.

2. Under the **User Accounts and Family Safety**, select **Add or remove user accounts.**

3. Click the **Got to the main User Accounts page** link.

4. Click on **Turn User Account Control on or off**. You may be prompted to provide permission to change this setting. Click **Continue**.

5. Deselect or uncheck the check box next to **Use User Account Control (UAC) to help protect your computer**. Click **OK** to save the setting.

You will need to restart to complete the process. Click **Restart Now** to reboot the machine and apply the changes. You can then follow the instructions below for installing Windows.

2.3.4.1 Using the MySQL Installation Wizard for Microsoft Windows

MySQL Installation Wizard is an installer for the MySQL server that uses the latest installer technologies for Microsoft Windows. The MySQL Installation Wizard, in combination with the MySQL Config Wizard, enables a user to install and configure a MySQL server that is ready for use immediately after installation.

The MySQL Installation Wizard uses the standard Microsoft Installer Engine (MSI) system is the standard installer for all MySQL server distributions. See MySQL Installation Wizard: Upgrading MySQL, for more information on upgrading from a previous version.

If you are upgrading an installation from MySQL 5.1.31 or earlier to MySQL 5.1.32 or later, read the notes provided in MySQL Installation Wizard: Upgrading MySQL.

The Microsoft Windows Installer Engine was updated with the release of Windows XP; those using a previous version of Windows can reference this Microsoft Knowledge Base article for information on upgrading to the latest version of the Windows Installer Engine.

In addition, Microsoft has introduced the WiX (Windows Installer XML) toolkit. This is the first highly acknowledged Open Source project from Microsoft. We have switched to WiX because it is an Open Source project and it enables us to handle the complete Windows installation process in a flexible manner using scripts.

Improving the MySQL Installation Wizard depends on the support and feedback of users like you. If you find that the MySQL Installation Wizard is lacking some feature important to you, or if you discover a bug, please report it in our bugs database using the instructions given in Section 1.7, "How to Report Bugs or Problems".

MySQL Installation Wizard: Downloading and Starting

The MySQL installation packages can be downloaded from http://dev.mysql.com/downloads/. If the package you download is contained within a Zip archive, you need to extract the archive first.

The process for starting the wizard depends on the contents of the installation package you download. If there is a `setup.exe` file present, double-click it to start the installation process. If there is an `.msi` file present, double-click it to start the installation process.

MySQL Installation Wizard: Choosing an Install Type

There are three installation types available: **Typical**, **Complete**, and **Custom**.

The **Typical** installation type installs the MySQL server, the `mysql` command-line client, and the command-line utilities. The command-line clients and utilities include `mysqldump`, `myisamchk`, and several other tools to help you manage the MySQL server.

The **Complete** installation type installs all components included in the installation package. The full installation package includes components such as the embedded server library, the benchmark suite, support scripts, and documentation.

The **Custom** installation type gives you complete control over which packages you wish to install and the installation path that is used. See MySQL Installation Wizard: The Custom Install Dialog, for more information on performing a custom install.

If you choose the **Typical** or **Complete** installation types and click the **Next** button, you advance to the confirmation screen to verify your choices and begin the installation. If you choose the **Custom** installation type and click the **Next** button, you advance to the custom installation dialog, described in MySQL Installation Wizard: The Custom Install Dialog.

MySQL Installation Wizard: The Custom Install Dialog

If you wish to change the installation path or the specific components that are installed by the MySQL Installation Wizard, choose the **Custom** installation type.

A tree view on the left side of the custom install dialog lists all available components. Components that are not installed have a red **X** icon; components that are installed have a gray icon. To change whether a component is installed, click that component's icon and choose a new option from the drop-down list that appears.

You can change the default installation path by clicking the **Change...** button to the right of the displayed installation path.

After choosing your installation components and installation path, click the **Next** button to advance to the confirmation dialog.

MySQL Installation Wizard: The Confirmation Dialog

Once you choose an installation type and optionally choose your installation components, you advance to the confirmation dialog. Your installation type and installation path are displayed for you to review.

To install MySQL if you are satisfied with your settings, click the **Install** button. To change your settings, click the **Back** button. To exit the MySQL Installation Wizard without installing MySQL, click the **Cancel** button.

In MySQL 5.1.47 and earlier, after installation is complete, you have the option of registering with the MySQL web site. Registration gives you access to post in the MySQL forums at forums.mysql.com, along with the ability to report bugs at bugs.mysql.com and to subscribe to our newsletter.

The final screen of the installer provides a summary of the installation and gives you the option to launch the MySQL Config Wizard, which you can use to create a configuration file, install the MySQL service, and configure security settings.

MySQL Installation Wizard: Changes Made

Once you click the **Install** button, the MySQL Installation Wizard begins the installation process and makes certain changes to your system which are described in the sections that follow.

Changes to the Registry

The MySQL Installation Wizard creates one Windows registry key in a typical install situation, located in `HKEY_LOCAL_MACHINE\SOFTWARE\MySQL AB`. For 64-bit Windows, the registry location is `HKEY_LOCAL_MACHINE\SOFTWARE\Wow6432Node\MYSQL AB`. A server version specific entry will be created for each release series of MySQL that you install.

The MySQL Installation Wizard creates a key named after the release series of the server that is being installed, such as `MySQL Server 5.1`. It contains two string values, `Location` and `Version`. The `Location` string contains the path to the installation directory. In a default installation it contains `C:\Program Files\MySQL\MySQL Server 5.1\`. The `Version` string contains the release number. For example, for an installation of MySQL Server 5.1.73, the key contains a value of `5.1.73`.

These registry keys are used to help external tools identify the installed location of the MySQL server, preventing a complete scan of the hard-disk to determine the installation path of the MySQL server. The registry keys are not required to run the server, and if you install MySQL using the `noinstall` Zip archive, the registry keys are not created.

Changes to the Start Menu

The MySQL Installation Wizard creates a new entry in the Windows **Start** menu under a common MySQL menu heading named after the release series of MySQL that you have installed. For example, if you install MySQL 5.1, the MySQL Installation Wizard creates a **MySQL Server 5.1** section in the **Start** menu.

The following entries are created within the new **Start** menu section:

- **MySQL Command-Line Client**: This is a shortcut to the `mysql` command-line client and is configured to connect as the `root` user. The shortcut prompts for a `root` user password when you connect.

- **MySQL Server Instance Config Wizard**: This is a shortcut to the MySQL Config Wizard. Use this shortcut to configure a newly installed server, or to reconfigure an existing server.

- **MySQL Documentation**: This is a link to the MySQL server documentation that is stored locally in the MySQL server installation directory. This option is not available when the MySQL server is installed using the Essentials installation package.

Changes to the File System

The MySQL Installation Wizard by default installs the MySQL 5.1 server to `C:\Program Files\MySQL\MySQL Server 5.1`, where `Program Files` is the default location for applications in your system, and `5.1` is the release series of your MySQL server. This is the recommended location for the MySQL server, replacing the former default location `C:\mysql`.

By default, all MySQL applications are stored in a common directory at `C:\Program Files\MySQL`, where `Program Files` is the default location for applications in your Windows installation. A typical MySQL installation on a developer machine might look like this:

```
C:\Program Files\MySQL\MySQL Server 5.1
C:\Program Files\MySQL\MySQL Workbench 5.1 OSS
```

This approach makes it easier to manage and maintain all MySQL applications installed on a particular system.

In MySQL 5.1.23 and earlier, the default location for the data files used by MySQL is located within the corresponding MySQL Server installation directory. For MySQL 5.1.24 and later, the default location of the data directory is the `AppData` directory configured for the user that installed the MySQL application.

MySQL Installation Wizard: Upgrading MySQL

The MySQL Installation Wizard can perform server upgrades automatically using the upgrade capabilities of MSI. That means you do not need to remove a previous installation manually before installing a new release. The installer automatically shuts down and removes the previous MySQL service before installing the new version.

Automatic upgrades are available only when upgrading between installations that have the same major and minor version numbers. For example, you can upgrade automatically from MySQL 5.1.5 to MySQL 5.1.6, but not from MySQL 5.0 to MySQL 5.1.

In MySQL 5.1.32 and later, the `EXE` version of the MSI installer packages were removed. When upgrading an existing MySQL installation from the old EXE based installer to the MSI based installer, please keep the following notes in mind:

- The MSI installer will not identify an existing installation that was installed using the old EXE installer. This means that the installer will not stop the existing server, or detect that the existing password is required before installing the new version. To work around this:

  1. Stop the current server manually using `net stop` or `mysqladmin shutdown`.

  2. Remove the existing installation manually by using the **Add/Remove Programs** control panel. This will keep the existing configuration and data files, as these are not removed automatically.

3. Install the new version of MySQL using the MSI installer. When running the installation, skip updating the security by deselecting the check box on the security screen.

4. Complete the installation, and then start the server again. You should be able to login with your existing user and password credentials.

- You can only upgrade the version and release using the MSI installer. For example, you can upgrade an open source installation with an open source installer. You cannot upgrade an open source installation using the enterprise installer.

See Section 2.3.9, "Upgrading MySQL Server on Microsoft Windows".

2.3.4.2 Automating MySQL Installation on Microsoft Windows Using the MSI Package

The Microsoft Installer (MSI) supports a both a *quiet* and a *passive* mode that can be used to install MySQL automatically without requiring intervention. You can use this either in scripts to automatically install MySQL or through a terminal connection such as Telnet where you do not have access to the standard Windows user interface. The MSI packages can also be used in combination with Microsoft's Group Policy system (part of Windows Server 2003 and Windows Server 2008) to install MySQL across multiple machines.

To install MySQL from one of the MSI packages automatically from the command line (or within a script), you need to use the `msiexec.exe` tool. For example, to perform a quiet installation (which shows no dialog boxes or progress):

```
shell> msiexec /i mysql-5.1.73.msi /quiet
```

The `/i` indicates that you want to perform an installation. The `/quiet` option indicates that you want no interactive elements.

To provide a dialog box showing the progress during installation, and the dialog boxes providing information on the installation and registration of MySQL, use `/passive` mode instead of `/quiet`:

```
shell> msiexec /i mysql-5.1.73.msi /passive
```

Regardless of the mode of the installation, installing the package in this manner performs a 'Typical' installation, and installs the default components into the standard location.

You can also use this method to uninstall MySQL by using the `/uninstall` or `/x` options:

```
shell> msiexec /x mysql-5.1.73.msi /uninstall
```

To install MySQL and configure a MySQL instance from the command line, see Section 2.3.5.13, "MySQL Server Instance Config Wizard: Creating an Instance from the Command Line".

For information on using MSI packages to install software automatically using Group Policy, see How to use Group Policy to remotely install software in Windows Server 2003.

2.3.4.3 Removing MySQL When Installed from the MSI Package

To uninstall a MySQL where you have used the MSI packages, you must use the **Add/Remove Programs** tool within **Control Panel**. To do this:

1. Right-click the **start** menu and choose **Control Panel**.

2. If the Control Panel is set to category mode (you will see **Pick a category** at the top of the **Control Panel** window), double-click **Add or Remove Programs**. If the Control is set to classic mode, double-click the **Add or Remove Programs** icon.

3. Find MySQL in the list of installed software. MySQL Server is installed against release series numbers (MySQL 5.0, MySQL 5.1, etc.). Select the version that you want to remove and click **Remove**.

4. You will be prompted to confirm the removal. Click **Yes** to remove MySQL.

When MySQL is removed using this method, only the installed components are removed. Any database information (including the tables and data), import or export files, log files, and binary logs produced during execution are kept in their configured location.

If you try to install MySQL again the information will be retained and you will be prompted to enter the password configured with the original installation.

If you want to delete MySQL completely:

- Delete the associated data directory. On Windows XP and Windows Server 2003, before MySQL 5.1.24, the default data directory would be located within the MySQL installation directory. On MySQL 5.1.24 and later, the default data directory is the configured AppData directory, which is `C:\Documents and Settings\All Users\Application Data\MySQL` by default.

- On Windows 7 and Windows Server 2008, the default data directory location is `C:\ProgramData\Mysql`.

> **Note**
>
> The `C:\ProgramData` directory is hidden by default. You must change your folder options to view the hidden file. Choose **Organize**, **Folder and search options**, **Show hidden folders**.

2.3.5 Using the MySQL Server Instance Config Wizard

The MySQL Server Instance Config Wizard helps automate the process of configuring your server. It creates a custom MySQL configuration file (`my.ini` or `my.cnf`) by asking you a series of questions and then applying your responses to a template to generate the configuration file that is tuned to your installation.

The complete and essential MSI installation packages include the MySQL Server Instance Config Wizard in the MySQL 5.1 server. The MySQL Server Instance Config Wizard is only available for Windows.

The workflow sequence for using the MySQL Server Instance Config Wizard is shown in the figure below:

Figure 3.18 MySQL Server Instance Config Wizard Workflow

2.3.5.1 Starting the MySQL Server Instance Config Wizard

The MySQL Server Instance Config Wizard is normally started as part of the installation process. You should only need to run the MySQL Server Instance Config Wizard again when you need to change the configuration parameters of your server.

If you chose not to open a port prior to installing MySQL on Windows Vista or newer, you can choose to use the MySQL Server Instance Config Wizard after installation. However, you must open a port in the Windows Firewall. To do this see the instructions given in MySQL Installation Wizard: Downloading and Starting. Rather than opening a port, you also have the option of adding MySQL as a program that bypasses the Windows Firewall. One or the other option is sufficient—you need not do both. Additionally, when running the MySQL Server Config Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.
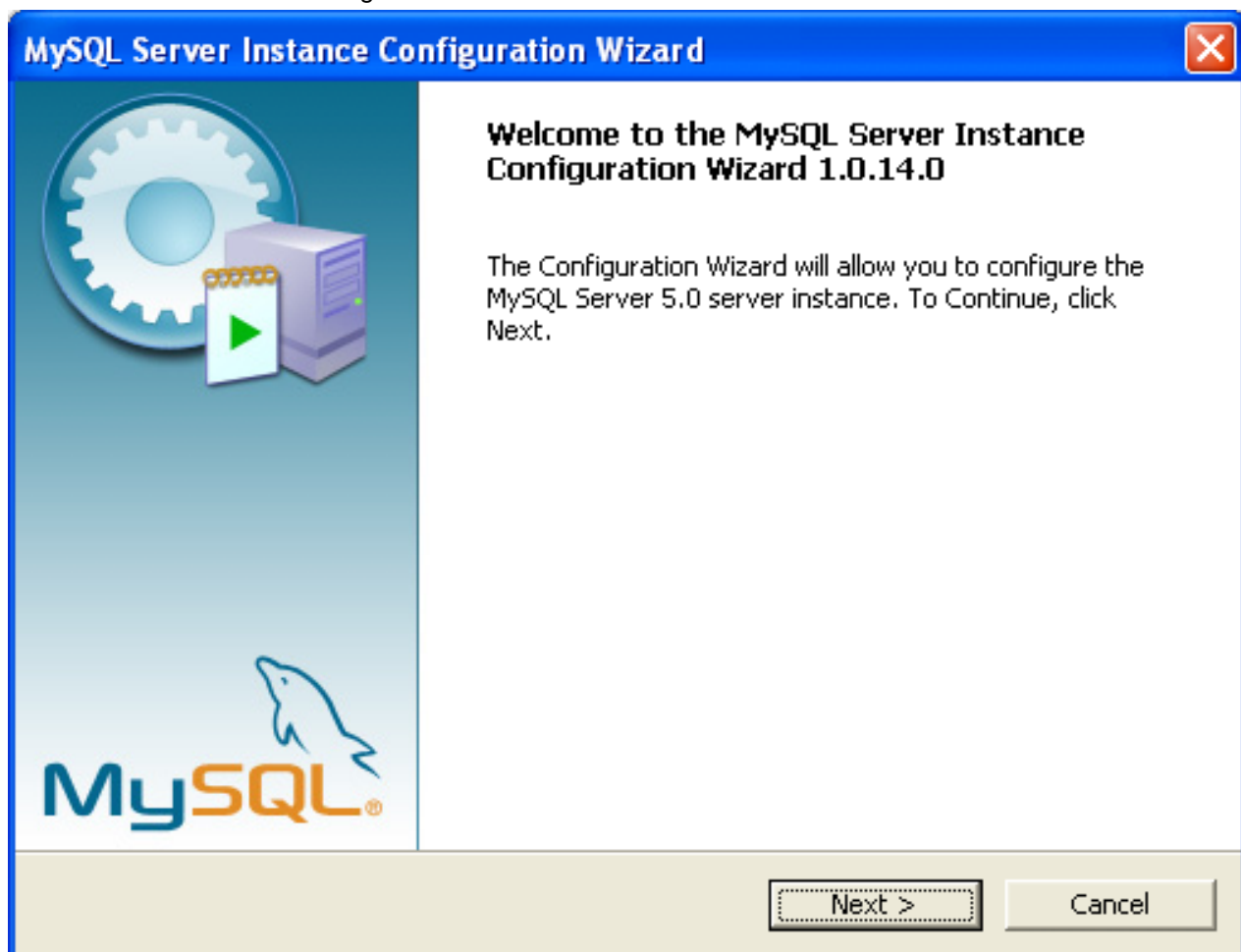
You can launch the MySQL Config Wizard by clicking the **MySQL Server Instance Config Wizard** entry in the **MySQL** section of the Windows **Start** menu.

Alternatively, you can navigate to the `bin` directory of your MySQL installation and launch the `MySQLInstanceConfig.exe` file directly.

The MySQL Server Instance Config Wizard places the `my.ini` file in the installation directory for the MySQL server. This helps associate configuration files with particular server instances.

To ensure that the MySQL server knows where to look for the `my.ini` file, an argument similar to this is passed to the MySQL server as part of the service installation:

```
--defaults-file="C:\Program Files\MySQL\MySQL Server 5.1\my.ini"
```

Here, `C:\Program Files\MySQL\MySQL Server 5.1` is replaced with the installation path to the MySQL Server. The `--defaults-file` option instructs the MySQL server to read the specified file for configuration options when it starts.

Apart from making changes to the `my.ini` file by running the MySQL Server Instance Config Wizard again, you can modify it by opening it with a text editor and making any necessary changes. You can also modify the server configuration with the http://www.mysql.com/products/administrator/ utility. For more information about server configuration, see Section 5.1.3, "Server Command Options".

MySQL clients and utilities such as the `mysql` and `mysqldump` command-line clients are not able to locate the `my.ini` file located in the server installation directory. To configure the client and utility applications, create a new `my.ini` file in the Windows installation directory (for example, `C:\WINDOWS`).

Under Windows Server 2003, Windows Server 2000, Windows XP, and Windows Vista, MySQL Server Instance Config Wizard will configure MySQL to work as a Windows service. To start and stop MySQL you use the `Services` application that is supplied as part of the Windows Administrator Tools.

2.3.5.2 MySQL Server Instance Config Wizard: Choosing a Maintenance Option

If the MySQL Server Instance Config Wizard detects an existing configuration file, you have the option of either reconfiguring your existing server, or removing the server instance by deleting the configuration file and stopping and removing the MySQL service.

To reconfigure an existing server, choose the **Re-configure Instance** option and click the **Next** button. Any existing configuration file is not overwritten, but renamed (within the same directory) using a timestamp (Windows) or sequential number (Linux). To remove the existing server instance, choose the **Remove Instance** option and click the **Next** button.

If you choose the **Remove Instance** option, you advance to a confirmation window. Click the **Execute** button. The MySQL Server Config Wizard stops and removes the MySQL service, and then deletes the configuration file. The server installation and its `data` folder are not removed.

If you choose the **Re-configure Instance** option, you advance to the **Configuration Type** dialog where you can choose the type of installation that you wish to configure.

2.3.5.3 MySQL Server Instance Config Wizard: Choosing a Configuration Type

When you start the MySQL Server Instance Config Wizard for a new MySQL installation, or choose the **Re-configure Instance** option for an existing installation, you advance to the **Configuration Type** dialog.
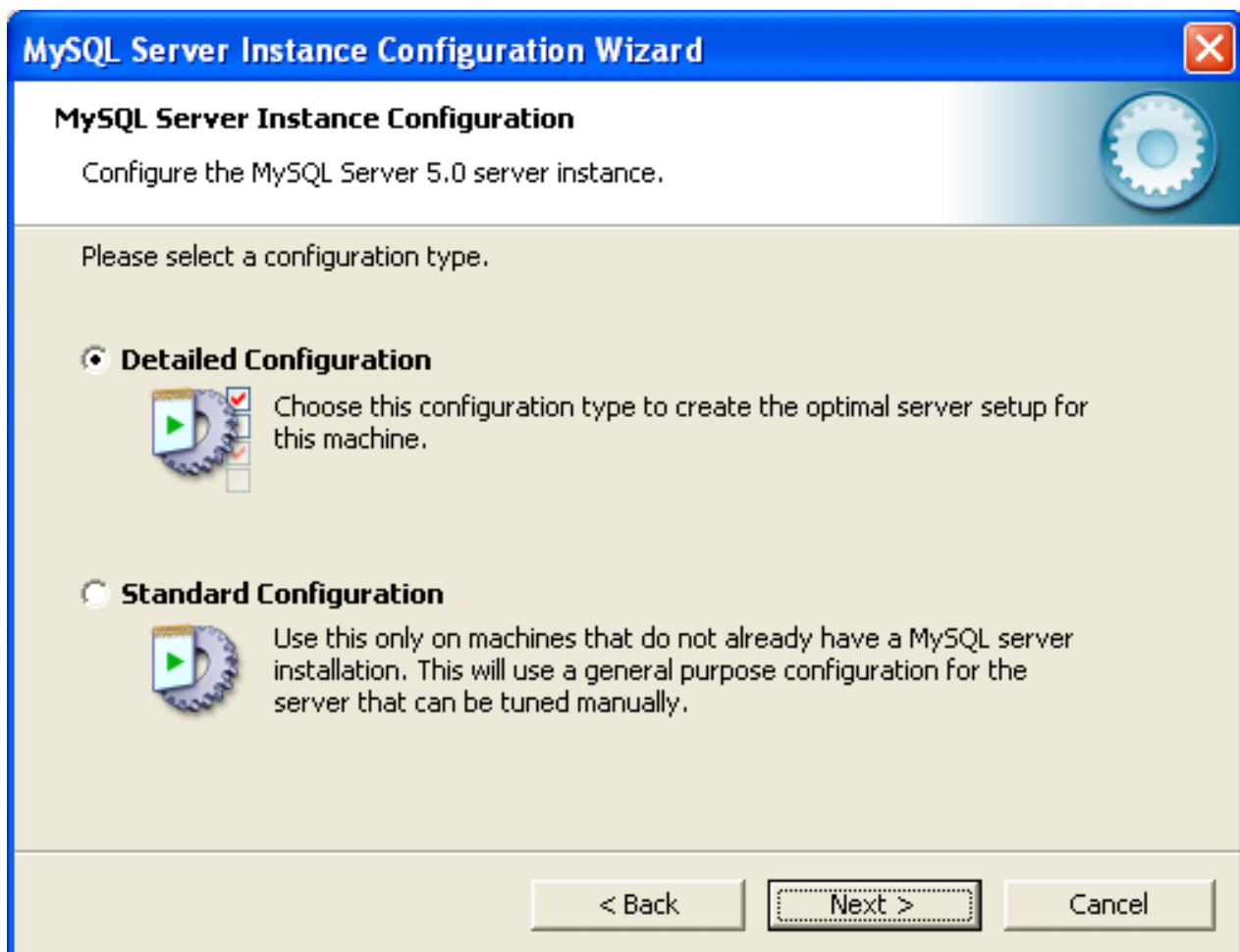
There are two configuration types available: **Detailed Configuration** and **Standard Configuration**. The **Standard Configuration** option is intended for new users who want to get started with MySQL quickly without having to make many decisions about server configuration. The **Detailed Configuration** option is intended for advanced users who want more fine-grained control over server configuration.

If you are new to MySQL and need a server configured as a single-user developer machine, the **Standard Configuration** should suit your needs. Choosing the **Standard Configuration** option causes the MySQL Config Wizard to set all configuration options automatically with the exception of **Service Options** and **Security Options**.

The **Standard Configuration** sets options that may be incompatible with systems where there are existing MySQL installations. If you have an existing MySQL installation on your system in addition to the installation you wish to configure, the **Detailed Configuration** option is recommended.

To complete the **Standard Configuration**, please refer to the sections on **Service Options** and **Security Options** in Section 2.3.5.10, "MySQL Server Instance Config Wizard: The Service Options Dialog", and Section 2.3.5.11, "MySQL Server Instance Config Wizard: The Security Options Dialog", respectively.

2.3.5.4 MySQL Server Instance Config Wizard: The Server Type Dialog

There are three different server types available to choose from. The server type that you choose affects the decisions that the MySQL Server Instance Config Wizard makes with regard to memory, disk, and processor usage.

- **Developer Machine**: Choose this option for a typical desktop workstation where MySQL is intended only for personal use. It is assumed that many other desktop applications are running. The MySQL server is configured to use minimal system resources.

- **Server Machine**: Choose this option for a server machine where the MySQL server is running alongside other server applications such as FTP, email, and Web servers. The MySQL server is configured to use a moderate portion of the system resources.

- **Dedicated MySQL Server Machine**: Choose this option for a server machine that is intended to run only the MySQL server. It is assumed that no other applications are running. The MySQL server is configured to use all available system resources.

> **Note**
>
> By selecting one of the preconfigured configurations, the values and settings of various options in your `my.cnf` or `my.ini` will be altered accordingly. The default values and options as described in the reference manual may therefore be different to the options and values that were created during the execution of the Config Wizard.

2.3.5.5 MySQL Server Instance Config Wizard: The Database Usage Dialog

The **Database Usage** dialog enables you to indicate the storage engines that you expect to use when creating MySQL tables. The option you choose determines whether the `InnoDB` storage engine is available and what percentage of the server resources are available to `InnoDB`.
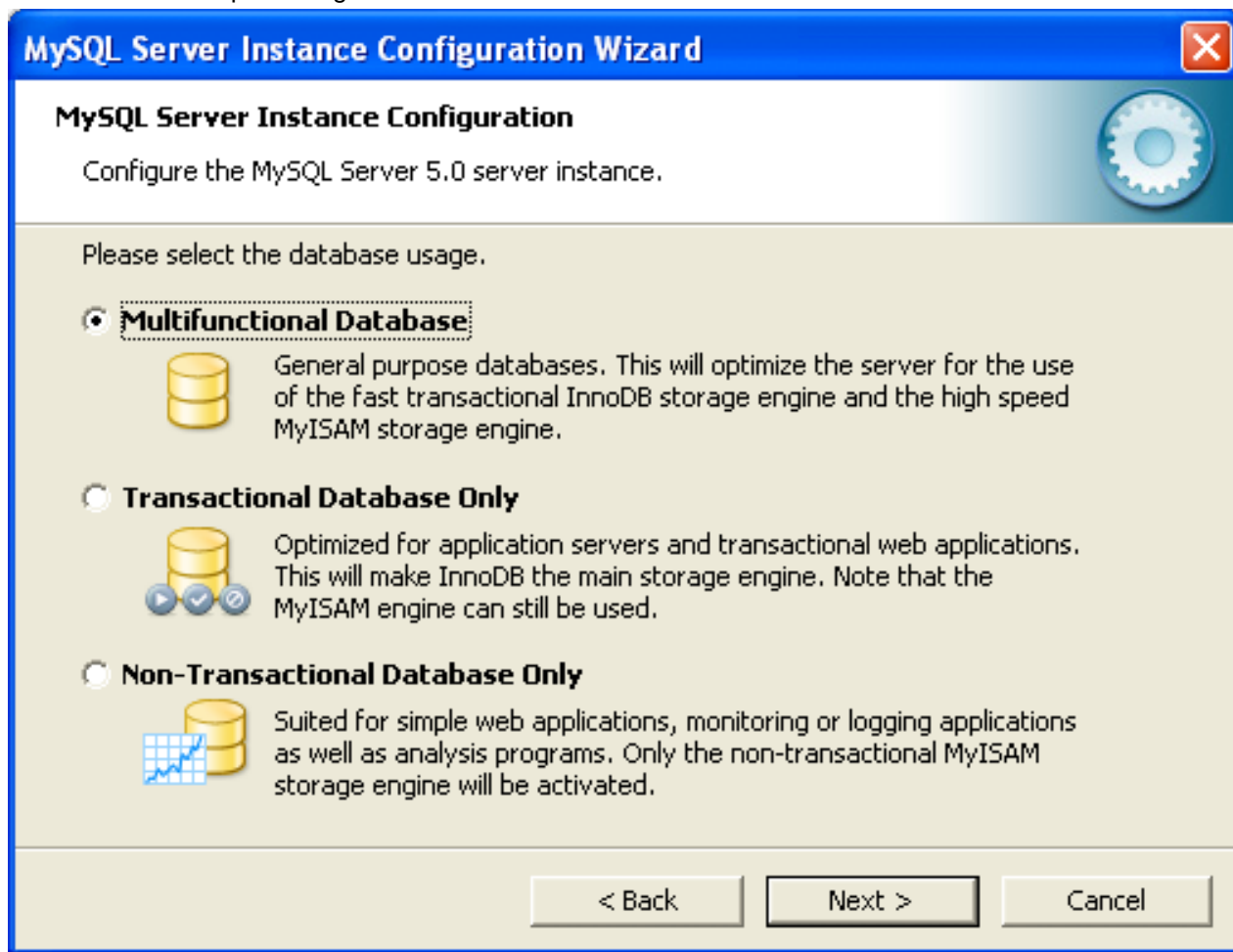
- **Multifunctional Database**: This option enables both the `InnoDB` and `MyISAM` storage engines and divides resources evenly between the two. This option is recommended for users who use both storage engines on a regular basis.

- **Transactional Database Only**: This option enables both the `InnoDB` and `MyISAM` storage engines, but dedicates most server resources to the `InnoDB` storage engine. This option is recommended for users who use `InnoDB` almost exclusively and make only minimal use of `MyISAM`.

- **Non-Transactional Database Only**: This option disables the `InnoDB` storage engine completely and dedicates all server resources to the `MyISAM` storage engine. This option is recommended for users who do not use `InnoDB`.

The Config Wizard uses a template to generate the server configuration file. The **Database Usage** dialog sets one of the following option strings:

```
Multifunctional Database:        MIXED
Transactional Database Only:     INNODB
Non-Transactional Database Only: MYISAM
```

When these options are processed through the default template (my-template.ini) the result is:

```
Multifunctional Database:
default-storage-engine=InnoDB
_myisam_pct=50

Transactional Database Only:
default-storage-engine=InnoDB
_myisam_pct=5

Non-Transactional Database Only:
default-storage-engine=MyISAM
_myisam_pct=100
skip-innodb
```

The `_myisam_pct` value is used to calculate the percentage of resources dedicated to `MyISAM`. The remaining resources are allocated to `InnoDB`.

2.3.5.6 MySQL Server Instance Config Wizard: The InnoDB Tablespace Dialog

Some users may want to locate the `InnoDB` tablespace files in a different location than the MySQL server data directory. Placing the tablespace files in a separate location can be desirable if your system has a higher capacity or higher performance storage device available, such as a RAID storage system.
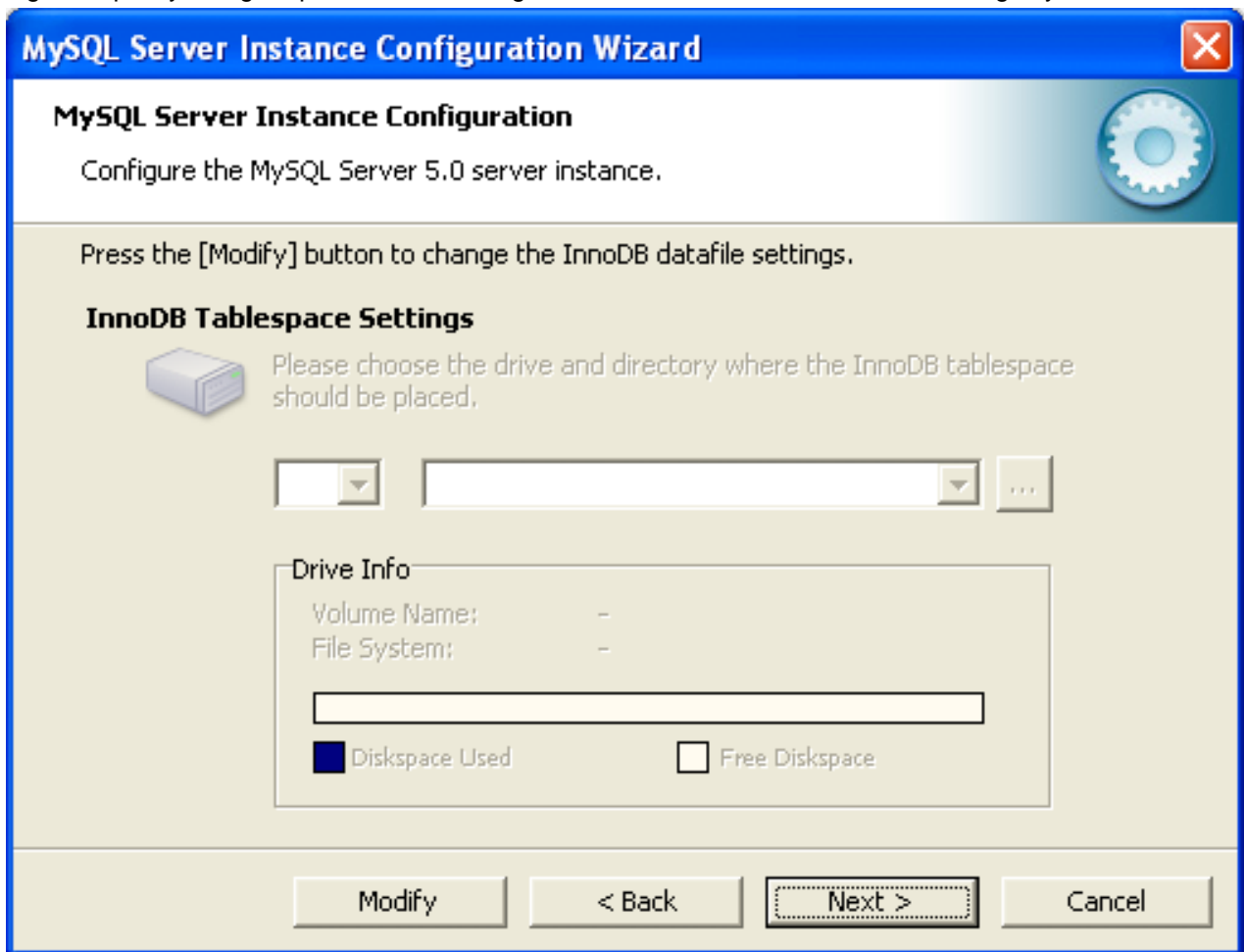
To change the default location for the `InnoDB` tablespace files, choose a new drive from the drop-down list of drive letters and choose a new path from the drop-down list of paths. To create a custom path, click the **...** button.

If you are modifying the configuration of an existing server, you must click the **Modify** button before you change the path. In this situation you must move the existing tablespace files to the new location manually before starting the server.

2.3.5.7 MySQL Server Instance Config Wizard: The Concurrent Connections Dialog

To prevent the server from running out of resources, it is important to limit the number of concurrent connections to the MySQL server that can be established. The **Concurrent Connections** dialog enables you to choose the expected usage of your server, and sets the limit for concurrent connections accordingly. It is also possible to set the concurrent connection limit manually.
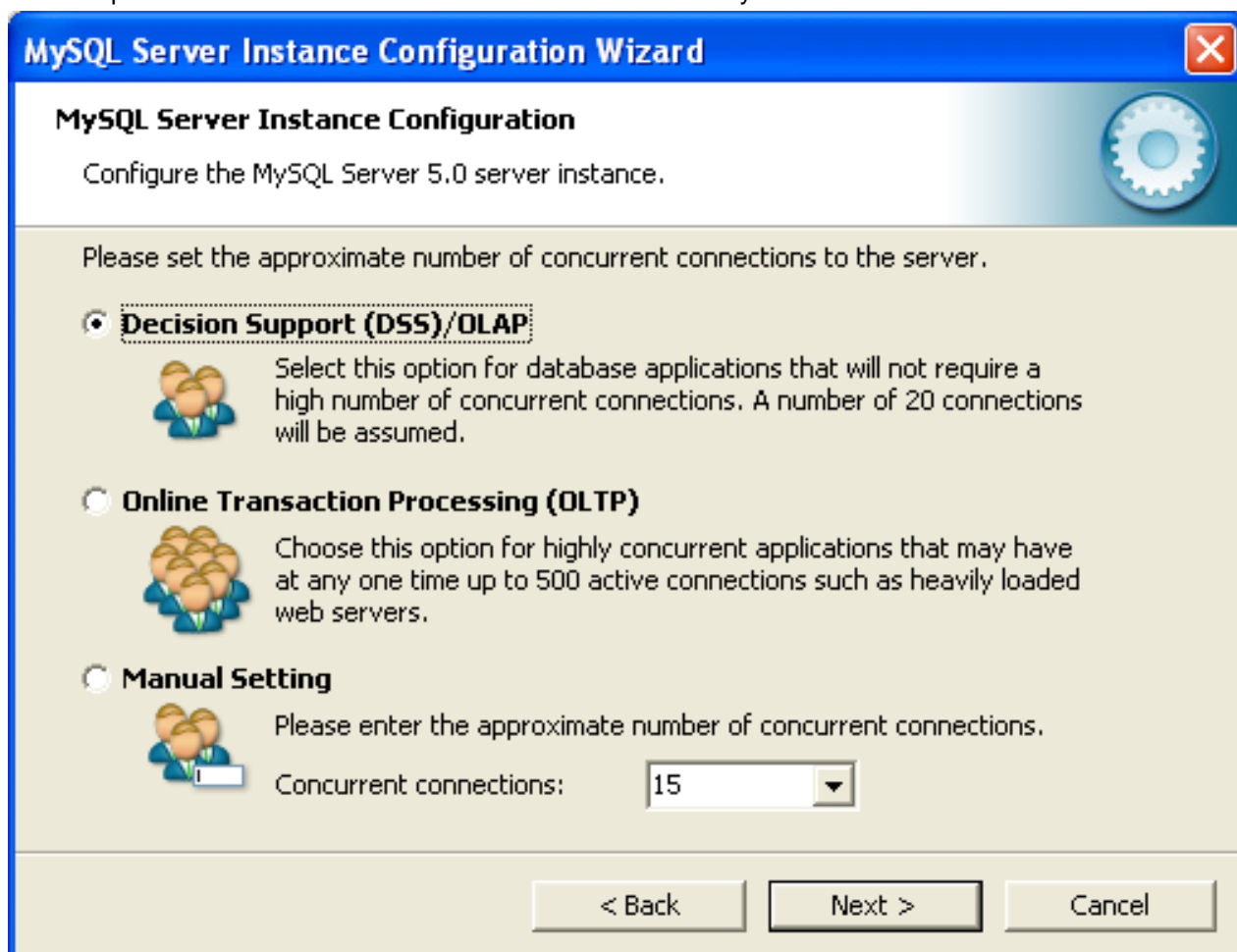
- **Decision Support (DSS)/OLAP**: Choose this option if your server does not require a large number of concurrent connections. The maximum number of connections is set at 100, with an average of 20 concurrent connections assumed.

- **Online Transaction Processing (OLTP)**: Choose this option if your server requires a large number of concurrent connections. The maximum number of connections is set at 500.

- **Manual Setting**: Choose this option to set the maximum number of concurrent connections to the server manually. Choose the number of concurrent connections from the drop-down box provided, or enter the maximum number of connections into the drop-down box if the number you desire is not listed.

2.3.5.8 MySQL Server Instance Config Wizard: The Networking and Strict Mode Options Dialog

Use the **Networking Options** dialog to enable or disable TCP/IP networking and to configure the port number that is used to connect to the MySQL server.
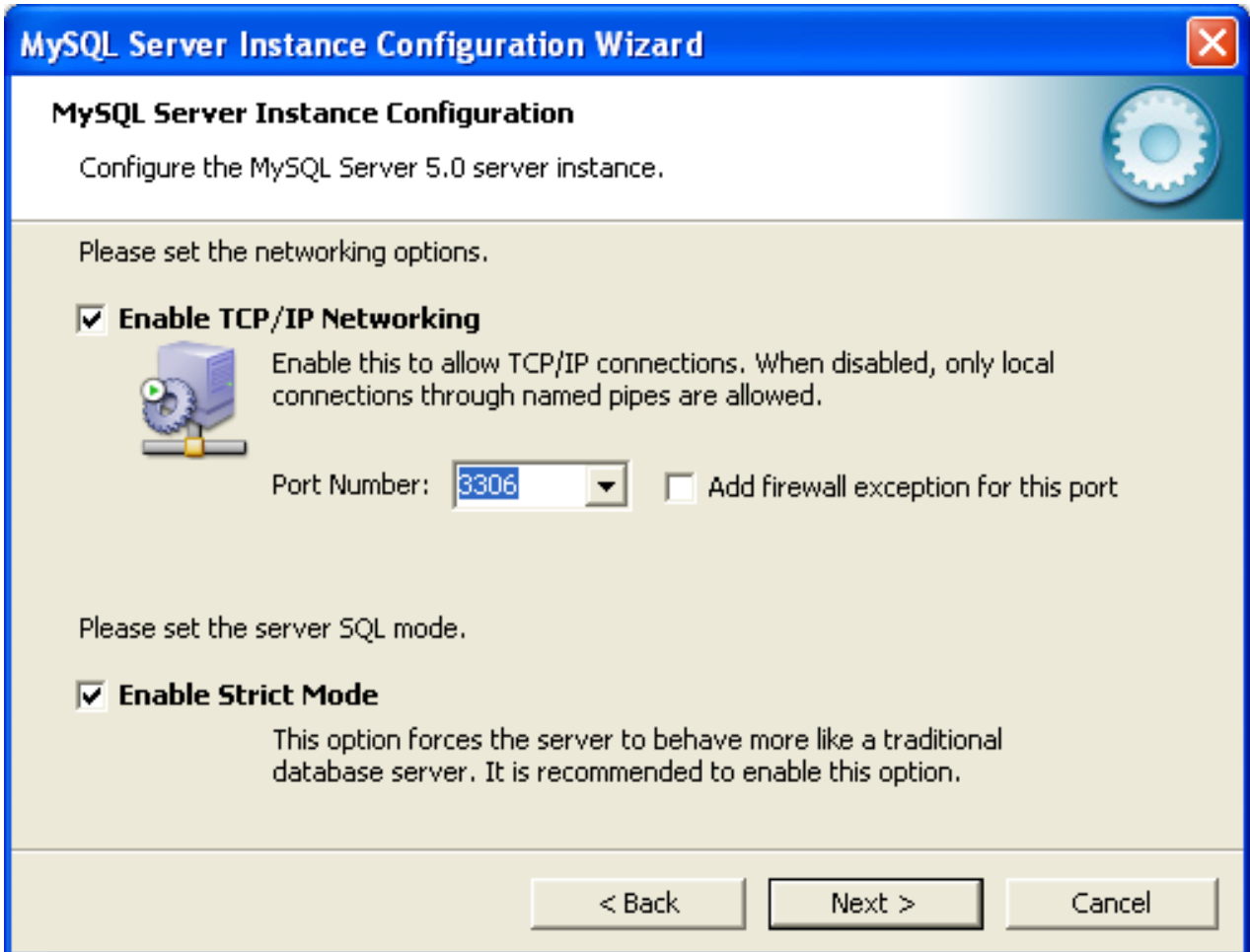
TCP/IP networking is enabled by default. To disable TCP/IP networking, uncheck the box next to the **Enable TCP/IP Networking** option.

Port 3306 is used by default. To change the port used to access MySQL, choose a new port number from the drop-down box or type a new port number directly into the drop-down box. If the port number you choose is in use, you are prompted to confirm your choice of port number.

Set the **Server SQL Mode** to either enable or disable strict mode. Enabling strict mode (default) makes MySQL behave more like other database management systems. *If you run applications that rely on MySQL's old "forgiving" behavior, make sure to either adapt those applications or to disable strict mode.* For more information about strict mode, see Section 5.1.7, "Server SQL Modes".

2.3.5.9 MySQL Server Instance Config Wizard: The Character Set Dialog

The MySQL server supports multiple character sets and it is possible to set a default server character set that is applied to all tables, columns, and databases unless overridden. Use the **Character Set** dialog to change the default character set of the MySQL server.
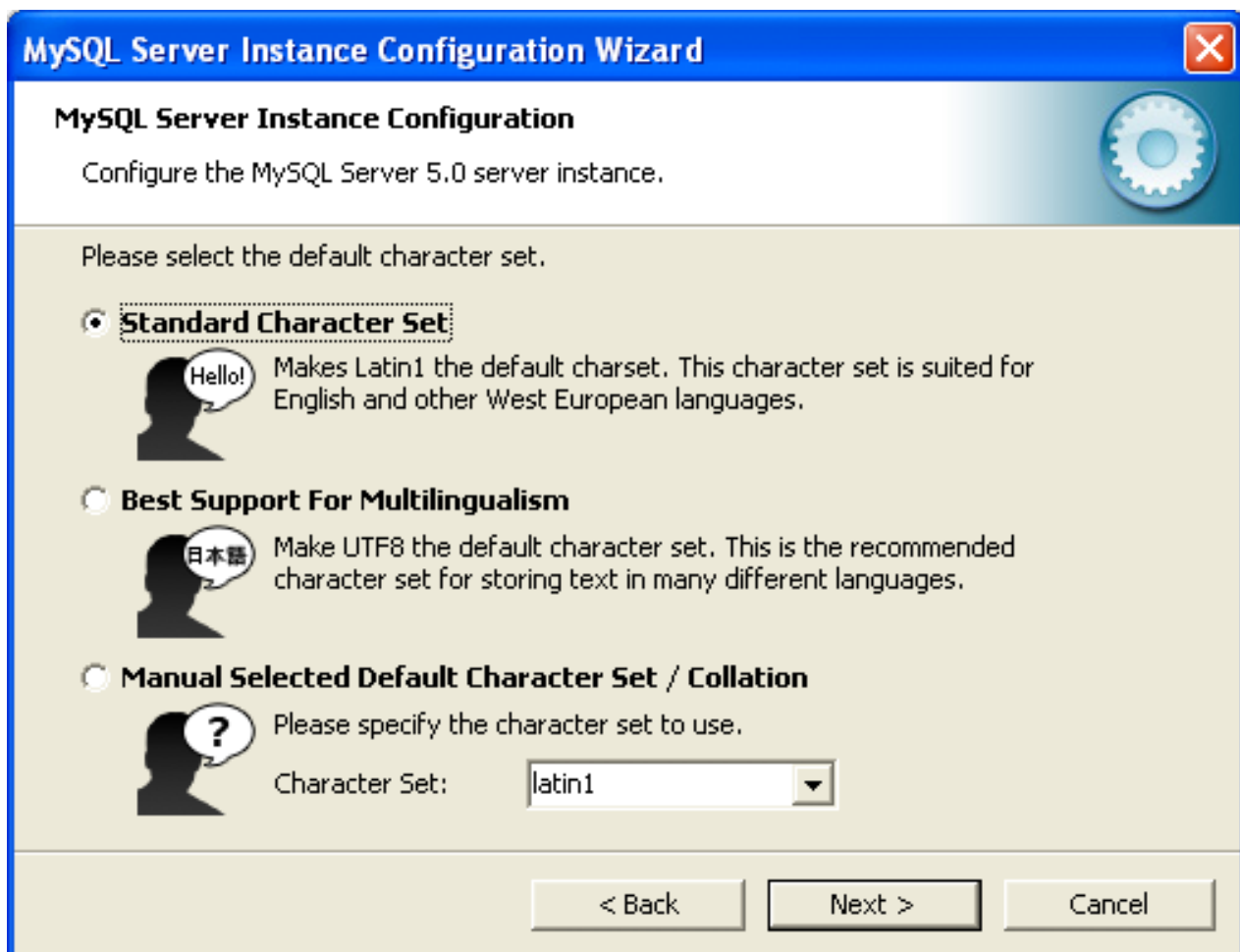
- **Standard Character Set**: Choose this option if you want to use `latin1` as the default server character set. `latin1` is used for English and many Western European languages.

- **Best Support For Multilingualism**: Choose this option if you want to use `utf8` as the default server character set. This is a Unicode character set that can store characters from many different languages.

- **Manual Selected Default Character Set / Collation**: Choose this option if you want to pick the server's default character set manually. Choose the desired character set from the provided drop-down list.

2.3.5.10 MySQL Server Instance Config Wizard: The Service Options Dialog

On Windows platforms, the MySQL server can be installed as a Windows service. When installed this way, the MySQL server can be started automatically during system startup, and even restarted automatically by Windows in the event of a service failure.

The MySQL Server Instance Config Wizard installs the MySQL server as a service by default, using the service name `MySQL`. If you do not wish to install the service, uncheck the box next to the **Install As Windows Service** option. You can change the service name by picking a new service name from the drop-down box provided or by entering a new service name into the drop-down box.

Note

Service names can include any legal character except forward (`/`) or backward (`\`) slashes, and must be less than 256 characters long.

Warning

If you are installing multiple versions of MySQL onto the same machine, you *must* choose a different service name for each version that you install. If you do not choose a different service for each installed version then the service manager information will be inconsistent and this will cause problems when you try to uninstall a previous version.

If you have already installed multiple versions using the same service name, you must manually edit the contents of the `HKEY_LOCAL_MACHINE\SYSTEM` `\CurrentControlSet\Services` parameters within the Windows registry to update the association of the service name with the correct server version.

Typically, when installing multiple versions you create a service name based on the version information. For example, you might install MySQL 5.x as `mysql5`, or specific versions such as MySQL 5.1.30 as `mysql50130`.

To install the MySQL server as a service but not have it started automatically at startup, uncheck the box next to the **Launch the MySQL Server Automatically** option.

2.3.5.11 MySQL Server Instance Config Wizard: The Security Options Dialog

The content of the security options portion of the MySQL Server Instance Configuration Wizard will depend on whether this is a new installation, or modifying an existing installation.

- **Setting the root password for a new installation**

  It is strongly recommended that you set a `root` password for your MySQL server, and the MySQL Server Instance Config Wizard requires by default that you do so. If you do not wish to set a `root` password, uncheck the box next to the **Modify Security Settings** option.

  Note

  If you have previously installed MySQL, but not deleted the data directory associated with the previous installation, you may be prompted to provide the current root password. The password will be the one configured with your old data directory. If you do not want to use this data, or do not know the root password, you should cancel the installation, delete the previous installation data, and then restart the installation process. For more information on deleting MySQL data on Microsoft Windows, see Section 2.3.4.3, "Removing MySQL When Installed from the MSI Package".

- To set the `root` password, enter the desired password into both the **New root password** and **Confirm** boxes.

Setting the root password for an existing installation

If you are modifying the configuration of an existing configuration, or you are installing an upgrade and the MySQL Server Instance Configuration Wizard has detected an existing MySQL system, then you must enter the existing password for `root` before changing the configuration information.

If you want to change the current `root` password, enter the desired new password into both the **New root password** and **Confirm** boxes.

To permit `root` logins from across the network, check the box next to the **Enable root access from remote machines** option. This decreases the security of your `root` account.

To create an anonymous user account, check the box next to the **Create An Anonymous Account** option. Creating an anonymous account can decrease server security and cause login and permission difficulties. For this reason, it is not recommended.

2.3.5.12 MySQL Server Instance Config Wizard: The Confirmation Dialog

The final dialog in the MySQL Server Instance Config Wizard is the **Confirmation Dialog**. To start the configuration process, click the **Execute** button. To return to a previous dialog, click the **Back** button. To exit the MySQL Server Instance Config Wizard without configuring the server, click the **Cancel** button.
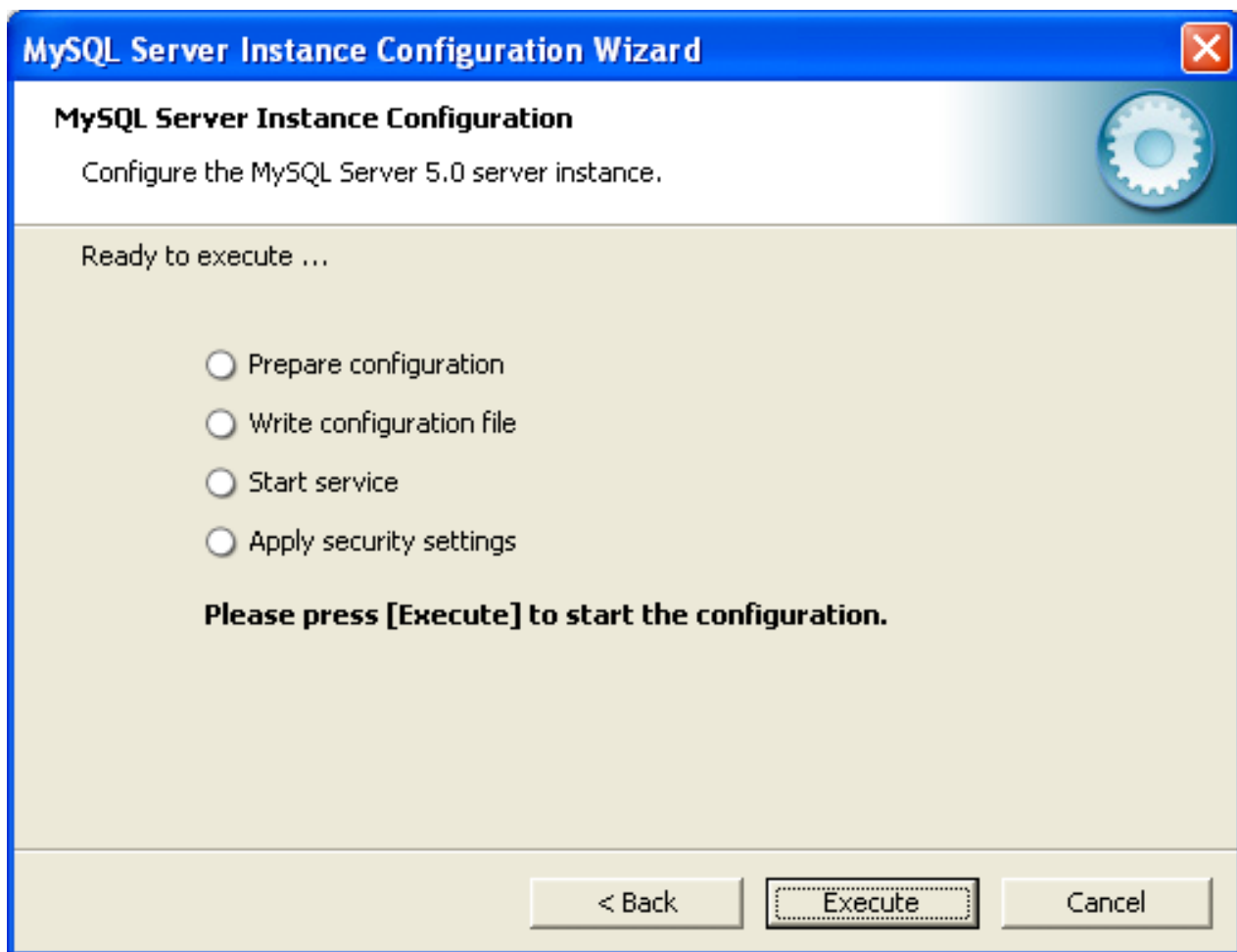
After you click the **Execute** button, the MySQL Server Instance Config Wizard performs a series of tasks and displays the progress onscreen as the tasks are performed.

The MySQL Server Instance Config Wizard first determines configuration file options based on your choices using a template prepared by MySQL developers and engineers. This template is named `my-template.ini` and is located in your server installation directory.

The MySQL Config Wizard then writes these options to the corresponding configuration file.

If you chose to create a service for the MySQL server, the MySQL Server Instance Config Wizard creates and starts the service. If you are reconfiguring an existing service, the MySQL Server Instance Config Wizard restarts the service to apply your configuration changes.

If you chose to set a `root` password, the MySQL Config Wizard connects to the server, sets your new `root` password, and applies any other security settings you may have selected.

After the MySQL Server Instance Config Wizard has completed its tasks, it displays a summary. Click the **Finish** button to exit the MySQL Server Config Wizard.

2.3.5.13 MySQL Server Instance Config Wizard: Creating an Instance from the Command Line

In addition to using the GUI interface to the MySQL Server Instance Config Wizard, you can also create instances automatically from the command line.

To use the MySQL Server Instance Config Wizard on the command line, you need to use the `MySQLInstanceConfig.exe` command that is installed with MySQL in the `bin` directory within the installation directory. `MySQLInstanceConfig.exe` takes a number of command-line arguments the set the properties that would normally be selected through the GUI interface, and then creates a new configuration file (`my.ini`) by combining these selections with a template configuration file to produce the working configuration file.

The main command line options are provided in the table below. Some of the options are required, while some options are optional.

Table 2.7 MySQL Server Instance Config Wizard Command Line Options

Option	Description
Required Parameters	
`-nPRODUCTNAME`	The name of the instance when installed
`-pPATH`	Path of the base directory for installation. This is equivalent to the directory when using the `basedir` configuration parameter
`-vVERSION`	The version tag to use for this installation
Action to Perform	
`-i`	Install an instance
`-r`	Remove an instance
`-s`	Stop an existing instance
`-q`	Perform the operation quietly
`-lFILENAME`	Sae the installation progress in a logfile
Config File to Use	
`-tFILENAME`	Path to the template config file that will be used to generate the installed configuration file
`-cFILENAME`	Path to a config file to be generated

The `-t` and `-c` options work together to set the configuration parameters for a new instance. The `-t` option specifies the template configuration file to use as the basic configuration, which are then merged with the configuration parameters generated by the MySQL Server Instance Config Wizard into the configuration file specified by the `-c` option.

A sample template file, `my-template.ini` is provided in the toplevel MySQL installation directory. The file contains elements are replaced automatically by the MySQL Server Instance Config Wizard during configuration.

If you specify a configuration file that already exists, the existing configuration file will be saved in the file with the original, with the date and time added. For example, the `mysql.ini` will be copied to `mysql 2009-10-27 1646.ini.bak`.

The parameters that you can specify on the command line are listed in the table below.

Table 2.8 MySQL Server Instance Config Wizard Parameters

Parameter	Description
`ServiceName=$`	Specify the name of the service to be created
`AddBinToPath={yes | no}`	Specifies whether to add the binary directory of MySQL to the standard `PATH` environment variable

Parameter	Description
`ServerType={DEVELOPMENT | SERVER | DEDICATED}`	Specify the server type. For more information, see Section 2.3.5.4, "MySQL Server Instance Config Wizard: The Server Type Dialog"
`DatabaseType={MIXED | INNODB | MYISAM}`	Specify the default database type. For more information, see Section 2.3.5.5, "MySQL Server Instance Config Wizard: The Database Usage Dialog"
`ConnectionUsage={DSS | OLTP}`	Specify the type of connection support, this automates the setting for the number of concurrent connections (see the `ConnectionCount` parameter). For more information, see Section 2.3.5.7, "MySQL Server Instance Config Wizard: The Concurrent Connections Dialog"
`ConnectionCount=#`	Specify the number of concurrent connections to support. For more information, see Section 2.3.5.4, "MySQL Server Instance Config Wizard: The Server Type Dialog"
`SkipNetworking={yes | no}`	Specify whether network support should be supported. Specifying `yes` disables network access altogether
`Port=#`	Specify the network port number to use for network connections. For more information, see Section 2.3.5.8, "MySQL Server Instance Config Wizard: The Networking and Strict Mode Options Dialog"
`StrictMode={yes | no}`	Specify whether to use the `strict` SQL mode. For more information, see Section 2.3.5.8, "MySQL Server Instance Config Wizard: The Networking and Strict Mode Options Dialog"
`Charset=$`	Specify the default character set. For more information, see Section 2.3.5.9, "MySQL Server Instance Config Wizard: The Character Set Dialog"
`RootPassword=$`	Specify the root password
`RootCurrentPassword=$`	Specify the current root password then stopping or reconfiguring an existing service

Note

When specifying options on the command line, you can enclose the entire command-line option and the value you are specifying using double quotation marks. This enables you to use spaces in the options. For example, `"-cC:\mysql.ini"`.

The following command installs a MySQL Server 5.1 instance from the directory `C:\Program Files\MySQL\MySQL Server 5.1` using the service name `MySQL51` and setting the root password to 1234.

```
shell> MySQLInstanceConfig.exe -i -q "-lC:\mysql_install_log.txt" »
   "-nMySQL Server 5.1" "-pC:\Program Files\MySQL\MySQL Server 5.1" -v5.1.73 »
   "-tmy-template.ini" "-cC:\mytest.ini" ServerType=DEVELOPMENT DatabaseType=MIXED »
   ConnectionUsage=DSS Port=3311 ServiceName=MySQL51 RootPassword=1234
```

In the above example, a log file will be generated in `mysql_install_log.txt` containing the information about the instance creation process. The log file generated by the above example is shown below:

```
Welcome to the MySQL Server Instance Configuration Wizard 1.0.16.0
Date: 2009-10-27 17:07:21


Installing service ...


Product Name:          MySQL Server 5.1
```

```
Version:            5.1.73
Installation Path:    C:\Program Files\MySQL\MySQL Server 5.1\

Creating configuration file C:\mytest.ini using template my-template.ini.
Options:
DEVELOPMENT
MIXED
DSS
STRICTMODE

Variables:
port: 3311
default-character-set: latin1
basedir: "C:/Program Files/MySQL/MySQL Server 5.1/"
datadir: "C:/Program Files/MySQL/MySQL Server 5.1/Data/"


Creating Windows service entry.
Service name: "MySQL51"
Parameters:    "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld" --defaults-file="C:\mytest.ini" MySQL51.
Windows service MySQL51 installed.
```

When using the command line, the return values in the following table indicate an error performing the specified option.

Table 2.9 Return Value from MySQL Server Instance Config Wizard

Value	Description
2	Configuration template file cannot be found
3	The Windows service entry cannot be created
4	Could not connect to the Service Control Manager
5	The MySQL service cannot be started
6	The MySQL service cannot be stopped
7	The security settings cannot be applied
8	The configuration file cannot be written
9	The Windows service entry cannot be removed

You can perform an installation of MySQL automatically using the MSI package. For more information, see Section 2.3.4.2, "Automating MySQL Installation on Microsoft Windows Using the MSI Package".

2.3.6 Installing MySQL on Microsoft Windows Using a noinstall Zip Archive

Users who are installing from the `noinstall` package can use the instructions in this section to manually install MySQL. The process for installing MySQL from a Zip archive is as follows:

1. Extract the archive to the desired install directory

2. Create an option file

3. Choose a MySQL server type

4. Start the MySQL server

5. Secure the default user accounts

This process is described in the sections that follow.

2.3.6.1 Extracting the Install Archive

To install MySQL manually, do the following:

1. If you are upgrading from a previous version please refer to Section 2.3.9, "Upgrading MySQL Server on Microsoft Windows", before beginning the upgrade process.

2. Make sure that you are logged in as a user with administrator privileges.

3. Choose an installation location. Traditionally, the MySQL server is installed in `C:\mysql`. The MySQL Installation Wizard installs MySQL under `C:\Program Files\MySQL`. If you do not install MySQL at `C:\mysql`, you must specify the path to the install directory during startup or in an option file. See Section 2.3.6.2, "Creating an Option File".

4. Extract the install archive to the chosen installation location using your preferred Zip archive tool. Some tools may extract the archive to a folder within your chosen installation location. If this occurs, you can move the contents of the subfolder into the chosen installation location.

2.3.6.2 Creating an Option File

If you need to specify startup options when you run the server, you can indicate them on the command line or place them in an option file. For options that are used every time the server starts, you may find it most convenient to use an option file to specify your MySQL configuration. This is particularly true under the following circumstances:

- The installation or data directory locations are different from the default locations (`C:\Program Files\MySQL\MySQL Server 5.1` and `C:\Program Files\MySQL\MySQL Server 5.1\data`).

- You need to tune the server settings, such as memory, cache, or InnoDB configuration information.

When the MySQL server starts on Windows, it looks for option files in several locations, such as the Windows directory, `C:\`, and the MySQL installation directory (for the full list of locations, see Section 4.2.6, "Using Option Files"). The Windows directory typically is named something like `C:\WINDOWS`. You can determine its exact location from the value of the `WINDIR` environment variable using the following command:

```
C:\> echo %WINDIR%
```

MySQL looks for options in each location first in the `my.ini` file, and then in the `my.cnf` file. However, to avoid confusion, it is best if you use only one file. If your PC uses a boot loader where `C:` is not the boot drive, your only option is to use the `my.ini` file. Whichever option file you use, it must be a plain text file.

You can also make use of the example option files included with your MySQL distribution; see Section 5.1.2, "Server Configuration Defaults".

An option file can be created and modified with any text editor, such as Notepad. For example, if MySQL is installed in `E:\mysql` and the data directory is in `E:\mydata\data`, you can create an option file containing a `[mysqld]` section to specify values for the `basedir` and `datadir` options:

```
[mysqld]
# set basedir to your installation path
basedir=E:/mysql
# set datadir to the location of your data directory
datadir=E:/mydata/data
```

Microsoft Windows path names are specified in option files using (forward) slashes rather than backslashes. If you do use backslashes, double them:

```
[mysqld]
# set basedir to your installation path
basedir=E:\\mysql
# set datadir to the location of your data directory
datadir=E:\\mydata\\data
```

The rules for use of backslash in option file values are given in Section 4.2.6, "Using Option Files".

In MySQL 5.1.23 and earlier, the MySQL installer places the data directory directly under the directory where you install MySQL. On MySQL 5.1.24 and later, the data directory is located within the `AppData` directory for the user running MySQL.

If you would like to use a data directory in a different location, you should copy the entire contents of the `data` directory to the new location. For example, if you want to use `E:\mydata` as the data directory instead, you must do two things:

1. Move the entire `data` directory and all of its contents from the default location (for example `C:\Program Files\MySQL\MySQL Server 5.1\data`) to `E:\mydata`.

2. Use a `--datadir` option to specify the new data directory location each time you start the server.

2.3.6.3 Selecting a MySQL Server Type

The following table shows the available servers for Windows in MySQL 5.1.20 and earlier.

Binary	Description
mysqld-nt	Optimized binary with named-pipe support
mysqld	Optimized binary without named-pipe support
mysqld-debug	Like mysqld-nt, but compiled with full debugging and automatic memory allocation checking

The following table shows the available servers for Windows in MySQL 5.1.21 and later.

Table 2.10 mysqld binary types for Microsoft Windows MySQL 5.1.21 and later

Binary	Description
mysqld	Optimized binary with named-pipe support
mysqld-debug	Like mysqld, but compiled with full debugging and automatic memory allocation checking

All of the preceding binaries are optimized for modern Intel processors, but should work on any Intel i386-class or higher processor.

Each of the servers in a distribution support the same set of storage engines. The SHOW ENGINES statement displays which engines a given server supports.

All Windows MySQL 5.1 servers have support for symbolic linking of database directories.

MySQL supports TCP/IP on all Windows platforms. MySQL servers on Windows support named pipes as indicated in the following list. However, the default is to use TCP/IP regardless of platform. (Named pipes are slower than TCP/IP in many Windows configurations.)

Use of named pipes is subject to these conditions:

- Named pipes are enabled only if you start the server with the `--enable-named-pipe` option. It is necessary to use this option explicitly because some users have experienced problems with shutting down the MySQL server when named pipes were used.

- For MySQL 5.1.20 and earlier, named-pipe connections are permitted only by the `mysqld-nt` and `mysqld-debug` servers. For MySQL 5.1.21 and later, the `mysqld` and `mysqld-debug` servers both contain support for named-pipe connections.

> **Note**
>
> Most of the examples in this manual use `mysqld` as the server name. If you choose to use a different server, such as `mysqld-nt` or `mysqld-debug`, make the appropriate substitutions in the commands that are shown in the examples.

2.3.6.4 Starting MySQL Server on Microsoft Windows for the First Time

This section gives a general overview of starting the MySQL server. The following sections provide more specific information for starting the MySQL server from the command line or as a Windows service.

The information here applies primarily if you installed MySQL using the `Noinstall` version, or if you wish to configure and test MySQL manually rather than with the GUI tools.

> **Note**
>
> The MySQL Notifier GUI can be used to start/stop/restart the MySQL server at any time.

The examples in these sections assume that MySQL is installed under the default location of `C:\Program Files\MySQL\MySQL Server 5.1`. Adjust the path names shown in the examples if you have MySQL installed in a different location.

Clients have two options. They can use TCP/IP, or they can use a named pipe if the server supports named-pipe connections.

MySQL for Windows also supports shared-memory connections if the server is started with the `--shared-memory` option. Clients can connect through shared memory by using the `--protocol=MEMORY` option.

For information about which server binary to run, see Section 2.3.6.3, "Selecting a MySQL Server Type".

Testing is best done from a command prompt in a console window (or "DOS window"). In this way you can have the server display status messages in the window where they are easy to see. If something is wrong with your configuration, these messages make it easier for you to identify and fix any problems.

To start the server, enter this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld" --console
```

For a server that includes `InnoDB` support, you should see the messages similar to those following as it starts (the path names and sizes may differ):

```
InnoDB: The first specified datafile c:\ibdata\ibdata1 did not exist:
InnoDB: a new database to be created!
InnoDB: Setting file c:\ibdata\ibdata1 size to 209715200
InnoDB: Database physically writes the file full: wait...
```

```
InnoDB: Log file c:\iblogs\ib_logfile0 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile0 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile1 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile1 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile2 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile2 size to 31457280
InnoDB: Doublewrite buffer not found: creating new
InnoDB: Doublewrite buffer created
InnoDB: creating foreign key constraint system tables
InnoDB: foreign key constraint system tables created
011024 10:58:25  InnoDB: Started
```

When the server finishes its startup sequence, you should see something like this, which indicates that the server is ready to service client connections:

```
mysqld: ready for connections
Version: '5.1.73'  socket: ''  port: 3306
```

The server continues to write to the console any further diagnostic output it produces. You can open a new console window in which to run client programs.

If you omit the `--console` option, the server writes diagnostic output to the error log in the data directory (`C:\Program Files\MySQL\MySQL Server 5.1\data` by default). The error log is the file with the `.err` extension, and may be set using the `--log-error` option.

> **Note**
>
> The accounts that are listed in the MySQL grant tables initially have no passwords. After starting the server, you should set up passwords for them using the instructions in Section 2.12.4, "Securing the Initial MySQL Accounts".

2.3.6.5 Starting MySQL Server from the Windows Command Line

The MySQL server can be started manually from the command line. This can be done on any version of Windows.

> **Note**
>
> The MySQL Notifier GUI can also be used to start/stop/restart the MySQL server.

To start the `mysqld` server from the command line, you should start a console window (or "DOS window") and enter this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld"
```

The path to `mysqld` may vary depending on the install location of MySQL on your system.

You can stop the MySQL server by executing this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqladmin" -u root shutdown
```

> **Note**
>
> If the MySQL `root` user account has a password, you need to invoke `mysqladmin` with the `-p` option and supply the password when prompted.

This command invokes the MySQL administrative utility `mysqladmin` to connect to the server and tell it to shut down. The command connects as the MySQL `root` user, which is the default administrative account in the MySQL grant system.

> **Note**
>
> Users in the MySQL grant system are wholly independent from any login users under Microsoft Windows.

If `mysqld` doesn't start, check the error log to see whether the server wrote any messages there to indicate the cause of the problem. By default, the error log is located in the `C:\Program Files\MySQL\MySQL Server 5.1\data` directory. It is the file with a suffix of `.err`, or may be specified by passing in the `--log-error` option. Alternatively, you can try to start the server with the `--console` option; in this case, the server may display some useful information on the screen that will help solve the problem.

The last option is to start `mysqld` with the `--standalone` and `--debug` options. In this case, `mysqld` writes a log file `C:\mysqld.trace` that should contain the reason why `mysqld` doesn't start. See Section 22.4.3, "The DBUG Package".

Use `mysqld --verbose --help` to display all the options that `mysqld` supports.

2.3.6.6 Customizing the PATH for MySQL Tools

To make it easier to invoke MySQL programs, you can add the path name of the MySQL `bin` directory to your Windows system `PATH` environment variable:

- On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.

- Next select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.

- Under **System Variables**, select **Path**, and then click the **Edit** button. The **Edit System Variable** dialogue should appear.

- Place your cursor at the end of the text appearing in the space marked **Variable Value**. (Use the **End** key to ensure that your cursor is positioned at the very end of the text in this space.) Then enter the complete path name of your MySQL `bin` directory (for example, `C:\Program Files\MySQL\MySQL Server 5.1\bin`)

> **Note**
>
> There must be a semicolon separating this path from any values present in this field.

Dismiss this dialogue, and each dialogue in turn, by clicking **OK** until all of the dialogues that were opened have been dismissed. You should now be able to invoke any MySQL executable program by typing its name at the DOS prompt from any directory on the system, without having to supply the path. This includes the servers, the `mysql` client, and all MySQL command-line utilities such as `mysqladmin` and `mysqldump`.

You should not add the MySQL `bin` directory to your Windows `PATH` if you are running multiple MySQL servers on the same machine.

> **Warning**
>
> You must exercise great care when editing your system `PATH` by hand; accidental deletion or modification of any portion of the existing `PATH` value can leave you with a malfunctioning or even unusable system.

2.3.6.7 Starting MySQL Server as a Microsoft Windows Service

On Windows, the recommended way to run MySQL is to install it as a Windows service, so that MySQL starts and stops automatically when Windows starts and stops, and can be managed using the service manager framework. A MySQL server installed as a service can also be controlled from the command line using `NET` commands, or with the graphical `Services` utility. Generally, to install MySQL as a Windows service you should be logged in using an account that has administrator rights.

> **Note**
>
> The MySQL Notifier GUI can also be used to monitor the status of the MySQL service.

The `Services` utility (the Windows `Service Control Manager`) can be found in the Windows Control Panel (under **Administrative Tools** on Windows 2000, XP, Vista, and Server 2003). To avoid conflicts, it is advisable to close the `Services` utility while performing server installation or removal operations from the command line.

Installing the service

Before installing MySQL as a Windows service, you should first stop the current server if it is running by using the following command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqladmin"
        -u root shutdown
```

> **Note**
>
> If the MySQL `root` user account has a password, you need to invoke `mysqladmin` with the `-p` option and supply the password when prompted.

This command invokes the MySQL administrative utility `mysqladmin` to connect to the server and tell it to shut down. The command connects as the MySQL `root` user, which is the default administrative account in the MySQL grant system.

> **Note**
>
> Users in the MySQL grant system are wholly independent from any login users under Windows.

Install the server as a service using this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld" --install
```

The service-installation command does not start the server. Instructions for that are given later in this section.

To make it easier to invoke MySQL programs, you can add the path name of the MySQL `bin` directory to your Windows system `PATH` environment variable:

• On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.

• Next select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.

• Under **System Variables**, select **Path**, and then click the **Edit** button. The **Edit System Variable** dialogue should appear.

- Place your cursor at the end of the text appearing in the space marked **Variable Value**. (Use the **End** key to ensure that your cursor is positioned at the very end of the text in this space.) Then enter the complete path name of your MySQL `bin` directory (for example, `C:\Program Files\MySQL\MySQL Server 5.1\bin`), and there should be a semicolon separating this path from any values present in this field. Dismiss this dialogue, and each dialogue in turn, by clicking **OK** until all of the dialogues that were opened have been dismissed. You should now be able to invoke any MySQL executable program by typing its name at the DOS prompt from any directory on the system, without having to supply the path. This includes the servers, the `mysql` client, and all MySQL command-line utilities such as `mysqladmin` and `mysqldump`.

  You should not add the MySQL `bin` directory to your Windows `PATH` if you are running multiple MySQL servers on the same machine.

  > **Warning**
  >
  > You must exercise great care when editing your system `PATH` by hand; accidental deletion or modification of any portion of the existing `PATH` value can leave you with a malfunctioning or even unusable system.

The following additional arguments can be used when installing the service:

- You can specify a service name immediately following the `--install` option. The default service name is `MySQL`.

- If a service name is given, it can be followed by a single option. By convention, this should be `--defaults-file=file_name` to specify the name of an option file from which the server should read options when it starts.

  The use of a single option other than `--defaults-file` is possible but discouraged. `--defaults-file` is more flexible because it enables you to specify multiple startup options for the server by placing them in the named option file.

- You can also specify a `--local-service` option following the service name. This causes the server to run using the `LocalService` Windows account that has limited system privileges. This account is available only for Windows XP or newer. If both `--defaults-file` and `--local-service` are given following the service name, they can be in any order.

For a MySQL server that is installed as a Windows service, the following rules determine the service name and option files that the server uses:

- If the service-installation command specifies no service name or the default service name (`MySQL`) following the `--install` option, the server uses the a service name of `MySQL` and reads options from the `[mysqld]` group in the standard option files.

- If the service-installation command specifies a service name other than `MySQL` following the `--install` option, the server uses that service name. It reads options from the `[mysqld]` group and the group that has the same name as the service in the standard option files. This enables you to use the `[mysqld]` group for options that should be used by all MySQL services, and an option group with the service name for use by the server installed with that service name.

- If the service-installation command specifies a `--defaults-file` option after the service name, the server reads options the same way as described in the previous item, except that it reads options only from the named file and ignores the standard option files.

As a more complex example, consider the following command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld"
        --install MySQL --defaults-file=C:\my-opts.cnf
```

Here, the default service name (`MySQL`) is given after the `--install` option. If no `--defaults-file` option had been given, this command would have the effect of causing the server to read the `[mysqld]` group from the standard option files. However, because the `--defaults-file` option is present, the server reads options from the `[mysqld]` option group, and only from the named file.

> **Note**
>
> On Windows, if the server is started with the `--defaults-file` and `--install` options, `--install` must be first. Otherwise, `mysqld.exe` will attempt to start the MySQL server.

You can also specify options as Start parameters in the Windows `Services` utility before you start the MySQL service.

Starting the service

Once a MySQL server has been installed as a service, Windows starts the service automatically whenever Windows starts. The service also can be started immediately from the `Services` utility, or by using a `NET START MySQL` command. The `NET` command is not case sensitive.

When run as a service, `mysqld` has no access to a console window, so no messages can be seen there. If `mysqld` does not start, check the error log to see whether the server wrote any messages there to indicate the cause of the problem. The error log is located in the MySQL data directory (for example, `C:\Program Files\MySQL\MySQL Server 5.1\data`). It is the file with a suffix of `.err`.

When a MySQL server has been installed as a service, and the service is running, Windows stops the service automatically when Windows shuts down. The server also can be stopped manually by using the `Services` utility, the `NET STOP MySQL` command, or the `mysqladmin shutdown` command.

You also have the choice of installing the server as a manual service if you do not wish for the service to be started automatically during the boot process. To do this, use the `--install-manual` option rather than the `--install` option:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld" --install-manual
```

Removing the service

To remove a server that is installed as a service, first stop it if it is running by executing `NET STOP MySQL`. Then use the `--remove` option to remove it:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld" --remove
```

If `mysqld` is not running as a service, you can start it from the command line. For instructions, see Section 2.3.6.5, "Starting MySQL Server from the Windows Command Line".

If you encounter difficulties during installation, see Section 2.3.7, "Troubleshooting a Microsoft Windows MySQL Server Installation".

For more information about stopping or removing a MySQL Windows service, see Section 5.5.2.2, "Starting Multiple MySQL Instances as Windows Services".

2.3.6.8 Testing The MySQL Server Installation on Microsoft Windows

You can test whether the MySQL server is working by executing any of the following commands:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqlshow"
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqlshow" -u root mysql
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqladmin" version status proc
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysql" test
```

> **Note**
>
> By default, `mysqlshow` will try to connect using the `ODBC` user. This user is not created by default. You should specify a valid user, or `root` with the right password to check the operation of the server.

If `mysqld` is slow to respond to TCP/IP connections from client programs, there is probably a problem with your DNS. In this case, start `mysqld` with the `--skip-name-resolve` option and use only `localhost` and IP addresses in the `Host` column of the MySQL grant tables. (Be sure that an account exists that specifies an IP address or you may not be able to connect.)

You can force a MySQL client to use a named-pipe connection rather than TCP/IP by specifying the `--pipe` or `--protocol=PIPE` option, or by specifying `.` (period) as the host name. Use the `--socket` option to specify the name of the pipe if you do not want to use the default pipe name.

If you have set a password for the `root` account, deleted the anonymous account, or created a new user account, then to connect to the MySQL server you must use the appropriate `-u` and `-p` options with the commands shown previously. See Section 4.2.2, "Connecting to the MySQL Server".

For more information about `mysqlshow`, see Section 4.5.6, "`mysqlshow` — Display Database, Table, and Column Information".

2.3.7 Troubleshooting a Microsoft Windows MySQL Server Installation

When installing and running MySQL for the first time, you may encounter certain errors that prevent the MySQL server from starting. This section helps you diagnose and correct some of these errors.

Your first resource when troubleshooting server issues is the error log. The MySQL server uses the error log to record information relevant to the error that prevents the server from starting. The error log is located in the data directory specified in your `my.ini` file. The default data directory location is `C:\Program Files\MySQL\MySQL Server 5.1\data`, or `C:\ProgramData\Mysql` on Windows 7 and Windows Server 2008. The `C:\ProgramData` directory is hidden by default. You need to change your folder options to see the directory and contents. For more information on the error log and understanding the content, see Section 5.4.2, "The Error Log".

For information regarding possible errors, also consult the console messages displayed when the MySQL service is starting. Use the `NET START MySQL` command from the command line after installing `mysqld` as a service to see any error messages regarding the starting of the MySQL server as a service. See Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

The following examples show other common error messages you might encounter when installing MySQL and starting the server for the first time:

- If the MySQL server cannot find the `mysql` privileges database or other critical files, it displays these messages:

```
System error 1067 has occurred.
Fatal error: Can't open and lock privilege tables:
Table 'mysql.user' doesn't exist
```

These messages often occur when the MySQL base or data directories are installed in different locations than the default locations (`C:\Program Files\MySQL\MySQL Server 5.1` and `C:\Program Files\MySQL\MySQL Server 5.1\data`, respectively).

This situation can occur when MySQL is upgraded and installed to a new location, but the configuration file is not updated to reflect the new location. In addition, old and new configuration files might conflict. Be sure to delete or rename any old configuration files when upgrading MySQL.

If you have installed MySQL to a directory other than `C:\Program Files\MySQL\MySQL Server 5.1`, ensure that the MySQL server is aware of this through the use of a configuration (`my.ini`) file. Put the `my.ini` file in your Windows directory, typically `C:\WINDOWS`. To determine its exact location from the value of the `WINDIR` environment variable, issue the following command from the command prompt:

```
C:\> echo %WINDIR%
```

You can create or modify an option file with any text editor, such as Notepad. For example, if MySQL is installed in `E:\mysql` and the data directory is `D:\MySQLdata`, you can create the option file and set up a `[mysqld]` section to specify values for the `basedir` and `datadir` options:

```
[mysqld]
# set basedir to your installation path
basedir=E:/mysql
# set datadir to the location of your data directory
datadir=D:/MySQLdata
```

Microsoft Windows path names are specified in option files using (forward) slashes rather than backslashes. If you do use backslashes, double them:

```
[mysqld]
# set basedir to your installation path
basedir=C:\\Program Files\\MySQL\\MySQL Server 5.1
# set datadir to the location of your data directory
datadir=D:\\MySQLdata
```

The rules for use of backslash in option file values are given in Section 4.2.6, "Using Option Files".

If you change the `datadir` value in your MySQL configuration file, you must move the contents of the existing MySQL data directory before restarting the MySQL server.

See Section 2.3.6.2, "Creating an Option File".

- If you reinstall or upgrade MySQL without first stopping and removing the existing MySQL service and install MySQL using the MySQL Config Wizard, you may see this error:

```
Error: Cannot create Windows service for MySql. Error: 0
```

This occurs when the Configuration Wizard tries to install the service and finds an existing service with the same name.

One solution to this problem is to choose a service name other than `mysql` when using the configuration wizard. This enables the new service to be installed correctly, but leaves the outdated service in place. Although this is harmless, it is best to remove old services that are no longer in use.

To permanently remove the old `mysql` service, execute the following command as a user with administrative privileges, on the command line:

```
C:\> sc delete mysql
[SC] DeleteService SUCCESS
```

If the `sc` utility is not available for your version of Windows, download the `delsrv` utility from http://www.microsoft.com/windows2000/techinfo/reskit/tools/existing/delsrv-o.asp and use the `delsrv mysql` syntax.

2.3.8 Windows Postinstallation Procedures

GUI tools exist that perform most of the tasks described in this section, including:

- MySQL Installer: Used to install and upgrade MySQL products.

- MySQL Workbench: Manages the MySQL server and edits SQL queries.

- MySQL Notifier: Starts, stops, or restarts the MySQL server, and monitors its status.

- MySQL for Excel: Edits MySQL data with Microsoft Excel.

On Windows, you need not create the data directory and the grant tables. MySQL Windows distributions include the grant tables with a set of preinitialized accounts in the `mysql` database under the data directory.

Regarding passwords, if you installed MySQL using the Windows Installation Wizard, you may have already assigned passwords to the accounts. (See Section 2.3.4.1, "Using the MySQL Installation Wizard for Microsoft Windows".) Otherwise, use the password-assignment procedure given in Section 2.12.4, "Securing the Initial MySQL Accounts".

Before assigning passwords, you might want to try running some client programs to make sure that you can connect to the server and that it is operating properly. Make sure that the server is running (see Section 2.3.6.4, "Starting MySQL Server on Microsoft Windows for the First Time"). You can also set up a MySQL service that runs automatically when Windows starts (see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service").

These instructions assume that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

If you installed MySQL using the Windows installation Wizard (see Section 2.3.4.1, "Using the MySQL Installation Wizard for Microsoft Windows"), the default installation directory is `C:\Program Files\MySQL\MySQL Server 5.1`:

```
C:\> cd "C:\Program Files\MySQL\MySQL Server 5.1"
```

A common installation location for installation from a Zip package is `C:\mysql`:

```
C:\> cd C:\mysql
```

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your command interpreter to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Section 2.3.6.6, "Customizing the PATH for MySQL Tools".

With the server running, issue the following commands to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use `mysqlshow` to see what databases exist:

```
C:\> bin\mysqlshow
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| test               |
+--------------------+
```

The list of installed databases may vary, but will always include the minimum of `mysql` and `information_schema`.

The preceding command (and commands for other MySQL programs such as `mysql`) may not work if the correct MySQL account does not exist. For example, the program may fail with an error, or you may not be able to view all databases. If you installed using the MSI packages and used the MySQL Server Instance Config Wizard, then the `root` user will have been created automatically with the password you supplied. In this case, you should use the `-u root` and `-p` options. (You will also need to use the `-u root` and `-p` options if you have already secured the initial MySQL accounts.) With `-p`, you will be prompted for the `root` password. For example:

```
C:\> bin\mysqlshow -u root -p
Enter password: (enter root password here)
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| test               |
+--------------------+
```

If you specify a database name, `mysqlshow` displays a list of the tables within the database:

```
C:\> bin\mysqlshow mysql
Database: mysql
+--------------------------+
|          Tables          |
+--------------------------+
| columns_priv             |
| db                       |
| event                    |
| func                     |
| help_category            |
| help_keyword             |
| help_relation            |
| help_topic               |
| host                     |
| ndb_binlog_index         |
| plugin                   |
| proc                     |
| procs_priv               |
| servers                  |
| tables_priv              |
| time_zone                |
| time_zone_leap_second    |
| time_zone_name           |
| time_zone_transition     |
| time_zone_transition_type |
| user                     |
+--------------------------+
```

Use the `mysql` program to select information from a table in the `mysql` database:

```
C:\> bin\mysql -e "SELECT User, Host FROM mysql.user" mysql
+------+-----------+
| User | Host      |
+------+-----------+
| root | localhost |
+------+-----------+
```

For more information about `mysql` and `mysqlshow`, see Section 4.5.1, "`mysql` — The MySQL Command-Line Tool", and Section 4.5.6, "`mysqlshow` — Display Database, Table, and Column Information".

If you are running a version of Windows that supports services, you can set up the MySQL server to run automatically when Windows starts. See Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

2.3.9 Upgrading MySQL Server on Microsoft Windows

To upgrade MySQL on Windows, follow these steps:

1. Review Section 2.13.1, "Upgrading MySQL", for additional information on upgrading MySQL that is not specific to Windows.

2. Always back up your current MySQL installation before performing an upgrade. See Section 7.2, "Database Backup Methods".

3. Download the latest Windows distribution of MySQL from http://dev.mysql.com/downloads/.

4. Before upgrading MySQL, stop the server. If the server is installed as a service, stop the service with the following command from the command prompt:

```
C:\> NET STOP MySQL
```

   If you are not running the MySQL server as a service, use `mysqladmin` to stop it. For example, before upgrading from MySQL 5.0 to 5.1, use `mysqladmin` from MySQL 5.0 as follows:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.0\bin\mysqladmin" -u root shutdown
```

   Note

   If the MySQL `root` user account has a password, invoke `mysqladmin` with the `-p` option and enter the password when prompted.

5. Before upgrading to MySQL 5.1 from a version previous to 4.1.5, or from a version of MySQL installed from a Zip archive to a version of MySQL installed with the MySQL Installation Wizard, you must first manually remove the previous installation and MySQL service (if the server is installed as a service).

   To remove the MySQL service, use the following command:

```
C:\> C:\mysql\bin\mysqld --remove
```

   Important

   If you do not remove the existing service, the MySQL Installation Wizard may fail to properly install the new MySQL service.

6. When upgrading from MySQL 5.1.23 to MySQL 5.1.24, the change in the default location of the data directory from a directory within the MySQL installation to the `AppData` folder means that you must manually copy the data files from your old installation to the new location.

7. If you are using the MySQL Installation Wizard, start the wizard as described in Section 2.3.4.1, "Using the MySQL Installation Wizard for Microsoft Windows".

8. If you are upgrading MySQL from a Zip archive, extract the archive. You may either overwrite your existing MySQL installation (usually located at `C:\mysql`), or install it into a different directory, such as `C:\mysql5`. Overwriting the existing installation is recommended. However, for upgrades (as opposed to installing for the first time), you must remove the data directory from your existing MySQL installation to avoid replacing your current data files. To do so, follow these steps:

   a. Unzip the Zip archive in some location other than your current MySQL installation

   b. Remove the data directory

   c. Rezip the Zip archive

   d. Unzip the modified Zip archive on top of your existing installation

   Alternatively:

   a. Unzip the Zip archive in some location other than your current MySQL installation

   b. Remove the data directory

   c. Move the data directory from the current MySQL installation to the location of the just-removed data directory

   d. Remove the current MySQL installation

   e. Move the unzipped installation to the location of the just-removed installation

9. If you were running MySQL as a Windows service and you had to remove the service earlier in this procedure, reinstall the service. (See Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".)

10. Restart the server. For example, use `NET START MySQL` if you run MySQL as a service, or invoke `mysqld` directly otherwise.

11. As Administrator, run `mysql_upgrade` to check your tables, attempt to repair them if necessary, and update your grant tables if they have changed so that you can take advantage of any new capabilities. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

12. If you encounter errors, see Section 2.3.7, "Troubleshooting a Microsoft Windows MySQL Server Installation".

2.4 Installing MySQL on OS X

For a list of OS X versions that the MySQL server supports, see http://www.mysql.com/support/supportedplatforms/database.html.

MySQL for OS X is available in a number of different forms:

• Native Package Installer format, which uses the native OS X installer (DMG) to walk you through the installation of MySQL. For more information, see Section 2.4.2, "Installing MySQL on OS X Using Native Packages". You can use the package installer with OS X 10.6 and later, and the package is available for

both 32-bit and 64-bit architectures. The user you use to perform the installation must have administrator privileges.

- Tar package format, which uses a file packaged using the Unix `tar` and `gzip` commands. To use this method, you will need to open a `Terminal` window. You do not need administrator privileges using this method, as you can install the MySQL server anywhere using this method. For more information on using this method, you can use the generic instructions for using a tarball, Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".You can use the package installer with OS X 10.6 and later, and available for both 32-bit and 64-bit architectures.

  In addition to the core installation, the Package Installer also includes Section 2.4.4, "Installing the MySQL Startup Item" and Section 2.4.5, "Installing and Using the MySQL Preference Pane", both of which simplify the management of your installation.

- OS X server includes a version of MySQL as standard. If you want to use a more recent version than that supplied with the OS X server release, you can make use of the package or tar formats. For more information on using the MySQL bundled with OS X, see Section 2.4.6, "Using the Bundled MySQL on OS X Server".

For additional information on using MySQL on OS X, see Section 2.4.1, "General Notes on Installing MySQL on OS X".

2.4.1 General Notes on Installing MySQL on OS X

You should keep the following issues and notes in mind:

- OS X 10.4 deprecated startup items in favor of launchd daemons, and as of OS X 10.10 (Yosemite), startup items do not function. For these reasons, using launchd daemons is preferred over startup items.

- The default location for the MySQL Unix socket is different on OS X and OS X Server depending on the installation type you chose. The following table shows the default locations by installation type.

  Table 2.11 MySQL Unix Socket Locations on OS X by Installation Type

Installation Type	Socket Location
Package Installer from MySQL	`/tmp/mysql.sock`
Tarball from MySQL	`/tmp/mysql.sock`
MySQL Bundled with OS X Server	`/var/mysql/mysql.sock`

  To prevent issues, you should either change the configuration of the socket used within your application (for example, changing `php.ini`), or you should configure the socket location using a MySQL configuration file and the `socket` option. For more information, see Section 5.1.3, "Server Command Options".

- You may need (or want) to create a specific `mysql` user to own the MySQL directory and data. You can do this through the `Directory Utility`, and the `mysql` user should already exist. For use in single user mode, an entry for `_mysql` (note the underscore prefix) should already exist within the system `/etc/passwd` file.

- If you get an "insecure startup item disabled" error when MySQL launches, use the following procedure. Adjust the pathnames appropriately for your system.

  1. Modify the `mysql.script` using this command (enter it on a single line):

     ```
     shell> sudo /Applications/TextEdit.app/Contents/MacOS/TextEdit
     ```

```
/usr/local/mysql/support-files/mysql.server
```

2. Locate the option file that defines the `basedir` value and modify it to contain these lines:

```
basedir=/usr/local/mysql
datadir=/usr/local/mysql/data
```

In the `/Library/StartupItems/MySQLCOM/` directory, make the following group ID changes from `staff` to `wheel`:

```
shell> sudo chgrp wheel MySQLCOM StartupParameters.plist
```

3. Start the server from System Preferences or Terminal.app.

- Because the MySQL package installer installs the MySQL contents into a version and platform specific directory, you can use this to upgrade and migrate your database between versions. You will need to either copy the `data` directory from the old version to the new version, or alternatively specify an alternative `datadir` value to set location of the data directory.

- You might want to add aliases to your shell's resource file to make it easier to access commonly used programs such as `mysql` and `mysqladmin` from the command line. The syntax for `bash` is:

```
alias mysql=/usr/local/mysql/bin/mysql
alias mysqladmin=/usr/local/mysql/bin/mysqladmin
```

For `tcsh`, use:

```
alias mysql /usr/local/mysql/bin/mysql
alias mysqladmin /usr/local/mysql/bin/mysqladmin
```

Even better, add `/usr/local/mysql/bin` to your `PATH` environment variable. You can do this by modifying the appropriate startup file for your shell. For more information, see Section 4.2.1, "Invoking MySQL Programs".

- After you have copied over the MySQL database files from the previous installation and have successfully started the new server, you should consider removing the old installation files to save disk space. Additionally, you should also remove older versions of the Package Receipt directories located in `/Library/Receipts/mysql-VERSION.pkg`.

2.4.2 Installing MySQL on OS X Using Native Packages

The package is located inside a disk image (`.dmg`) file that you first need to mount by double-clicking its icon in the Finder. It should then mount the image and display its contents.

> **Note**
>
> Before proceeding with the installation, be sure to stop all running MySQL server instances by using either the MySQL Manager Application (on OS X Server) or `mysqladmin shutdown` on the command line.

When installing from the package version, you should also install the MySQL Preference Pane, which will enable you to control the startup and execution of your MySQL server from System Preferences. For more information, see Section 2.4.5, "Installing and Using the MySQL Preference Pane".

When installing using the package installer, the files are installed into a directory within `/usr/local` matching the name of the installation version and platform. For example, the installer file

`mysql-5.1-osx10.6-x86_64.dmg` installs MySQL into `/usr/local/mysql-5.1-osx10.6-x86_64/` . The following table shows the layout of the installation directory.

Table 2.12 MySQL Installation Layout on OS X

Directory	Contents of Directory
`bin`, `scripts`	`mysqld` server, client and utility programs
`data`	Log files, databases
`docs`	Helper documents, like the Release Notes and build information
`include`	Include (header) files
`lib`	Libraries
`man`	Unix manual pages
`mysql-test`	MySQL test suite
`share`	Miscellaneous support files, including error messages, sample configuration files, SQL for database installation
`sql-bench`	Benchmarks
`support-files`	Scripts and sample configuration files
`/tmp/mysql.sock`	Location of the MySQL Unix socket

During the package installer process, a symbolic link from `/usr/local/mysql` to the version/platform specific directory created during installation will be created automatically.

1. Download and open the MySQL package installer, which is provided on a disk image (`.dmg`) that includes the main MySQL installation package, the `MySQLStartupItem.pkg` installation package, and the `MySQL.prefPane`. Double-click the disk image to open it.

Figure 2.19 MySQL Package Installer: DMG Contents
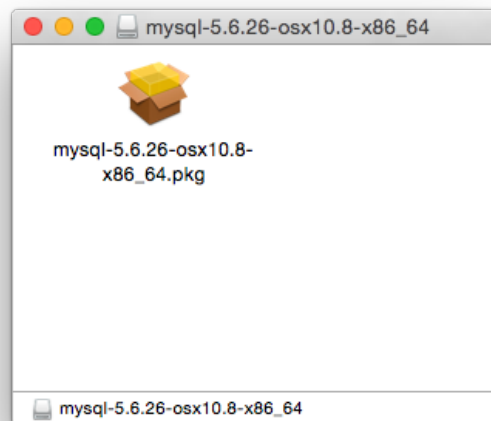
2. Double-click the MySQL installer package. It will be named according to the version of MySQL you have downloaded. For example, if you have downloaded MySQL server 5.1.73, double-click `mysql-5.1.73-osx-10.6-x86_64.pkg`.

3. You will be presented with the opening installer dialog. Click **Continue** to begin installation.

Figure 2.20 MySQL Package Installer: Introduction

4. A copy of the installation instructions and other important information relevant to this installation are displayed. Click **Continue** .

5. If you have downloaded the community version of MySQL, you will be shown a copy of the relevant GNU General Public License. Click **Continue** .

6. Select the drive you want to use to install the MySQL Startup Item. The drive must have a valid, bootable, OS X operating system installed. Click **Continue**.

Figure 2.21 MySQL Package Installer: Choose your Hard drive
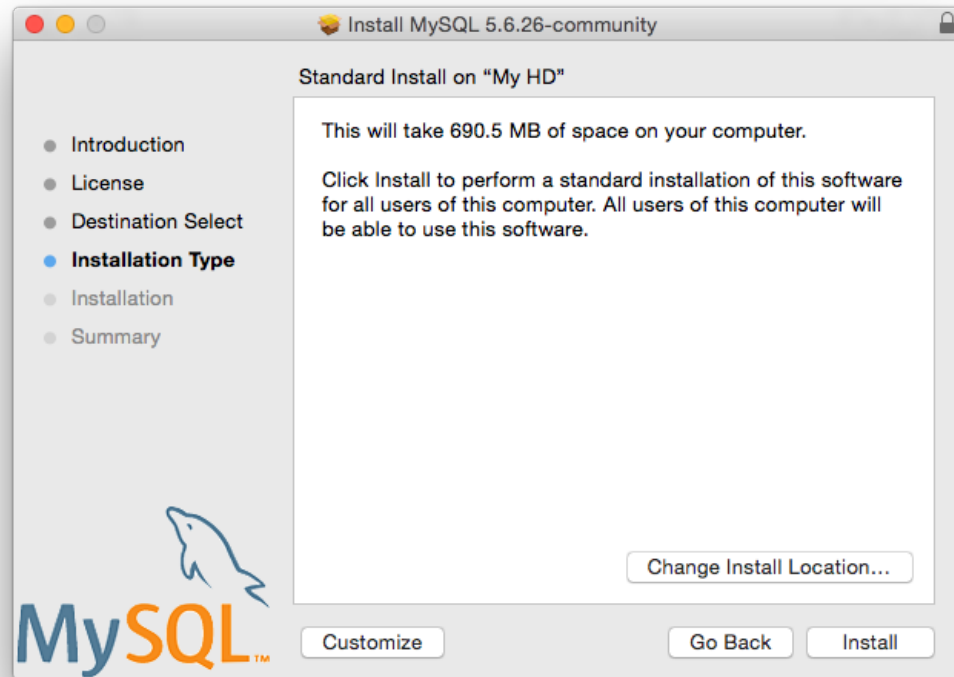
7. You will be asked to confirm the details of the installation, including the space required for the installation. To change the drive on which the MySQL server is installed, click either **Go Back** or **Change Install Location...**. To install the MySQL server, click **Install**.

8. Once the installation has been completed successfully, you will be shown an **Install Succeeded** message.

For convenience, you may also want to install the startup item and preference pane. See Section 2.4.4, "Installing the MySQL Startup Item", and Section 2.4.5, "Installing and Using the MySQL Preference Pane".

2.4.3 Installing a MySQL Launch Daemon

OS X uses launch daemons to automatically start, stop, and manage processes and applications such as MySQL. Using launch daemons is recommended over startup items on OS X.

Note

OS X 10.4 deprecated startup items in favor of launchd daemons, and as of OS X 10.10 (Yosemite), startup items do not function. For these reasons, using launchd daemons is preferred over startup items.

Here is an example **launchd** file that starts MySQL:

```
<?xml version="1.0" encoding="UTF-8"?>
<plist version="1.0">
  <dict>
    <key>KeepAlive</key>
    <true/>
    <key>Label</key>
    <string>com.mysql.mysqld</string>
    <key>ProgramArguments</key>
    <array>
    <string>/usr/local/mysql/bin/mysqld_safe</string>
    <string>--user=mysql</string>
    </array>
  </dict>
</plist>
```

Note

Some users report that adding a plist DOCTYPE declaration causes the launchd operation to fail, despite it passing the lint check. For this reason, we have removed it from the example above.

Adjust the *ProgramArguments* array according to your system, as for example your path to `mysqld_safe` might be different. After making the proper adjustments, do the following:

- Save the XML as a file named `/Library/LaunchDaemons/com.mysql.mysql.plist`

- Adjust the file permissions using the Apple recommended owner "root", owning group "wheel", and file permissions "644"

```
shell> sudo chown root:wheel /Library/LaunchDaemons/com.mysql.mysql.plist
shell> sudo chmod 644 /Library/LaunchDaemons/com.mysql.mysql.plist
```

- Enable this new MySQL service

```
shell> sudo launchctl load -w /Library/LaunchDaemons/com.mysql.mysql.plist
```

The MySQL daemon is now running, and automatically starts when your system is rebooted.

2.4.4 Installing the MySQL Startup Item

The MySQL Installation Package includes a startup item that can be used to automatically start and stop MySQL.

Important

Startup items are deprecated in favor of launchd daemons. For additional information, see Section 2.4.3, "Installing a MySQL Launch Daemon".

To install the MySQL Startup Item:

1. Download and open the MySQL package installer, which is provided on a disk image (`.dmg`) that includes the main MySQL installation package, the `MySQLStartupItem.pkg` installation package, and the `MySQL.prefPane`. Double-click the disk image to open it.

Figure 2.22 MySQL Package Installer: DMG Contents
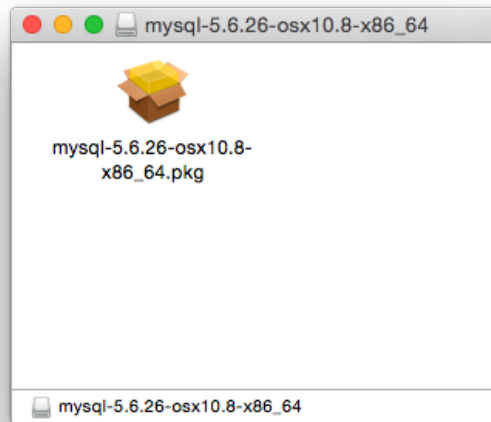
2. Double-click the `MySQLStartItem.pkg` file to start the installation process.

3. You will be presented with the **Install MySQL Startup Item** dialog.

Figure 2.23 MySQL Startup Item Installer: Introduction
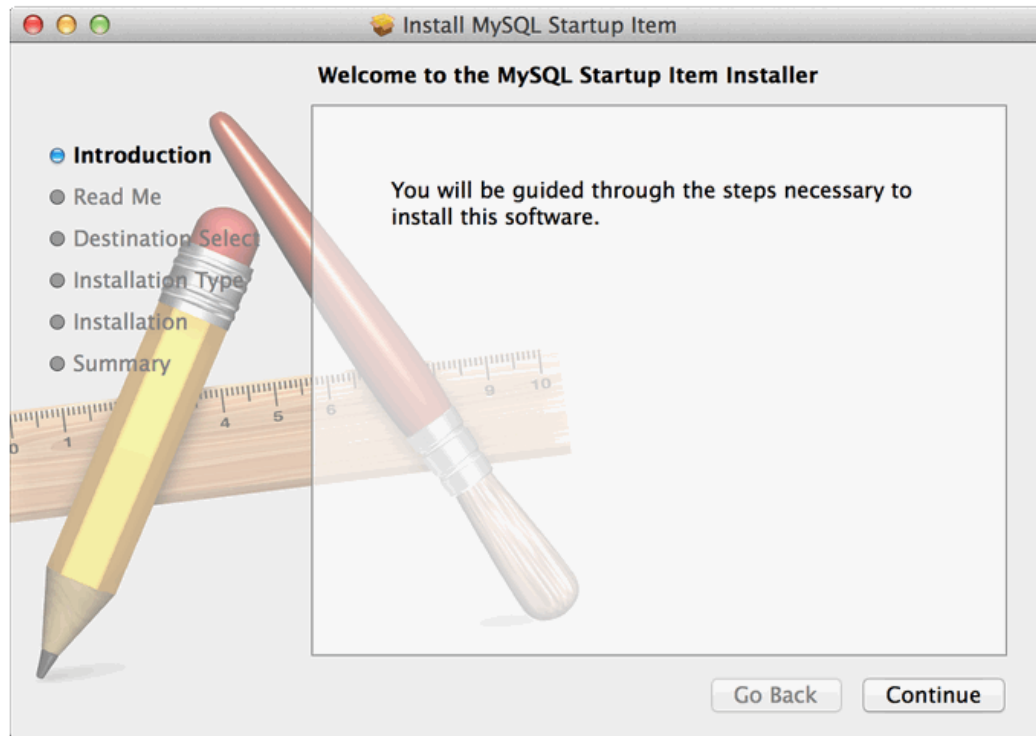
Click **Continue** to continue the installation process.

4. A copy of the installation instructions and other important information relevant to this installation are displayed. Click **Continue** .

5. Select the drive you want to use to install the MySQL Startup Item. The drive must have a valid, bootable, OS X operating system installed. Click **Continue**.

Figure 2.24 MySQL Startup Item Installer: Choose Your Hard drive
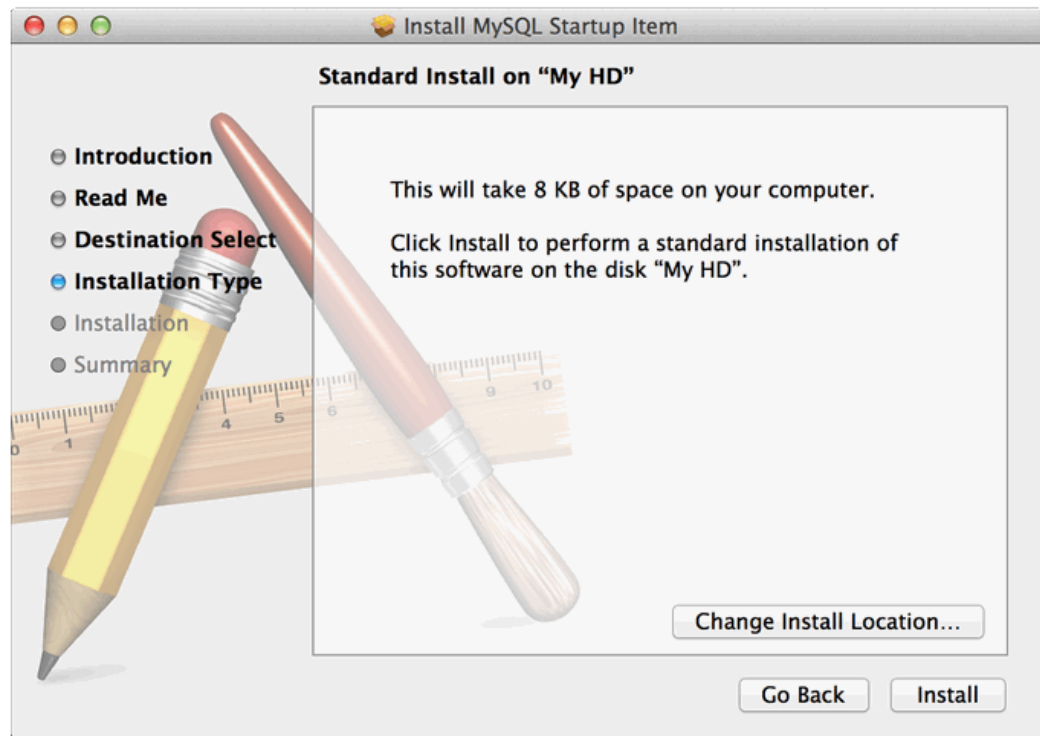
6. You will be asked to confirm the details of the installation. To change the drive on which the startup item is installed, click either **Go Back** or **Change Install Location...**. To install the startup item, click **Install**.

7. Once the installation has been completed successfully, you will be shown an **Install Succeeded** message.

Figure 2.25 MySQL Startup Item Installer: Summary
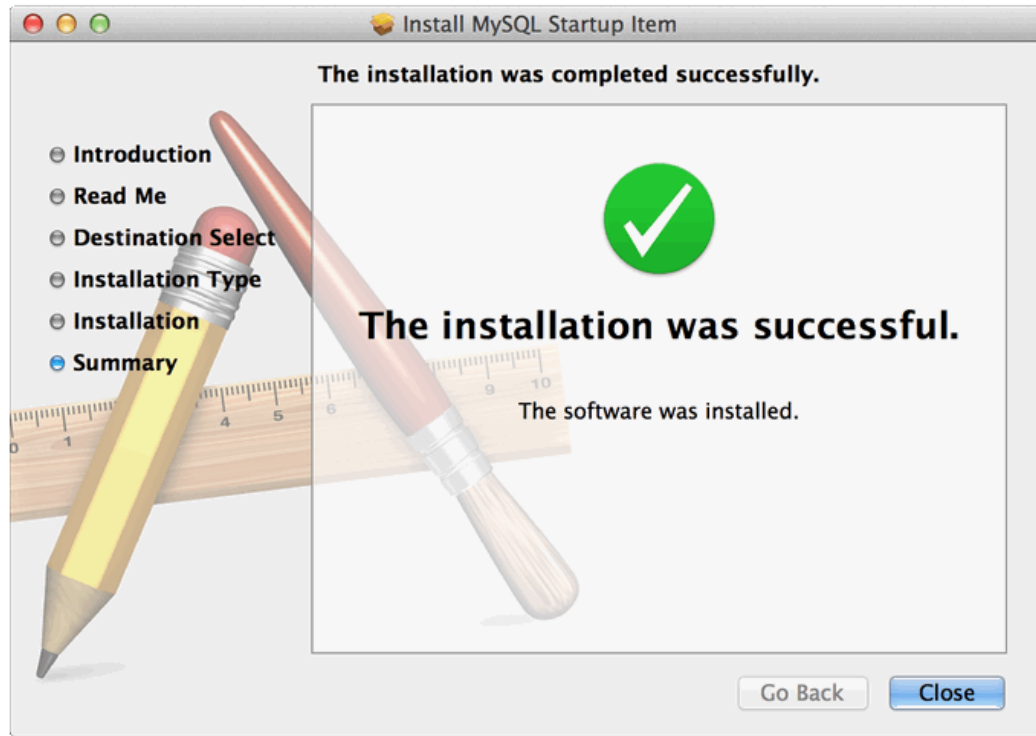
The Startup Item for MySQL is installed into `/Library/StartupItems/MySQLCOM`. The Startup Item installation adds a variable `MYSQLCOM=-YES-` to the system configuration file `/etc/hostconfig`. If you want to disable the automatic startup of MySQL, change this variable to `MYSQLCOM=-NO-`.

> **Note**
>
> Deselecting **Automatically Start MySQL Server on Startup** from the MySQL Preference Pane sets the `MYSQLCOM` variable to **-NO-**.

After the installation, you can start and stop the MySQL server from the MySQL Preference Pane (preferred), or by running the following commands in a terminal window. You must have administrator privileges to perform these tasks, and you may be prompted for your password.

If you have installed the Startup Item, use this command to start the server:

```
shell> sudo /Library/StartupItems/MySQLCOM/MySQLCOM start
```

If you have installed the Startup Item, use this command to stop the server:

```
shell> sudo /Library/StartupItems/MySQLCOM/MySQLCOM stop
```

2.4.5 Installing and Using the MySQL Preference Pane

The MySQL Package installer disk image also includes a custom MySQL Preference Pane that enables you to start, stop, and control automated startup during boot of your MySQL installation.

To install the MySQL Preference Pane:

1. Download and open the MySQL package installer package, which is provided on a disk image (`.dmg`) that includes the main MySQL installation package, the `MySQLStartupItem.pkg` installation package, and the `MySQL.prefPane`. Double-click the disk image to open it.

   Figure 2.26 MySQL Package Installer: DMG Contents

2. Double-click the `MySQL.prefPane`. The MySQL System Preferences will open.

3. If this is the first time you have installed the preference pane, you will be asked to confirm installation and whether you want to install the preference pane for all users, or only the current user. To install the preference pane for all users you will need administrator privileges. If necessary, you will be prompted for the username and password for a user with administrator privileges.

4. If you already have the MySQL Preference Pane installed, you will be asked to confirm whether you want to overwrite the existing MySQL Preference Pane.

   > **Note**
   >
   > The MySQL Preference Pane only starts and stops MySQL installation installed from the MySQL package installation that have been installed in the default location.

Once the MySQL Preference Pane has been installed, you can control your MySQL server instance using the preference pane. To use the preference pane, open the **System Preferences...** from the Apple menu. Select the MySQL preference pane by clicking the MySQL logo within the **Other** section of the preference panes list.

Figure 2.27 MySQL Preference Pane: Location
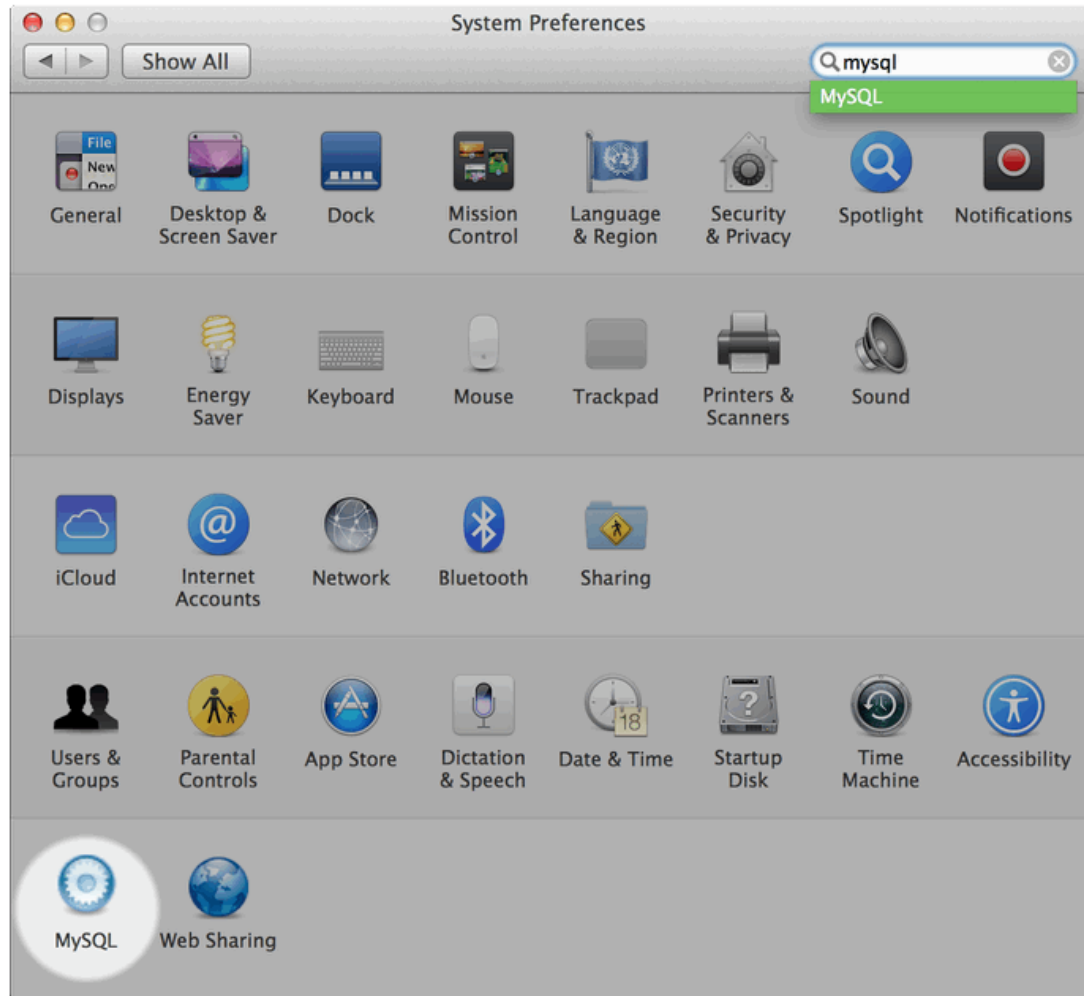
The MySQL Preference Pane shows the current status of the MySQL server, showing **stopped** (in red) if the server is not running and **running** (in green) if the server has already been started. The preference pane also shows the current setting for whether the MySQL server has been set to start automatically.

- **To start the MySQL server using the preference pane:**

  Click **Start MySQL Server**. You may be prompted for the username and password of a user with administrator privileges to start the MySQL server.

- **To stop the MySQL server using the preference pane:**

  Click **Stop MySQL Server**. You may be prompted for the username and password of a user with administrator privileges to stop the MySQL server.

- **To automatically start the MySQL server when the system boots:**

Check the check box next to **Automatically Start MySQL Server on Startup**.

- **To disable automatic MySQL server startup when the system boots:**

Uncheck the check box next to **Automatically Start MySQL Server on Startup**.

You can close the `System Preferences...` window once you have completed your settings.

2.4.6 Using the Bundled MySQL on OS X Server

If you are running OS X Server, a version of MySQL should already be installed. The following table shows the versions of MySQL that ship with OS X Server versions.

Table 2.13 MySQL Versions Preinstalled with OS X Server

OS X Server Version	MySQL Version
10.2-10.2.2	3.23.51
10.2.3-10.2.6	3.23.53
10.3	4.0.14
10.3.2	4.0.16
10.4.0	4.1.10a
10.5.0	5.0.45
10.6.0	5.0.82

The following table shows the installation layout of MySQL on OS X Server.

Table 2.14 MySQL Directory Layout for Preinstalled MySQL Installations on OS X Server

Directory	Contents of Directory
`/usr/bin`	Client programs
`/var/mysql`	Log files, databases
`/usr/libexec`	The `mysqld` server
`/usr/share/man`	Unix manual pages
`/usr/share/mysql/mysql-test`	MySQL test suite
`/usr/share/mysql`	Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation
`/var/mysql/mysql.sock`	Location of the MySQL Unix socket

Additional Resources

- For more information on managing the bundled MySQL instance in OS X Server 10.5, see Mac OS X Server: Web Technologies Administration For Version 10.5 Leopard.

- For more information on managing the bundled MySQL instance in OS X Server 10.6, see Mac OS X Server: Web Technologies Administration Version 10.6 Snow Leopard.

- The MySQL server bundled with OS X Server does not include the MySQL client libraries and header files required to access and use MySQL from a third-party driver, such as Perl DBI or PHP. For more information on obtaining and installing MySQL libraries, see OS X Server version 10.5: MySQL libraries

available for download. Alternatively, you can ignore the bundled MySQL server and install MySQL from the package or tarball installation.

2.5 Installing MySQL on Linux

Linux supports a number of different solutions for installing MySQL. The recommended method is to use one of the distributions from Oracle. If you choose this method, there are several options available:

- Installing from a generic binary package in `.tar.gz` format. See Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries" for more information.

- Extracting and compiling MySQL from a source distribution. For detailed instructions, see Section 2.11, "Installing MySQL from Source".

- Installing using a precompiled RPM package. For more information, see Section 2.5.1, "Installing MySQL on Linux Using RPM Packages".

As an alternative, you can use the native package manager within your Linux distribution to automatically download and install MySQL for you. Native package installations can take care of the download and dependencies required to run MySQL, but the MySQL version will often be some versions behind the currently available release. You will also normally be unable to install development releases, as these are not usually made available in the native repository. For more information on using the native package installers, see Section 2.5.2, "Installing MySQL on Linux Using Native Package Managers".

> **Note**
>
> For many Linux installations, you will want to set up MySQL to be started automatically when your machine starts. Many of the native package installations perform this operation for you, but for source, binary and RPM solutions you may need to set this up separately. The required script, `mysql.server`, can be found in the `support-files` directory under the MySQL installation directory or in a MySQL source tree. You can install it as `/etc/init.d/mysql` for automatic MySQL startup and shutdown. See Section 4.3.3, "`mysql.server` — MySQL Server Startup Script".

2.5.1 Installing MySQL on Linux Using RPM Packages

The recommended way to install MySQL on RPM-based Linux distributions is by using the RPM packages. The RPMs that we provide to the community should work on all versions of Linux that support RPM packages and use `glibc` 2.3. To obtain RPM packages, see Section 2.1.2, "How to Get MySQL".

For non-RPM Linux distributions, you can install MySQL using a `.tar.gz` package. See Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

Installations created from our Linux RPM distributions result in files under the system directories shown in the following table.

Table 2.15 MySQL Installation Layout for Linux RPM Packages

Directory	Contents of Directory
`/usr/bin`	Client programs and scripts
`/usr/sbin`	The `mysqld` server
`/var/lib/mysql`	Log files, databases
`/usr/share/info`	MySQL manual in Info format
`/usr/share/man`	Unix manual pages

Directory	Contents of Directory
`/usr/include/mysql`	Include (header) files
`/usr/lib/mysql`	Libraries
`/usr/share/mysql`	Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation
`/usr/share/sql-bench`	Benchmarks

Note

RPM distributions of MySQL are also provided by other vendors. Be aware that they may differ from those built by Oracle in features, capabilities, and conventions (including communication setup), and that the instructions in this manual do not necessarily apply to installing them. The vendor's instructions should be consulted instead. Because of these differences, RPM packages built by Oracle check whether such RPMs built by other vendors are installed. If so, the RPM does not install and produces a message explaining this.

Conflicts can arise when an RPM from another vendor is already installed, such as when a vendor's conventions about which files belong with the server and which belong with the client library differ from the breakdown used for Oracle packages. In such cases, attempts to install an Oracle RPM with `rpm -i` may result in messages that files in the RPM to be installed conflict with files from an installed package (denoted `mysql-libs` in the following paragraphs).

Each MySQL release provides a `MySQL-shared-compat` package that is meant to replace `mysql-libs` and provides a replacement-compatible client library for older MySQL series. `MySQL-shared-compat` is set up to make `mysql-libs` obsolete, but `rpm` explicitly refuses to replace obsoleted packages when invoked with `-i` (unlike `-U`), which is why installation with `rpm -i` produces a conflict.

`MySQL-shared-compat` can safely be installed alongside `mysql-libs` because libraries are installed to different locations. Therefore, it is possible to install `MySQL-shared-compat` first, then manually remove `mysql-libs` before continuing with the installation. After `mysql-libs` is removed, the dynamic linker stops looking for the client library in the location where `mysql-libs` puts it, and the library provided by the `MySQL-shared-compat` package takes over.

Another alternative is to install packages using `yum`. In a directory containing all RPM packages for a MySQL release, `yum install MySQL*rpm` installs them in the correct order and removes `mysql-libs` in one step without conflicts.

In most cases, you need install only the `MySQL-server` and `MySQL-client` packages to get a functional standard MySQL installation. The other packages are not required for a standard installation.

RPMs for MySQL Cluster. Beginning with MySQL 5.1.24, standard MySQL server RPMs built by MySQL no longer provide support for the `NDBCLUSTER` storage engine. MySQL Cluster users should check the MySQL Cluster Downloads page at http://dev.mysql.com/downloads/cluster/ for RPMs that should work with most Linux distributions for both of these release series.

Important

When upgrading a MySQL Cluster RPM installation, you must upgrade *all* installed RPMs, including the `Server` and `Client` RPMs.

For more information about installing MySQL Cluster from RPMs, see .

For upgrades, if your installation was originally produced by installing multiple RPM packages, it is best to upgrade all the installed packages, not just some. For example, if you previously installed the server and client RPMs, do not upgrade just the server RPM.

The following list shows the available RPM packages. The names shown here use a suffix of `.glibc23.i386.rpm`, but particular packages can have different suffixes, described later.

- `MySQL-server-VERSION.glibc23.i386.rpm`

  The MySQL server. You need this unless you only want to connect to a MySQL server running on another machine.

- `MySQL-client-VERSION.glibc23.i386.rpm`

  The standard MySQL client programs. You probably always want to install this package.

- `MySQL-devel-VERSION.glibc23.i386.rpm`

  The libraries and include files needed to compile other MySQL clients, such as the Perl MySQL module. Install this RPM if you intend to compile C API applications.

- `MySQL-debuginfo-VERSION.glibc23.i386.rpm`

  Debugging information. It is specific to Red Hat Enterprise Linux. `debuginfo` RPMs are never needed to use MySQL software; this is true both for the server and for client programs. However, they contain additional information that might be needed by a debugger to analyze a crash.

- `MySQL-shared-VERSION.glibc23.i386.rpm`

  The shared libraries (`libmysqlclient.so*`) that certain languages and applications need to dynamically load and use MySQL. It contains single-threaded and thread-safe libraries. Install this RPM if you intend to compile or run C API applications that depend on the shared client library. If you install this package, do not install the `MySQL-shared-compat` package.

- `MySQL-shared-compat-VERSION.glibc23.i386.rpm`

  The shared libraries for older releases, up to the current release. It contains single-threaded and thread-safe libraries. Install this package instead of `MySQL-shared` if you have applications installed that are dynamically linked against older versions of MySQL but you want to upgrade to the current version without breaking the library dependencies.

- `MySQL-shared-compat-advanced-gpl-VERSION.glibc23.i386.rpm`, `MySQL-shared-compat-advanced-VERSION.glibc23.i386.rpm`

  These are like the `MySQL-shared-compat` package, but are for the "MySQL Enterprise Server – Advanced Edition" products. Install these packages rather than the normal `MySQL-shared-compat` package if you want to included shared client libraries for older MySQL versions.

- `MySQL-embedded-VERSION.glibc23.i386.rpm`

  The embedded MySQL server library.

- `MySQL-ndb-management-VERSION.glibc23.i386.rpm`, `MySQL-ndb-storage-VERSION.glibc23.i386.rpm`, `MySQL-ndb-tools-VERSION.glibc23.i386.rpm`, `MySQL-ndb-extra-VERSION.glibc23.i386.rpm`

Packages that contain additional files for MySQL Cluster installations.

> **Note**
>
> The `MySQL-ndb-tools` RPM requires a working installation of perl. Prior to MySQL 5.1.18, the `DBI` and `HTML::Template` packages were also required. See Section 2.15, "Perl Installation Notes", and Section 17.4.24, "`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator", for more information.

- `MySQL-test-VERSION.glibc23.i386.rpm`

  The MySQL test suite.

- `MySQL-VERSION.src.rpm`

  The source code for all of the previous packages. It can also be used to rebuild the RPMs on other architectures (for example, SPARC).

In RPM package names, the suffix (following the `VERSION` value) has the following syntax:

```
.PLATFORM.CPU.rpm
```

The `PLATFORM` and `CPU` values indicate the type of system for which the package is built. `PLATFORM` indicates the platform and `CPU` indicates the processor type or family.

All packages are dynamically linked against `glibc` 2.3. The `PLATFORM` value indicates whether the package is platform independent or intended for a specific platform, as shown in the following table.

Table 2.16 MySQL Linux RPM Package Platforms

`PLATFORM` Value	Intended Use
`glibc23`	Platform independent, should run on any Linux distribution that supports `glibc` 2.3
`rhel4`, `rhel5`	Red Hat Enterprise Linux 4 or 5
`sles10`, `sles11`	SuSE Linux Enterprise Server 10 or 11

In MySQL 5.1, only `glibc23` packages are available currently.

The `CPU` value indicates the processor type or family for which the package is built, as shown in the following table.

Table 2.17 MySQL Linux RPM Package CPU Identifiers

`CPU` Value	Intended Processor Type or Family
`i386`, `i586`, `i686`	Pentium processor or better, 32 bit
`x86_64`	64-bit x86 processor
`ia64`	Itanium (IA-64) processor

To see all files in an RPM package (for example, a `MySQL-server` RPM), run a command like this (modify the platform and CPU identifiers appropriately for your system):

```
shell> rpm -qpl MySQL-server-VERSION.glibc23.i386.rpm
```

To perform a standard minimal installation, install the server and client RPMs:

```
shell> rpm -i MySQL-server-VERSION.glibc23.i386.rpm
shell> rpm -i MySQL-client-VERSION.glibc23.i386.rpm
```

To install only the client programs, install just the client RPM:

```
shell> rpm -i MySQL-client-VERSION.glibc23.i386.rpm
```

RPM provides a feature to verify the integrity and authenticity of packages before installing them. To learn more about this feature, see Section 2.1.3, "Verifying Package Integrity Using MD5 Checksums or GnuPG".

The server RPM places data under the /var/lib/mysql directory. The RPM also creates a login account for a user named mysql (if one does not exist) to use for running the MySQL server, and creates the appropriate entries in /etc/init.d/ to start the server automatically at boot time. (This means that if you have performed a previous installation and have made changes to its startup script, you may want to make a copy of the script so that you can reinstall it after you install a newer RPM.) See Section 2.12.5, "Starting and Stopping MySQL Automatically", for more information on how MySQL can be started automatically at system startup.

In MySQL 5.1.49 and later, during an upgrade installation using RPM packages, if the MySQL server is running when the upgrade occurs, the MySQL server is stopped, the upgrade occurs, and the MySQL server is restarted. If the MySQL server is not already running when the RPM upgrade occurs, the MySQL server is not started at the end of the installation.

If something goes wrong, you can find more information in the binary installation section. See Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

> **Note**
>
> The accounts created in the MySQL grant tables for an RPM installation initially have no passwords. After starting the server, you should assign passwords to them using the instructions in Section 2.12, "Postinstallation Setup and Testing".

An RPM installation creates a user named mysql and a group named mysql on the system using the useradd, groupadd, and usermod commands. Those commands require appropriate administrative privileges, which is required for locally managed users and groups (as listed in the /etc/passwd and /etc/group files) by the RPM installation process being run by root.

If you log in as the mysql user, you may find that MySQL displays "Invalid (old?) table or database name" errors that mention .mysqlgui, lost+found, .mysqlgui, .bash_history, .fonts.cache-1, .lesshst, .mysql_history, .profile, .viminfo, and similar files created by MySQL or operating system utilities. You can safely ignore these error messages or remove the files or directories that cause them if you do not need them.

For nonlocal user management (LDAP, NIS, and so forth), the administrative tools may require additional authentication (such as a password), and will fail if the installing user does not provide this authentication. Even if they fail, the RPM installation will not abort but succeed, and this is intentional. If they failed, some of the intended transfer of ownership may be missing, and it is recommended that the system administrator then manually ensures some appropriate user and group exists and manually transfers ownership following the actions in the RPM spec file.

2.5.2 Installing MySQL on Linux Using Native Package Managers

Many Linux distributions include a version of the MySQL server, client tools, and development components into the standard package management system built into distributions such as Fedora, Debian, and Ubuntu. This section provides basic instructions for installing MySQL using these systems.

⚠️ **Important**

Native package installations can take care of the download and dependencies required to run MySQL, but the MySQL version will often be some way behind the currently available release. You will also normally be unable to install development releases, as these are not usually made available in the native repository.

Distribution specific instructions are shown below:

• **Red Hat Linux, Fedora, CentOS**

For Red Hat and similar distributions, the MySQL distribution is divided into a number of separate packages, `mysql` for the client tools, `mysql-server` for the server and associated tools, and `mysql-libs` for the libraries. The libraries are required if you want to provide connectivity from different languages and environments such as Perl, Python and others.

To install, use the `yum` command to specify the packages that you want to install. For example:

```
root-shell> yum install mysql mysql-server mysql-libs mysql-server
Loaded plugins: presto, refresh-packagekit
Setting up Install Process
Resolving Dependencies
--> Running transaction check
---> Package mysql.x86_64 0:5.1.48-2.fc13 set to be updated
---> Package mysql-libs.x86_64 0:5.1.48-2.fc13 set to be updated
---> Package mysql-server.x86_64 0:5.1.48-2.fc13 set to be updated
--> Processing Dependency: perl-DBD-MySQL for package: mysql-server-5.1.48-2.fc13.x86_64
--> Running transaction check
---> Package perl-DBD-MySQL.x86_64 0:4.017-1.fc13 set to be updated
--> Finished Dependency Resolution

Dependencies Resolved

================================================================================
 Package                 Arch            Version                 Repository       Size
================================================================================
Installing:
 mysql                   x86_64          5.1.48-2.fc13           updates          889 k
 mysql-libs              x86_64          5.1.48-2.fc13           updates          1.2 M
 mysql-server            x86_64          5.1.48-2.fc13           updates          8.1 M
Installing for dependencies:
 perl-DBD-MySQL          x86_64          4.017-1.fc13            updates          136 k

Transaction Summary
================================================================================
Install       4 Package(s)
Upgrade       0 Package(s)

Total download size: 10 M
Installed size: 30 M
Is this ok [y/N]: y
Downloading Packages:
Setting up and reading Presto delta metadata
Processing delta metadata
Package(s) data still to download: 10 M
(1/4): mysql-5.1.48-2.fc13.x86_64.rpm                          | 889 kB     00:04
(2/4): mysql-libs-5.1.48-2.fc13.x86_64.rpm                     | 1.2 MB     00:06
(3/4): mysql-server-5.1.48-2.fc13.x86_64.rpm                   | 8.1 MB     00:40
(4/4): perl-DBD-MySQL-4.017-1.fc13.x86_64.rpm                  | 136 kB     00:00
--------------------------------------------------------------------------------
Total                                         201 kB/s |  10 MB     00:52
Running rpm_check_debug
Running Transaction Test
```

```
Transaction Test Succeeded
Running Transaction
  Installing     : mysql-libs-5.1.48-2.fc13.x86_64                          1/4
  Installing     : mysql-5.1.48-2.fc13.x86_64                               2/4
  Installing     : perl-DBD-MySQL-4.017-1.fc13.x86_64                       3/4
  Installing     : mysql-server-5.1.48-2.fc13.x86_64                        4/4

Installed:
  mysql.x86_64 0:5.1.48-2.fc13             mysql-libs.x86_64 0:5.1.48-2.fc13
  mysql-server.x86_64 0:5.1.48-2.fc13

Dependency Installed:
  perl-DBD-MySQL.x86_64 0:4.017-1.fc13

Complete!
```

MySQL and the MySQL server should now be installed. A sample configuration file is installed into `/etc/my.cnf`. An init script, to start and stop the server, will have been installed into `/etc/init.d/mysqld`. To start the MySQL server use `service`:

```
root-shell> service mysqld start
```

To enable the server to be started and stopped automatically during boot, use `chkconfig`:

```
root-shell> chkconfig --levels 235 mysqld on
```

Which enables the MySQL server to be started (and stopped) automatically at the specified the run levels.

The database tables will have been automatically created for you, if they do not already exist. You should, however, run `mysql_secure_installation` to set the root passwords on your server.

- **Debian, Ubuntu, Kubuntu**

  On Debian and related distributions, there are two packages, `mysql-client` and `mysql-server`, for the client and server components respectively. You should specify an explicit version, for example `mysql-client-5.1`, to ensure that you install the version of MySQL that you want.

  To download and install, including any dependencies, use the `apt-get` command, specifying the packages that you want to install.

  > **Note**
  >
  > Before installing, make sure that you update your `apt-get` index files to ensure you are downloading the latest available version.

  A sample installation of the MySQL packages might look like this (some sections trimmed for clarity):

  ```
  root-shell> apt-get install mysql-client-5.1 mysql-server-5.1
  Reading package lists... Done
  Building dependency tree
  Reading state information... Done
  The following packages were automatically installed and are no longer required:
    linux-headers-2.6.28-11 linux-headers-2.6.28-11-generic
  Use 'apt-get autoremove' to remove them.
  The following extra packages will be installed:
    bsd-mailx libdbd-mysql-perl libdbi-perl libhtml-template-perl
    libmysqlclient15off libmysqlclient16 libnet-daemon-perl libplrpc-perl mailx
    mysql-common postfix
  ```

```
Suggested packages:
  dbishell libipc-sharedcache-perl tinyca procmail postfix-mysql postfix-pgsql
  postfix-ldap postfix-pcre sasl2-bin resolvconf postfix-cdb
The following NEW packages will be installed
  bsd-mailx libdbd-mysql-perl libdbi-perl libhtml-template-perl
  libmysqlclient15off libmysqlclient16 libnet-daemon-perl libplrpc-perl mailx
  mysql-client-5.1 mysql-common mysql-server-5.1 postfix
0 upgraded, 13 newly installed, 0 to remove and 182 not upgraded.
Need to get 1907kB/25.3MB of archives.
After this operation, 59.5MB of additional disk space will be used.
Do you want to continue [Y/n]? Y
Get: 1 http://gb.archive.ubuntu.com jaunty-updates/main mysql-common 5.1.30really5.0.75-0ubuntu10.5 [63.
Get: 2 http://gb.archive.ubuntu.com jaunty-updates/main libmysqlclient15off 5.1.30really5.0.75-0ubuntu10
Fetched 1907kB in 9s (205kB/s)
Preconfiguring packages ...
Selecting previously deselected package mysql-common.
(Reading database ... 121260 files and directories currently installed.)
...
Processing 1 added doc-base file(s)...
Registering documents with scrollkeeper...
Setting up libnet-daemon-perl (0.43-1) ...
Setting up libplrpc-perl (0.2020-1) ...
Setting up libdbi-perl (1.607-1) ...
Setting up libmysqlclient15off (5.1.30really5.0.75-0ubuntu10.5) ...

Setting up libdbd-mysql-perl (4.008-1) ...
Setting up libmysqlclient16 (5.1.31-1ubuntu2) ...

Setting up mysql-client-5.1 (5.1.31-1ubuntu2) ...

Setting up mysql-server-5.1 (5.1.31-1ubuntu2) ...
 * Stopping MySQL database server mysqld
   ...done.
100825 11:46:15  InnoDB: Started; log sequence number 0 46409
100825 11:46:15  InnoDB: Starting shutdown...
100825 11:46:17  InnoDB: Shutdown completed; log sequence number 0 46409
100825 11:46:17 [Warning] Forcing shutdown of 1 plugins
 * Starting MySQL database server mysqld
   ...done.
 * Checking for corrupt, not cleanly closed and upgrade needing tables.
...
Processing triggers for libc6 ...
ldconfig deferred processing now taking place
```

Note

The `apt-get` command will install a number of packages, including the MySQL server, in order to provide the typical tools and application environment. This can mean that you install a large number of packages in addition to the main MySQL package.

During installation, the initial database will be created, and you will be prompted for the MySQL root password (and confirmation). A configuration file will have been created in `/etc/mysql/my.cnf`. An init script will have been created in `/etc/init.d/mysql`.

The server will already be started. You can manually start and stop the server using:

```
root-shell> service mysql [start|stop]
```

The service will automatically be added to the 2, 3 and 4 run levels, with stop scripts in the single, shutdown and restart levels.

2.6 Installing MySQL on Solaris and OpenSolaris

MySQL on Solaris and OpenSolaris is available in a number of different formats.

- For information on installing using the native Solaris PKG format, see Section 2.6.1, "Installing MySQL on Solaris Using a Solaris PKG".

- On OpenSolaris, the standard package repositories include MySQL packages specially built for OpenSolaris that include entries for the Service Management Framework (SMF) to enable control of the installation using the SMF administration commands. For more information, see Section 2.6.2, "Installing MySQL on OpenSolaris Using IPS".

- To use a standard `tar` binary installation, use the notes provided in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries". Check the notes and hints at the end of this section for Solaris specific notes that you may need before or after installation.

- For information on installing MySQL on Solaris or OpenSolaris using a source distribution, first check the Solaris advice, Section 2.11.8, "Notes on Installing MySQL on Solaris from Source". For detailed instructions on installing from source, see Section 2.11, "Installing MySQL from Source".

To obtain a binary MySQL distribution for Solaris in tarball or PKG format, http://dev.mysql.com/downloads/mysql/5.1.html.

Additional notes to be aware of when installing and using MySQL on Solaris:

- If you want to use MySQL with the `mysql` user and group, use the `groupadd` and `useradd` commands:

```
groupadd mysql
useradd -g mysql -s /bin/false mysql
```

- If you install MySQL using a binary tarball distribution on Solaris, you may run into trouble even before you get the MySQL distribution unpacked, as the Solaris `tar` cannot handle long file names. This means that you may see errors when you try to unpack MySQL.

  If this occurs, you must use GNU `tar` (`gtar`) to unpack the distribution. In Solaris 10 and OpenSolaris `gtar` is normally located in `/usr/sfw/bin/gtar`, but may not be included in the default path definition.

- When using Solaris 10 for x86_64, you should mount any file systems on which you intend to store `InnoDB` files with the `forcedirectio` option. (By default mounting is done without this option.) Failing to do so will cause a significant drop in performance when using the `InnoDB` storage engine on this platform.

- If you would like MySQL to start automatically, you can copy `support-files/mysql.server` to `/etc/init.d` and create a symbolic link to it named `/etc/rc3.d/S99mysql.server`.

- If too many processes try to connect very rapidly to `mysqld`, you should see this error in the MySQL log:

```
Error in accept: Protocol error
```

  You might try starting the server with the `--back_log=50` option as a workaround for this.

- To configure the generation of core files on Solaris you should use the `coreadm` command. Because of the security implications of generating a core on a `setuid()` application, by default, Solaris does not support core files on `setuid()` programs. However, you can modify this behavior using `coreadm`.

If you enable `setuid()` core files for the current user, they will be generated using the mode 600 and owned by the superuser.

2.6.1 Installing MySQL on Solaris Using a Solaris PKG

You can install MySQL on Solaris and OpenSolaris using a binary package using the native Solaris PKG format instead of the binary tarball distribution.

To use this package, download the corresponding `mysql-VERSION-solaris10-PLATFORM.pkg.gz` file, then uncompress it. For example:

```
shell> gunzip mysql-5.1.73-solaris10-x86_64.pkg.gz
```

To install a new package, use `pkgadd` and follow the onscreen prompts. You must have root privileges to perform this operation:

```
shell> pkgadd -d mysql-5.1.73-solaris10-x86_64.pkg

The following packages are available:
  1  mysql     MySQL Community Server (GPL)
               (i86pc) 5.1.73

Select package(s) you wish to process (or 'all' to process
all packages). (default: all) [?,??,q]:
```

The PKG installer installs all of the files and tools needed, and then initializes your database if one does not exist. To complete the installation, you should set the root password for MySQL as provided in the instructions at the end of the installation. Alternatively, you can run the `mysql_secure_installation` script that comes with the installation.

By default, the PKG package installs MySQL under the root path `/opt/mysql`. You can change only the installation root path when using `pkgadd`, which can be used to install MySQL in a different Solaris zone. If you need to install in a specific directory, use a binary `tar` file distribution.

The `pkg` installer copies a suitable startup script for MySQL into `/etc/init.d/mysql`. To enable MySQL to startup and shutdown automatically, you should create a link between this file and the init script directories. For example, to ensure safe startup and shutdown of MySQL you could use the following commands to add the right links:

```
shell> ln /etc/init.d/mysql /etc/rc3.d/S91mysql
shell> ln /etc/init.d/mysql /etc/rc0.d/K02mysql
```

To remove MySQL, the installed package name is `mysql`. You can use this in combination with the `pkgrm` command to remove the installation.

To upgrade when using the Solaris package file format, you must remove the existing installation before installing the updated package. Removal of the package does not delete the existing database information, only the server, binaries and support files. The typical upgrade sequence is therefore:

```
shell> mysqladmin shutdown
shell> pkgrm mysql
shell> pkgadd -d mysql-5.1.73-solaris10-x86_64.pkg
shell> mysqld_safe &
shell> mysql_upgrade
```

You should check the notes in Section 2.13, "Upgrading or Downgrading MySQL" before performing any upgrade.

2.6.2 Installing MySQL on OpenSolaris Using IPS

OpenSolaris includes standard packages for MySQL in the core repository. The MySQL packages are based on a specific release of MySQL and updated periodically. For the latest release you must use either the native Solaris PKG, `tar`, or source installations. The native OpenSolaris packages include SMF files so that you can easily control your MySQL installation, including automatic startup and recovery, using the native service management tools.

To install MySQL on OpenSolaris, use the `pkg` command. You will need to be logged in as root, or use the `pfexec` tool, as shown in the example below:

```
shell> pfexec pkg install SUNWmysql51
```

The package set installs three individual packages, `SUNWmysql51lib`, which contains the MySQL client libraries; `SUNWmysql51r` which contains the root components, including SMF and configuration files; and `SUNWmysql51u` which contains the scripts, binary tools and other files. You can install these packages individually if you only need the corresponding components.

The MySQL files are installed into `/usr/mysql` which symbolic links for the sub directories (`bin`, `lib`, etc.) to a version specific directory. For MySQL 5.1, the full installation is located in `/usr/mysql/5.1`. The default data directory is `/var/mysql/5.1/data`. The configuration file is installed in `/etc/mysql/5.1/my.cnf`. This layout permits multiple versions of MySQL to be installed, without overwriting the data and binaries from other versions.

Once installed, you must initialize the data directory (see Section 2.12.1, "Initializing the Data Directory"), and use the `mysql_secure_installation` to secure your installation.

Using SMF to manage your MySQL installation

Once installed, you can start and stop your MySQL server using the installed SMF configuration. The service name is `mysql`, or if you have multiple versions installed, you should use the full version name, for example `mysql:version_51`. To start and enable MySQL to be started at boot time:

```
shell> svcadm enable mysql
```

To disable MySQL from starting during boot time, and shut the MySQL server down if it is running, use:

```
shell> svcadm disable mysql
```

To restart MySQL, for example after a configuration file changes, use the `restart` option:

```
shell> svcadm restart mysql
```

You can also use SMF to configure the data directory and enable full 64-bit mode. For example, to set the data directory used by MySQL:

```
shell> svccfg
svc:> select mysql:version_51
svc:/application/database/mysql:version_51> setprop mysql/data=/data0/mysql
```

By default, the 32-bit binaries are used. To enable the 64-bit server on 64-bit platforms, set the `enable_64bit` parameter. For example:

```
svc:/application/database/mysql:version_51> setprop mysql/enable_64bit=1
```

You need to refresh the SMF after settings these options:

```
shell> svcadm refresh mysql
```

2.7 Installing MySQL on IBM AIX

MySQL for IBM AIX is available in a number of different forms:

- Using a binary tarball distribution provided at http://dev.mysql.com/downloads/. Please read the general notes on AIX installation before continuing. For more information on binary installations, see Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

- Using a source tarball and compiling MySQL. Please read the general notes on AIX installation before continuing. You should also check the instructions on building on AIX from source. For general information on building from source, see Section 2.11, "Installing MySQL from Source".

2.7.1 General Notes on Installing MySQL on AIX

General notes on using MySQL on IBM AIX:

- If you have problems with threads on AIX 5.3, you should upgrade AIX 5.3 to technology level 7 (5300-07).

2.8 Installing MySQL on HP-UX

MySQL for HP-UX is available in a number of different forms:

- Using a DEPOT distribution provided at http://dev.mysql.com/downloads/. Please read the general notes on HP-UX installation before continuing. For more information on DEPOT installations, see Section 2.8.2, "Installing MySQL on HP-UX Using DEPOT Packages".

- Using a binary tarball distribution provided at http://dev.mysql.com/downloads/. Please read the general notes on HP-UX installation before continuing. For more information on binary installations, see Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

- Using a source tarball and compiling MySQL. Please read the general notes on HP-UX installation before continuing. You should also check the instructions on building on HP-UX from source. For general information on building from source, see Section 2.11, "Installing MySQL from Source".

2.8.1 General Notes on Installing MySQL on HP-UX

Some additional notes on installing and using MySQL on HP-UX:

- If you install MySQL using a binary tarball distribution on HP-UX, you may run into trouble even before you get the MySQL distribution unpacked, as the HP-UX `tar` cannot handle long file names. This means that you may see errors when you try to unpack MySQL.

  If this occurs, you must use GNU `tar` (`gtar`) to unpack the distribution.

- Because of some critical bugs in the standard HP-UX libraries, you should install the following patches before trying to run MySQL on HP-UX 11.0:

  ```
  PHKL_22840 Streams cumulative
  PHNE_22397 ARPA cumulative
  ```

  This solves the problem of getting `EWOULDBLOCK` from `recv()` and `EBADF` from `accept()` in threaded applications.

2.8.2 Installing MySQL on HP-UX Using DEPOT Packages

The HP-UX DEPOT format packages can be installed using the `swinstall` command. You should install the `ncurses` and `zlib` libraries before installing the MySQL DEPOT package. You can use the free software `depothelper` tool to install these packages and any dependencies for you automatically.

To install using the MySQL DEPOT packages, follow this guide:

1. Download the MySQL DEPOT package from http://dev.mysql.com/downloads/. You must uncompress the package before installation:

   ```
   root-shell> gunzip mysql-5.1.48-hpux11.31-ia64-64bit.depot.gz
   ```

2. Install the DEPOT package using `swinstall`:

   ```
   root-shell> swinstall -s mysql-5.1.49-hpux11.31-ia64-64bit.depot
   ```

   MySQL will be installed into a directory matching the depot package name, within `/usr/local`. For convenience, you may want to create a symbolic link to the installed directory, for example:

   ```
   root-shell> ln -s mysql-5.1.49-hpux11.31-ia64-64bit mysql
   ```

3. Your package is now installed. You should complete the configuration of MySQL by creating a user and group:

   ```
   root-shell> /usr/sbin/groupadd mysql
   root-shell> /usr/sbin/useradd -g mysql -d /var/lib/mysql/ -s /bin/false mysql
   ```

4. Create the standard database using the new user/group you have created, and set the permissions:

   ```
   root-shell> cd /usr/local/
   root-shell> scripts/mysql_install_db --user=mysql
   root-shell> chown -R root .
   root-shell> chown -R mysql data
   ```

5. Finally, secure your new installation by setting the root passwords, and then start your MySQL server using the `mysql` user:

   ```
   root-shell> mysql_secure_installation
   root-shell> mysqld_safe --user=mysql &
   ```

2.9 Installing MySQL on FreeBSD

This section provides information about installing MySQL on variants of FreeBSD Unix.

You can install MySQL on FreeBSD by using the binary distribution provided by Oracle. For more information, see Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

The easiest (and preferred) way to install MySQL is to use the `mysql-server` and `mysql-client` ports available at http://www.freebsd.org/. Using these ports gives you the following benefits:

- A working MySQL with all optimizations enabled that are known to work on your version of FreeBSD.

- Automatic configuration and build.

- Startup scripts installed in `/usr/local/etc/rc.d`.

- The ability to use `pkg_info -L` to see which files are installed.

- The ability to use `pkg_delete` to remove MySQL if you no longer want it on your machine.

The MySQL build process requires GNU make (`gmake`) to work. If GNU `make` is not available, you must install it first before compiling MySQL.

To install using the ports system:

```
# cd /usr/ports/databases/mysql51-server
# make
...
# cd /usr/ports/databases/mysql51-client
# make
...
```

The standard port installation places the server into `/usr/local/libexec/mysqld`, with the startup script for the MySQL server placed in `/usr/local/etc/rc.d/mysql-server`.

Some additional notes on the BSD implementation:

- To remove MySQL after installation using the ports system:

```
# cd /usr/ports/databases/mysql51-server
# make deinstall
...
# cd /usr/ports/databases/mysql51-client
# make deinstall
...
```

- If you get problems with the current date in MySQL, setting the `TZ` variable should help. See Section 2.14, "Environment Variables".

2.10 Installing MySQL on i5/OS

The i5/OS POWER MySQL package was created in cooperation with IBM. MySQL works within the Portable Application Solution Environment (PASE) on the System i series of hardware and will also provide database services for the Zend Core for i5/OS.

MySQL for i5/OS is provided both as a `tar` file and as a save file (`.savf`) package that can be downloaded and installed directly without any additional installation steps required. To install MySQL using the `tar` file, see Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

MySQL is only supported on i5/OS V5R4 or later releases. The i5/OS PASE must be installed for MySQL to operate. You must be able to login as a user in `*SECOFR` class.

You should the installation notes and tips for i5/OS before starting installation. See i5/OS Installation Notes.

Before Installation:

Note

The installation package will use an existing configuration if you have previously installed MySQL (which is identified by looking for the file `/etc/my.cnf`). The values for the data directory (`DATADIR`) and owner of the MySQL files (`USRPRF`)

> specified during the installation will be ignored, and the values determined from the `/etc/my.cnf` will be used instead.
>
> If you want to change these parameters during a new install, you should temporarily rename `/etc/my.cnf`, install MySQL using the new parameters you want to use, and then merge your previous `/etc/my.cnf` configuration settings with the new `/etc/my.cnf` file that is created during installation.

- You must have a user profile with PASE with suitable privileges. The user should be within the `*SECOFR` class, such as the `QSECOFR` user ID. You can use the `WRKUSRPRF` command to check your user profile.

- For network connections to MySQL, you must have TCP/IP enabled. You should also check the following:

  - Ensure that a name has defined for the system. Run the Configure TCP/IP (`CFGTCP`) command and select option 12 (Change TCP/IP domain information) to display this setting. Make sure that a value is listed in the Host name field.

  - Make sure that the system has a loopback entry which represents the `localhost` or `127.0.0.1`.

  - Ensure that the IP address of the IBM i machine is mapped correctly to the host name.

To install MySQL on i5/OS, follow these steps:

1. On the System i machine, create a save file that will be used to receive the downloaded installation save file. The file should be located within the General Purpose Library (`QGPL`):

   ```
   CRTSAVF FILE(QGPL/MYSQLINST) TESXT('MySQL Save file')
   ```

2. Download the MySQL installation save file in 32-bit (`mysql-5.1.73-i5os-power-32bit.savf`) or 64-bit (`mysql-5.1.73-i5os-power-64bit.savf`) from MySQL Downloads.

3. You need to FTP the downloaded `.savf` file directly into the `QGPL/MYSQLINST` file on the System i server. You can do this through FTP using the following steps after logging in to the System i machine:

   ```
   ftp> bin
   ftp> cd qgpl
   ftp> put mysql-5.1.73-i5os-power.savf mysqlinst
   ```

4. Log into the System i server using a user in the `*SECOFR` class, such as the `QSECOFR` user ID.

5. You need to restore the installation library stored in the `.savf` save file:

   ```
   RSTLIB MYSQLINST DEV(*SAVF) SAVF(QGPL/MYSQLINST) MBROPT(*ALL) ALWOBJDIF(*ALL)
   ```

   > **Note**
   >
   > You can ignore the security changes-type message at the bottom of the installation panel.

6. Once you have finished restoring the `MYSQLINST` library, check that all the necessary objects for installation are on the system by using the Display Library (`DSPLIB`) command:

   ```
   DSPLIB LIB(MYSQLINST)
   ```

7. You need to execute the installation command, `MYSQLINST/INSMYSQL`. You can specify three parameter settings during installation:

   - `DIR('/QOpenSys/usr/local/mysql')` sets the installation location for the MySQL files. The directory will be created if it does not already exist.

- `DATADIR('/QOpenSys/usr/local/mysql/data')` sets the location of the directory that will be used to store the database files and binary logs. The default setting is `/QOpenSys/usr/local/mysql/data`. Note that if the installer detects an existing installation (due to the existence of `/etc/my.cnf`), then the existing setting will be used instead of the default.

- `USRPRF(MYSQL)` sets the user profile that will own the files that are installed. The profile will be created if it does not already exist.

  Note

  You should choose an appropriate user for using the MySQL server installation. The user will be used whenever you need to do any administration on the MySQL server.

Once you have set the appropriate parameters, you can begin the installation.

The installation copies all the necessary files into a directory matching the `DIR` configuration value; sets the ownership on those files, sets up the MySQL environment and creates the MySQL configuration file (in `/etc/my.cnf`) completing all the steps in a typical binary installation process automatically. If this is a new installation of MySQL, or if the installer detects that this is a new version (because the `/etc/my.cnf` file does not exist), then the initial core MySQL databases will also be created during installation.

Once the installation has been completed, you will get a notice advising you to set the password for the root user. For more information, Section 2.12, "Postinstallation Setup and Testing".

8. Once the installation has completed, you can delete the installation file:

```
DLTLIB LIB(MYSQLINST)
```

Upgrading an existing MySQL instance

You need to execute the upgrade command, `MYSQLINST/UPGMYSQL`.

Note

You cannot use `MYSQLINST/UPGMYSQL` to upgrade between release series of MySQL (for example from 5.0 to 5.1). For information and advice on migrating between release series you can use the advice provided in Section 2.13.1.1, "Changes Affecting Upgrades to 5.1".

You must specify 6 parameters to perform an upgrade:

- `DIR('/QOpenSys/usr/local/')`: Sets the installation location for the MySQL files. The directory will be created if it does not already exist. This is the directory that the MySQL server will be installed into, inside a directory with a name matching the version and release. For example, if installing MySQL 5.1.73 with the `DIR` set to `/QOpenSys/usr/local/` would result in `/QOpenSys/usr/local/mysql-5.1.73-i5os-power64` and a symbolic link to this directory will be created in `/QOpenSys/usr/local/mysql`.

- `DATADIR('/QOpenSys/mysql/data')`: Sets the location of the directory that will be upgraded.

- `USRPRF('MYSQL')`: Sets the user profile that will own the files that are installed. The profile will be created if it does not already exist; if it is created as part of the upgrade process, it will be disabled initially. You may wish to enable this user profile so that it can be used to start the MySQL server later. It is best practice to use the one previously created during the first installation.

- MYSQLUSR('root user'): Any user account in the current MySQL server with SUPER privileges.

- PASSWORD('root user password'): The password for the above account. This is necessary as the upgrade starts the MySQL server to upgrade the tables and the password is need to be able to shutdown the MySQL server.

- CURINST('path to previous install'): The full path to the installation that is being upgraded. For example an installation in /QOpenSys/usr/local/ will be /QOpenSys/usr/local/mysql-5.1.73-i5os-power64. Failure to specify this option may result in corruption of your existing data files.

For example:

```
MYSQLINST/UPGMYSQL DIR('/QOpenSys/usr/local/') DATADIR('/QOpenSys/mysql/data') »
    USERPRF(MYSQL) MYSQLUSR('root') PASSWORD('root') CURINST('/QOpenSys/usr/local/mysql-5.1.73-i5os-power64')
```

You should receive a Program Message indicating UPGRADE SUCCESSFUL! upon completion or an error message if there is a problem.You can view the upgrade programs progression and the error in the text file upgrade.log in the installation directory.

To start MySQL:

1. Log into the System i server using the user profile create or specified during installation. By default, this is MYSQL.

   > **Note**
   >
   > You should start mysqld_safe using a user that in the PASE environment has the id=0 (the equivalent of the standard Unix root user). If you do not use a user with this ID then the system will be unable to change the user when executing mysqld as set using --user option. If this happens, mysqld may be unable to read the files located within the MySQL data directory and the execution will fail.

2. Enter the PASE environment using call qp2term.

3. Start the MySQL server by changing to the installation directory and running mysqld_safe, specifying the user name used to install the server. The installer conveniently installs a symbolic link to the installation directory (mysql-5.0.42-i5os-power-32bit) as /opt/mysql/mysql:

   ```
   > cd /opt/mysql/mysql
   > bin/mysqld_safe --user=mysql &
   ```

   You should see a message similar to the following:

   ```
   Starting mysqld daemon with databases »
        from /opt/mysql/mysql-enterprise-5.0.42-i5os-power-32bit/data
   ```

If you are having problems starting MySQL server, see Section 2.12.2.1, "Troubleshooting Problems Starting the MySQL Server".

To stop MySQL:

1. Log into the System i server using the user profile create or specified during installation. By default, this is MYSQL.

2. Enter the PASE environment using call qp2term.

3. Stop the MySQL server by changing into the installation directory and running mysqladmin, specifying the user name used to install the server:

```
> cd /opt/mysql/mysql
> bin/mysqladmin -u root shutdown
```

If the session that you started and stopped MySQL are the same, you may get the log output from `mysqld`:

```
STOPPING server from pid file »
   /opt/mysql/mysql-enterprise-5.0.42-i5os-power-32bit/data/I5DBX.RCHLAND.IBM.COM.pid
070718 10:34:20  mysqld ended
```

If the sessions used to start and stop MySQL are different, you will not receive any confirmation of the shutdown.

Notes and tips

• A problem has been identified with the installation process on DBCS systems. If you are having problems install MySQL on a DBCS system, you need to change your job's coded character set identifier (`CSSID`) to 37 (`EBCDIC`) before executing the install command, `INSMYSQL`. To do this, determine your existing `CSSID` (using `DSPJOB` and selecting option 2), execute `CHGJOB CSSID(37)`, run `INSMYSQL` to install MySQL and then execute `CHGJOB` again with your original `CSSID.`

• If you want to use the Perl scripts that are included with MySQL, you need to download the iSeries Tools for Developers (5799-PTL). See http://www-03.ibm.com/servers/enable/site/porting/tools/.

2.11 Installing MySQL from Source

Building MySQL from the source code enables you to customize build parameters, compiler optimizations, and installation location. For a list of systems on which MySQL is known to run, see http://www.mysql.com/support/supportedplatforms/database.html.

Before you proceed with an installation from source, check whether we produce a precompiled binary distribution for your platform and whether it works for you. We put a great deal of effort into ensuring that our binaries are built with the best possible options for optimal performance. Instructions for installing binary distributions are available in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

To obtain a source distribution for MySQL, see Section 2.1.2, "How to Get MySQL". MySQL source distributions are available as compressed `tar` files, Zip archives, or RPM packages. Distribution files have names of the form `mysql-VERSION.tar.gz`, `mysql-VERSION.zip`, or `mysql-VERSION.rpm`, where `VERSION` is a number like `5.1.73`.

To perform a MySQL installation using the source code:

• To build MySQL from source on Unix-like systems, including Linux, commercial Unix, BSD, OS X and others using a `.tar.gz` or RPM-based source code distribution, see Section 2.11.2, "Installing MySQL Using a Standard Source Distribution".

• To build MySQL from source on Windows (Windows XP or newer required), see Section 2.11.7, "Installing MySQL from Source on Windows".

• For information on building from one of our development trees, see Section 2.11.3, "Installing MySQL Using a Development Source Tree".

• For information on using the `configure` command to specify the source build parameters, including links to platform specific parameters that you might need, see Section 2.11.4, "MySQL Source-Configuration Options".

To install MySQL from source, the following system requirements must be satisfied:

- GNU `gunzip` to uncompress the distribution and a reasonable `tar` to unpack it (if you use a `.tar.gz` distribution), or `WinZip` or another tool that can read `.zip` files (if you use a `.zip` distribution).

  GNU `tar` is known to work. The standard `tar` provided with some operating systems is not able to unpack the long file names in the MySQL distribution. You should download and install GNU `tar`, or if available, use a preinstalled version of GNU tar. Usually this is available as `gnutar`, `gtar`, or as `tar` within a GNU or Free Software directory, such as `/usr/sfw/bin` or `/usr/local/bin`. GNU `tar` is available from http://www.gnu.org/software/tar/.

- A working ANSI C++ compiler. GCC 3.4.6 or later, Sun Studio 10 or later, Visual Studio 2005 or later, and many current vendor-supplied compilers are known to work.

- A good `make` program. Although some platforms come with their own `make` implementations, it is highly recommended that you use GNU `make` 3.75 or newer. It may already be available on your system as `gmake`. GNU `make` is available from http://www.gnu.org/software/make/.

- `libtool` 1.5, available from http://www.gnu.org/software/libtool/. 1.5.24 or later is recommended.

If you run into problems and need to file a bug report, please use the instructions in Section 1.7, "How to Report Bugs or Problems".

2.11.1 MySQL Layout for Source Installation

By default, when you install MySQL after compiling it from a source distribution, the installation step installs files under `/usr/local`. Components are installed in the directories shown in the following table. To configure particular installation locations, use the options described at Section 2.11.4, "MySQL Source-Configuration Options".

Table 2.18 MySQL Layout for Installation from Source

Directory	Contents of Directory
`bin`	Client programs and scripts
`include/mysql`	Include (header) files
`Docs`	Manual in Info format
`man`	Unix manual pages
`lib/mysql`	Libraries
`libexec`	The `mysqld` server
`share/mysql`	Miscellaneous support files, including error messages, sample configuration files, SQL for database installation
`sql-bench`	Benchmarks
`var`	Log files, databases

Within its installation directory, the layout of a source installation differs from that of a binary installation in the following ways:

- The `mysqld` server is installed in the `libexec` directory rather than in the `bin` directory.

- The data directory is `var` rather than `data`.

- `mysql_install_db` is installed in the `bin` directory rather than in the `scripts` directory.

- The header file and library directories are `include/mysql` and `lib/mysql` rather than `include` and `lib`.

2.11.2 Installing MySQL Using a Standard Source Distribution

To install MySQL from source, first configure, build, and install from a source package. Then follow the same postinstallation setup sequence as for a binary installation.

If you start from a source RPM, use the following command to make a binary RPM that you can install. If you do not have `rpmbuild`, use `rpm` instead.

```
shell> rpmbuild --rebuild --clean MySQL-VERSION.src.rpm
```

The result is one or more binary RPM packages that you install as indicated in Section 2.5.1, "Installing MySQL on Linux Using RPM Packages".

The sequence for installation from a compressed `tar` file source distribution is similar to the process for installing from a generic binary distribution that is detailed in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries". For a MySQL `.tar.gz` source distribution, the basic installation command sequence looks like this:

```
# Preconfiguration setup
shell> groupadd mysql
shell> useradd -g mysql -s /bin/false mysql
# Beginning of source-build specific instructions
shell> tar zxvf mysql-VERSION.tar.gz
shell> cd mysql-VERSION
shell> ./configure --prefix=/usr/local/mysql
shell> make
shell> make install
# End of source-build specific instructions
# Postinstallation setup
shell> cd /usr/local/mysql
shell> chown -R mysql .
shell> chgrp -R mysql .
shell> bin/mysql_install_db --user=mysql
shell> chown -R root .
shell> chown -R mysql var
# Next command is optional
shell> cp support-files/my-medium.cnf /etc/my.cnf
shell> bin/mysqld_safe --user=mysql &
# Next command is optional
shell> cp support-files/mysql.server /etc/init.d/mysql.server
```

A more detailed version of the source-build specific instructions is shown following. Perform the following steps as the `mysql` user, except as noted.

> **Note**
>
> The procedure shown here does not set up any passwords for MySQL accounts. After following the procedure, proceed to Section 2.12, "Postinstallation Setup and Testing", for postinstallation setup and testing.

1. Set up the `mysql` user and group that will be used to run and execute the MySQL server and own the database directory. For details, see Creating a `mysql` System User and Group, in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

2. Pick the directory under which you want to unpack the distribution and change location into it.

3. Obtain a distribution file using the instructions in Section 2.1.2, "How to Get MySQL".

4. Unpack the distribution into the current directory. `tar` can uncompress and unpack the distribution if it has `z` option support:

```
shell> tar zxvf /path/to/mysql-VERSION.tar.gz
```

This command creates a directory named `mysql-VERSION`.

If your `tar` does not have `z` option support, use `gunzip` to unpack the distribution and `tar` to unpack it:

```
shell> gunzip < /path/to/mysql-VERSION.tar.gz | tar xvf -
```

5. Change location into the top-level directory of the unpacked distribution:

```
shell> cd mysql-VERSION
```

6. Configure the source directory:

```
shell> ./configure --prefix=/usr/local/mysql
```

When you run `configure`, you might want to specify other options. For example, if you need to debug `mysqld` or a MySQL client, run `configure` with the `--with-debug` option, and then recompile and link your clients with the new client library. See Section 22.4, "Debugging and Porting MySQL".

Run `./configure --help` for a list of options. Section 2.11.4, "MySQL Source-Configuration Options", discusses some of the more useful options.

If `configure` fails and you are going to send mail to a MySQL mailing list to ask for assistance, please include any lines from `config.log` that you think can help solve the problem. Also include the last couple of lines of output from `configure`. To file a bug report, please use the instructions in Section 1.7, "How to Report Bugs or Problems".

7. Compile the source distribution:

```
shell> make
```

Use `gmake` instead on systems where you are using GNU `make` and it has been installed as `gmake`.

If the compile fails, see Section 2.11.5, "Dealing with Problems Compiling MySQL", for help.

8. Install the distribution:

```
shell> make install
```

You might need to run this command as `root`.

The remainder of the installation process, including setting up the configuration file, creating the core databases, and starting the MySQL server, are identical to the remainder of the process as shown in Generic Binary Install.

After everything has been installed, test the distribution. To start the MySQL server, use the following command:

```
shell> /usr/local/mysql/bin/mysqld_safe --user=mysql &
```

If you run the command as `root`, you should use the `--user` option as shown. The option value is the name of the login account that you created in the first step to use for running the server. If you run the `mysqld_safe` command while logged in as that user, you can omit the `--user` option.

If the command fails immediately and prints `mysqld ended`, look for information in the error log (which by default is the *host_name*`.err` file in the data directory).

For more information about `mysqld_safe`, see Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".

To make it more convenient to invoke programs installed in `/usr/local/mysql/bin`, you can add that directory to your `PATH` environment variable setting. That enables you to run a program by typing only its name, not its entire path name. See Section 4.2.10, "Setting Environment Variables".

> **Note**
>
> The accounts that are listed in the MySQL grant tables initially have no passwords. After starting the server, you should set up passwords for them using the instructions in Section 2.12, "Postinstallation Setup and Testing".

2.11.3 Installing MySQL Using a Development Source Tree

This section discusses how to install MySQL from the latest development source code.

To obtain the source tree, you must have Bazaar installed. The Bazaar VCS Web site has instructions for downloading and installing Bazaar on different platforms. Bazaar is supported on any platform that supports Python, and is therefore compatible with any Linux, Unix, Windows, or OS X host.

MySQL development projects are hosted on Launchpad. MySQL projects, including MySQL Server, MySQL Workbench, and others are available from the Oracle/MySQL Engineering page. For the repositories related only to MySQL Server, see the MySQL Server page.

To build under Unix/Linux, you must have the following tools installed:

* A good `make` program. Although some platforms come with their own `make` implementations, it is highly recommended that you use GNU `make` 3.75 or newer. It may already be available on your system as `gmake`. GNU `make` is available from http://www.gnu.org/software/make/.

* `autoconf` 2.58 (or newer), available from http://www.gnu.org/software/autoconf/.

* `automake` 1.8.1, available from http://www.gnu.org/software/automake/.

* `libtool` 1.5, available from http://www.gnu.org/software/libtool/. 1.5.24 or later is recommended.

* `m4`, available from http://www.gnu.org/software/m4/.

* `bison` 2.1 or newer, available from http://www.gnu.org/software/bison/. (Version 1 is no longer supported.) Use the latest version of `bison` where possible; if you experience problems, upgrade to a later version, rather than revert to an earlier one.

To build under Windows you must have Microsoft Visual C++ 2005 Express Edition, Visual Studio .Net 2003 (7.1), or Visual Studio 2005 (8.0) compiler system.

Once the necessary tools are installed, create a local branch of the MySQL development tree on your machine using this procedure:

1. To obtain a copy of the MySQL source code, you must create a new Bazaar branch. If you do not already have a Bazaar repository directory set up, you must initialize a new directory:

```
shell> mkdir mysql-server
shell> bzr init-repo --trees mysql-server
```

This is a one-time operation.

2. Assuming that you have an initialized repository directory, you can branch from the public MySQL server repositories to create a local source tree. To create a branch of a specific version:

```
shell> cd mysql-server
shell> bzr branch lp:mysql-server/5.1 mysql-5.1
```

This is a one-time operation per source tree. You can branch the source trees for several versions of MySQL under the `mysql-server` directory.

3. The initial download will take some time to complete, depending on the speed of your connection. Please be patient. Once you have downloaded the first tree, additional trees should take significantly less time to download.

4. When building from the Bazaar branch, you may want to create a copy of your active branch so that you can make configuration and other changes without affecting the original branch contents. You can achieve this by branching from the original branch:

```
shell> bzr branch mysql-5.1 mysql-5.1-build
```

5. To obtain changes made after you have set up the branch initially, update it using the `pull` option periodically. Use this command in the top-level directory of the local copy:

```
shell> bzr pull
```

To examine the changeset comments for the tree, use the `log` option to `bzr`:

```
shell> bzr log
```

You can also browse changesets, comments, and source code online at the Launchpad MySQL Server page.

If you see diffs (changes) or code that you have a question about, do not hesitate to send email to the MySQL `internals` mailing list. See Section 1.6.1, "MySQL Mailing Lists". If you think you have a better idea on how to do something, send an email message to the list with a patch.

After you have the local branch, you can build MySQL server from the source code. On Windows, the build process is different from Unix/Linux: see Section 2.11.7, "Installing MySQL from Source on Windows".

On Unix/Linux, use the `autoconf` system to create the `configure` script so that you can configure the build environment before building. The following example shows the typical commands required to build MySQL from a source tree.

1. Change location to the top-level directory of the source tree; replace `mysql-5.1` with the appropriate directory name.

```
shell> cd mysql-5.1
```

2. Prepare the source tree for configuration.

Prior to MySQL 5.1.12, you must separately configure the `InnoDB` storage engine. Run the following command from the main source directory:

```
shell> (cd storage/innobase; autoreconf --force --install)
```

You can omit the previous command for MySQL 5.1.12 and later, or if you do not require `InnoDB` support.

Prepare the remainder of the source tree:

```
shell> autoreconf --force --install
```

As an alternative to the preceding `autoreconf` command, you can use `BUILD/autorun.sh`, which acts as a shortcut for the following sequence of commands:

```
shell> aclocal; autoheader
shell> libtoolize --automake --force
shell> automake --force --add-missing; autoconf
```

If you get some strange errors during this stage, verify that you have the correct version of `libtool` installed.

3. Configure the source tree and compile MySQL:

```
shell> ./configure   # Add your favorite options here
shell> make
```

For a description of some `configure` options, see Section 2.11.4, "MySQL Source-Configuration Options".

A collection of configuration scripts is located in the `BUILD/` subdirectory. For example, you may find it more convenient to use the `BUILD/compile-pentium-debug` script than the preceding set of shell commands. To compile on a different architecture, modify the script by removing flags that are Pentium-specific, or use another script that may be more appropriate. These scripts are provided on an "as-is" basis. They are not supported and their contents may change from release to release.

4. When the build is done, run `make install`. Be careful with this on a production machine; the installation command may overwrite your live release installation. If you already have MySQL installed and do not want to overwrite it, run `./configure` with values for the `--prefix`, `--with-tcp-port`, and `--with-unix-socket-path` options different from those used by your production server. For additional information about preventing multiple servers from interfering with each other, see Section 5.5, "Running Multiple MySQL Instances on One Machine".

5. Play hard with your new installation. For example, try to make new features crash. Start by running `make test`. See Section 22.1.2, "The MySQL Test Suite".

6. If you have gotten to the `make` stage, but the distribution does not compile, please enter the problem into our bugs database using the instructions given in Section 1.7, "How to Report Bugs or Problems". If you have installed the latest versions of the required tools, and they crash trying to process our configuration files, please report that also. However, if you get a `command not found` error or a similar problem for required tools, do not report it. Instead, make sure that all the required tools are installed and that your `PATH` variable is set correctly so that your shell can find them.

2.11.4 MySQL Source-Configuration Options

The `configure` script provides a great deal of control over how you configure a MySQL source distribution. Typically, you do this using options on the `configure` command line. For a full list of options supported by `configure`, run this command:

```
shell> ./configure --help
```

You can also affect `configure` using certain environment variables. See Section 2.14, "Environment Variables".

The following table shows the available `configure` options.

Table 2.19 MySQL Source-Configuration Option Reference (`configure`)

Formats	Description	Default	Introduced	Removed
`--bindir`	User executables	`EPREFIX/bin`		
`--build`	Configure for building on BUILD	`guessed`		
`--cache-file`	Cache test results in FILE	`disabled`		
`--config-cache`	Alias for `--cache-file=config.cache'			
`--datadir`	Read-only architecture-independent data	`PREFIX/share`		
`--disable-FEATURE`	Do not include FEATURE			
`--disable-community-features`	Disable additional features provided by the community		5.1.28	
`--disable-dependency-tracking`	Disable dependency tracking			
`--disable-grant-options`	Disable GRANT options			
`--disable-largefile`	Omit support for large files			
`--disable-libtool-lock`	Disable libtool lock			
`--disable-thread-safe-client`	Compile the client without threads		5.1.7	
`--enable-FEATURE`	Enable FEATURE			
`--enable-assembler`	Use assembler versions of some string functions if available			
`--enable-debug-sync`	Compile in Debug Sync facility		5.1.41	
`--enable-dependency-tracking`	Do not reject slow dependency extractors			
`--enable-fast-install`	Optimize for fast installation	`yes`		
`--enable-local-infile`	Enable LOCAL for LOAD DATA INFILE	`disabled`		
`--enable-profiling`	Build a version with query profiling code		5.1.24	
`--enable-shared`	Build shared libraries	`yes`		
`--enable-static`	Build static libraries	`yes`		

Formats	Description	Default	Introduced	Removed
`--enable-thread-safe-client`	Compile the client with threads			5.1.6
`--exec-prefix`	Install architecture-dependent files in EPREFIX			
`--help`	Display help message and exit			
`--host`	Cross-compile to build programs to run on HOST			
`--includedir`	C header files	`PREFIX/include`		
`--infodir`	Info documentation	`PREFIX/info`		
`--libdir`	Object code libraries	`EPREFIX/lib`		
`--libexecdir`	Program executables	`EPREFIX/libexec`		
`--localstatedir`	Modifiable single-machine data	`PREFIX/var`		
`--mandir`	man documentation	`PREFIX/man`		
`--no-create`	Do not create output files			
`--oldincludedir`	C header files for non-gcc	`/usr/include`		
`--prefix`	Install architecture-independent files in PREFIX			
`--program-prefix`	Prepend PREFIX to installed program names			
`--program-suffix`	Append SUFFIX to installed program names			
`--program-transform-name`	run sed PROGRAM on installed program names			
`--quiet`	Do not print `checking...' messages			
`--sbindir`	System administrative executables	`EPREFIX/sbin`		
`--sharedstatedir`	Modifiable architecture-independent data	`PREFIX/com`		
`--srcdir`	Find the sources in DIR	`configure directory or ..`		
`--sysconfdir`	Read-only single-machine data	`PREFIX/etc`		
`--target`	Configure for building compilers for TARGET			
`--version`	Display version information and exit			
`--with-PACKAGE`	Use PACKAGE			
`--with-archive-storage-engine`	Enable the Archive Storage Engine	`no`		5.1.9
`--with-atomic-ops`	Implement atomic operations using pthread rwlocks or		5.1.12	

Formats	Description	Default	Introduced	Removed
	atomic CPU instructions for multi-processor			
`--with-berkeley-db`	Use BerkeleyDB located in DIR	`no`		5.1.11
`--with-berkeley-db-includes`	Find Berkeley DB headers in DIR			5.1.11
`--with-berkeley-db-libs`	Find Berkeley DB libraries in DIR			5.1.11
`--with-big-tables`	Support tables with more than 4 G rows even on 32 bit platforms			
`--with-blackhole-storage-engine`	Enable the Blackhole Storage Engine	`no`		5.1.9
`--with-charset`	Default character set			
`--with-client-ldflags`	Extra linking arguments for clients			
`--with-collation`	Default collation			
`--with-comment`	Comment about compilation environment			
`--with-csv-storage-engine`	Enable the CSV Storage Engine	`yes`		5.1.9
`--with-darwin-mwcc`	Use Metrowerks CodeWarrior wrappers on OS X/Darwin			
`--with-debug`	Add debug code (optionally with memory checker, very slow)		5.1.7	
`--with-embedded-privilege-control`	Build parts to check user's privileges (only affects embedded library)			
`--with-embedded-server`	Build the embedded server			
`--with-error-inject`	Enable error injection in MySQL Server		5.1.11	
`--with-example-storage-engine`	Enable the Example Storage Engine	`no`		5.1.9
`--with-extra-charsets`	Use charsets in addition to default			
`--with-fast-mutexes`	Compile with fast mutexes	`disabled`	5.1.5	
`--with-federated-storage-engine`	Enable federated storage engine	`no`	5.1.3	5.1.9
`--with-gnu-ld`	Assume the C compiler uses GNU ld	`no`		
`--with-innodb`	Enable innobase storage engine	`no`	5.1.3	5.1.9
`--with-lib-ccflags`	Extra CC options for libraries			

Formats	Description	Default	Introduced	Removed
`--with-libwrap`	Compile in libwrap (tcp_wrappers) support			
`--with-low-memory`	Try to use less memory to compile to avoid memory limitations			
`--with-machine-type`	Set the machine type, like "powerpc"			
`--with-maria-temp-tables`	Make the temporary tables within MySQL use the Maria storage engine		5.1.24	
`--with-max-indexes`	Sets the maximum number of indexes per table	`64`		
`--with-mysqld-ldflags`	Extra linking arguments for mysqld			
`--with-mysqld-libs`	Extra libraries to link with for mysqld			
`--with-mysqld-user`	What user the mysqld daemon shall be run as			
`--with-mysqlmanager`	Build the mysqlmanager binary	`Build if server is built`		
`--with-named-curses-libs`	Use specified curses libraries			
`--with-named-thread-libs`	Use specified thread libraries			
`--with-ndb-ccflags`	Extra CC options for ndb compile			
`--with-ndb-docs`	Include the NDB Cluster ndbapi and mgmapi documentation			
`--with-ndb-port`	Port for NDB Cluster management server			
`--with-ndb-port-base`	Port for NDB Cluster management server			
`--with-ndb-sci`	Provide MySQL with a custom location of sci library			
`--with-ndb-test`	Include the NDB Cluster ndbapi test programs			
`--with-ndbcluster`	Include the NDB Cluster table handler	`no`		5.1.9
`--with-openssl`	Include the OpenSSL support			5.1.9
`--with-openssl-includes`	Find OpenSSL headers in DIR			5.1.9
`--with-openssl-libs`	Find OpenSSL libraries in DIR			5.1.9

Formats	Description	Default	Introduced	Removed
`--with-other-libc`	Link against libc and other standard libraries installed in the specified nonstandard location			
`--with-pic`	Try to use only PIC/non-PIC objects	`Use both`		
`--with-plugin-PLUGIN`	Forces the named plugin to be linked into mysqld statically		5.1.11	
`--with-plugins`	Plugins to include in mysqld	`none`	5.1.11	
`--with-pstack`	Use the pstack backtrace library			5.1.54
`--with-pthread`	Force use of pthread library			
`--with-row-based-replication`	Include row-based replication		5.1.5	5.1.6
`--with-server-suffix`	Append value to the version string			
`--with-ssl`	Include SSL support		5.1.11	
`--with-system-type`	Set the system type, like "sun-solaris10"			
`--with-tags`	Include additional configurations	`automatic`		
`--with-tcp-port`	Which port to use for MySQL services	`3306`		
`--with-unix-socket-path`	Where to put the unix-domain socket			
`--with-yassl`	Include the yaSSL support			5.1.9
`--with-zlib-dir`	Provide MySQL with a custom location of compression library			
`--without-PACKAGE`	Do not use PACKAGE			
`--without-bench`	Skip building of the benchmark suite			5.1.11
`--without-debug`	Build a production version without debugging code			5.1.6
`--without-docs`	Skip building of the documentation			
`--without-extra-tools`	Skip building utilities in the tools directory			5.1.9
`--without-geometry`	Do not build geometry-related parts			
`--without-libedit`	Use system libedit instead of bundled copy			
`--without-man`	Skip building of the man pages			
`--without-ndb-binlog`	Disable ndb binlog		5.1.6	

Formats	Description	Default	Introduced	Removed
`--without-ndb-debug`	Disable special ndb debug features			
`--without-plugin-PLUGIN`	Exclude PLUGIN		5.1.11	
`--without-query-cache`	Do not build query cache			
`--without-readline`	Use system readline instead of bundled copy			
`--without-row-based-replication`	Don't include row-based replication		5.1.7	5.1.14
`--without-server`	Only build the client			
`--without-uca`	Skip building of the national Unicode collations			

If you are using a version of `gcc` recent enough to understand the `-fno-exceptions` option, it is *very important* that you use this option. Otherwise, you may compile a binary that crashes randomly. Also use `-felide-constructors` and `-fno-rtti` along with `-fno-exceptions`. When in doubt, do the following:

```
CFLAGS="-O3" CXX=gcc CXXFLAGS="-O3 -felide-constructors \
     -fno-exceptions -fno-rtti" ./configure \
     --prefix=/usr/local/mysql --enable-assembler \
     --with-mysqld-ldflags=-all-static
```

On most systems, this gives you a fast and stable binary.

When compiling from source, you should also be aware of any platform specific considerations that may influence and impact the build process. Knowing and applying this information will help to ensure you get the best performance and most stable binary for your chosen platform. For more information, use the following sections:

- Section 2.11.9, "Notes on Installing MySQL on AIX from Source"

- Section 2.11.10, "Notes on Installing MySQL on HP-UX from Source"

- Section 2.11.8, "Notes on Installing MySQL on Solaris from Source"

Some of the `configure` options available are described here. For options that may be of use if you have difficulties building MySQL, see Section 2.11.5, "Dealing with Problems Compiling MySQL".

Many options configure compile-time defaults that can be overridden at server startup. For example, the `--prefix`, `--with-tcp-port`, and `with-unix-socket-path` options that configure the default installation base directory location, TCP/IP port number, and Unix socket file can be changed at server startup with the `--basedir`, `--port`, and `--socket` options for `mysqld`.

- To compile just the MySQL client libraries and client programs and not the server, use the `--without-server` option:

  ```
  shell> ./configure --without-server
  ```

  If you have no C++ compiler, some client programs such as `mysql` cannot be compiled because they require C++. In this case, you can remove the code in `configure` that tests for the C++ compiler and

then run `./configure` with the `--without-server` option. The compile step should still try to build all clients, but you can ignore any warnings about files such as `mysql.cc`. (If `make` stops, try `make -k` to tell it to continue with the rest of the build even if errors occur.)

- To build the embedded MySQL library (`libmysqld.a`), use the `--with-embedded-server` option.

- To place your log files and database directories elsewhere than under `/usr/local/var`, use a `configure` command something like one of these:

```
shell> ./configure --prefix=/usr/local/mysql
shell> ./configure --prefix=/usr/local \
         --localstatedir=/usr/local/mysql/data
```

The first command changes the installation prefix so that everything is installed under `/usr/local/mysql` rather than the default of `/usr/local`. The second command preserves the default installation prefix, but overrides the default location for database directories (normally `/usr/local/var`) and changes it to `/usr/local/mysql/data`.

You can also specify the installation directory and data directory locations at server startup time by using the `--basedir` and `--datadir` options. These can be given on the command line or in an MySQL option file, although it is more common to use an option file. See Section 4.2.6, "Using Option Files".

- The `--with-tcp-port` option specifies the port number on which the server listens for TCP/IP connections. The default is port 3306. To listen on a different port, use a `configure` command like this:

```
shell> ./configure --with-tcp-port=3307
```

- On Unix, if you want the MySQL socket file location to be somewhere other than the default location (normally in the directory `/tmp` or `/var/run`), use a `configure` command like this:

```
shell> ./configure \
         --with-unix-socket-path=/usr/local/mysql/tmp/mysql.sock
```

The socket file name must be an absolute path name. You can also change the location of `mysql.sock` at server startup by using a MySQL option file. See Section B.5.3.6, "How to Protect or Change the MySQL Unix Socket File".

- To compile statically linked programs (for example, to make a binary distribution, to get better performance, or to work around problems with some Red Hat Linux distributions), run `configure` like this:

```
shell> ./configure --with-client-ldflags=-all-static \
         --with-mysqld-ldflags=-all-static
```

- If you are using `gcc` and do not have `libg++` or `libstdc++` installed, you can tell `configure` to use `gcc` as your C++ compiler:

```
shell> CC=gcc CXX=gcc ./configure
```

When you use `gcc` as your C++ compiler, it does not attempt to link in `libg++` or `libstdc++`. This may be a good thing to do even if you have those libraries installed. Some versions of them have caused strange problems for MySQL users in the past.

In most cases, you can get a reasonably optimized MySQL binary by using the following options on the `configure` line:

```
--prefix=/usr/local/mysql --enable-assembler \
--with-mysqld-ldflags=-all-static
```

The full `configure` line would, in other words, be something like the following for all recent `gcc` versions:

```
CFLAGS="-O3 -mpentiumpro" CXX=gcc CXXFLAGS="-O3 -mpentiumpro \
-felide-constructors -fno-exceptions -fno-rtti" ./configure \
--prefix=/usr/local/mysql --enable-assembler \
--with-mysqld-ldflags=-all-static
```

The binaries we provide on the MySQL Web site at http://dev.mysql.com/downloads/ are all compiled with full optimization and should work well for most users. See Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

- If the build fails and produces errors about your compiler or linker not being able to create the shared library `libmysqlclient.so.N` (where `N` is a version number), you can work around this problem by giving the `--disable-shared` option to `configure`. In this case, `configure` does not build a shared `libmysqlclient.so.N` library.

- By default, MySQL uses the `latin1` (cp1252 West European) character set. To change the default set, use the `--with-charset` option:

```
shell> ./configure --with-charset=CHARSET
```

`CHARSET` may be one of `binary`, `armscii8`, `ascii`, `big5`, `cp1250`, `cp1251`, `cp1256`, `cp1257`, `cp850`, `cp852`, `cp866`, `cp932`, `dec8`, `eucjpms`, `euckr`, `gb2312`, `gbk`, `geostd8`, `greek`, `hebrew`, `hp8`, `keybcs2`, `koi8r`, `koi8u`, `latin1`, `latin2`, `latin5`, `latin7`, `macce`, `macroman`, `sjis`, `swe7`, `tis620`, `ucs2`, `ujis`, `utf8`. (Additional character sets might be available. Check the output from `./configure --help` for the current list.)

The default collation may also be specified. MySQL uses the `latin1_swedish_ci` collation by default. To change this, use the `--with-collation` option:

```
shell> ./configure --with-collation=COLLATION
```

To change both the character set and the collation, use both the `--with-charset` and `--with-collation` options. The collation must be a legal collation for the character set. (Use the `SHOW COLLATION` statement to determine which collations are available for each character set.)

With the `configure` option `--with-extra-charsets=LIST`, you can define which additional character sets should be compiled into the server. `LIST` is one of the following:

- A list of character set names separated by spaces

- `complex` to include all character sets that can't be dynamically loaded

- `all` to include all character sets into the binaries

Clients that want to convert characters between the server and the client should use the `SET NAMES` statement. See Section 10.1.4, "Connection Character Sets and Collations".

- To configure MySQL with debugging code, use the `--with-debug` option:

```
shell> ./configure --with-debug
```

This causes a safe memory allocator to be included that can find some errors and that provides output about what is happening. See Section 22.4, "Debugging and Porting MySQL".

As of MySQL 5.1.12, using `--with-debug` to configure MySQL with debugging support enables you to use the `--debug="d,parser_debug"` option when you start the server. This causes the Bison parser that is used to process SQL statements to dump a parser trace to the server's standard error output. Typically, this output is written to the error log.

- To cause the Debug Sync facility to be compiled into the server, use the `--enable-debug-sync` option. This facility is used for testing and debugging. When compiled in, Debug Sync is disabled by default at runtime. To enable it, start `mysqld` with the `--debug-sync-timeout=N` option, where `N` is a timeout value greater than 0. (The default value is 0, which disables Debug Sync.) `N` becomes the default timeout for individual synchronization points.

  Debug Sync is also compiled in if you configure with the `--with-debug` option (which implies `--enable-debug-sync`), unless you also use the `--disable-debug-sync` option.

  For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

  The `--enable-debug-sync` and `--disable-debug-sync` options were added in MySQL 5.1.41.

- If your client programs are using threads, you must compile a thread-safe version of the MySQL client library with the `--enable-thread-safe-client` configure option. This creates a `libmysqlclient_r` library with which you should link your threaded applications. See Section 21.8.4.2, "Writing C API Threaded Client Programs".

- Some features require that the server be built with compression library support, such as the `COMPRESS()` and `UNCOMPRESS()` functions, and compression of the client/server protocol. The `--with-zlib-dir=no|bundled|DIR` option provides control over compression library support. The value `no` explicitly disables compression support. `bundled` causes the `zlib` library bundled in the MySQL sources to be used. A `DIR` path name specifies the directory in which to find the compression library sources.

- It is possible to build MySQL with large table support using the `--with-big-tables` option.

  This option causes the variables that store table row counts to be declared as `unsigned long long` rather than `unsigned long`. This enables tables to hold up to approximately 1.844E+19 (($2^{32})^2$) rows rather than 2^{32} (~4.295E+09) rows. Previously it was necessary to pass `-DBIG_TABLES` to the compiler manually in order to enable this feature.

- Run `configure` with the `--disable-grant-options` option to cause the `--bootstrap`, `--skip-grant-tables`, and `--init-file` options for `mysqld` to be disabled. For Windows, the `configure.js` script recognizes the `DISABLE_GRANT_OPTIONS` flag, which has the same effect. The capability is available as of MySQL 5.1.15.

- This option allows MySQL Community Server features to be enabled. Additional options may be required for individual features, such as `--enable-profiling` to enable statement profiling. This option was added in MySQL 5.1.24. It is enabled by default as of MySQL 5.1.28; to disable it, use `--disable-community-features`.

- When given with `--enable-community-features`, the `--enable-profiling` option enables the statement profiling capability exposed by the `SHOW PROFILE` and `SHOW PROFILES` statements. (See Section 13.7.5.33, "SHOW PROFILES Syntax".) This option was added in MySQL 5.1.24. It is enabled by default as of MySQL 5.1.28; to disable it, use `--disable-profiling`.

- See Section 2.1, "General Installation Guidance", for options that pertain to particular operating systems.

- See Section 6.4.2, "Building MySQL with Support for Secure Connections", for options that pertain to configuring MySQL to support secure (encrypted) connections.

- Several `configure` options apply to plugin selection and building:

```
--with-plugins=PLUGIN[,PLUGIN]...
--with-plugins=GROUP
--with-plugin-PLUGIN
--without-plugin-PLUGIN
```

PLUGIN is an individual plugin name such as `csv` or `archive`.

As shorthand, *GROUP* is a configuration group name such as `none` (select no plugins) or `all` (select all plugins).

You can build a plugin as static (compiled into the server) or dynamic (built as a dynamic library that must be installed using the `INSTALL PLUGIN` statement or the `--plugin-load` option before it can be used). Some plugins might not support static or dynamic build.

`configure --help` shows the following information pertaining to plugins:

- The plugin-related options

- The names of all available plugins

- For each plugin, a description of its purpose, which build types it supports (static or dynamic), and which plugin groups it is a part of.

`--with-plugins` can take a list of one or more plugin names separated by commas, or a plugin group name. The named plugins are configured to be built as static plugins.

`--with-plugin-`*PLUGIN* configures the given plugin to be built as a static plugin.

`--without-plugin-`*PLUGIN* disables the given plugin from being built.

If a plugin is named both with a `--with` and `--without` option, the result is undefined.

For any plugin that is not explicitly selected or disabled, it is selected to be built dynamically if it supports dynamic build, and not built if it does not support dynamic build. (Thus, in the case that no plugin options are given, all plugins that support dynamic build are selected to be built as dynamic plugins. Plugins that do not support dynamic build are not built.)

2.11.5 Dealing with Problems Compiling MySQL

All MySQL programs compile cleanly for us with no warnings on Solaris or Linux using `gcc`. On other systems, warnings may occur due to differences in system include files. For other problems, check the following list.

The solution to many problems involves reconfiguring. If you do need to reconfigure, take note of the following:

- If `configure` is run after it has previously been run, it may use information that was gathered during its previous invocation. This information is stored in `config.cache`. When `configure` starts up, it looks for that file and reads its contents if it exists, on the assumption that the information is still correct. That assumption is invalid when you reconfigure.

- Each time you run `configure`, you must run `make` again to recompile. However, you may want to remove old object files from previous builds first because they were compiled using different configuration options.

To prevent old configuration information or object files from being used, run these commands before re-running `configure`:

```
shell> rm config.cache
shell> make clean
```

Alternatively, you can run `make distclean`.

The following list describes some of the problems that have been found to occur most often when compiling MySQL:

- If you get errors such as the ones shown here when compiling `sql_yacc.cc`, you probably have run out of memory or swap space:

```
Internal compiler error: program cc1plus got fatal signal 11
Out of virtual memory
Virtual memory exhausted
```

The problem is that `gcc` requires a huge amount of memory to compile `sql_yacc.cc` with inline functions. Try running `configure` with the `--with-low-memory` option:

```
shell> ./configure --with-low-memory
```

This option causes `-fno-inline` to be added to the compile line if you are using `gcc` and `-O0` if you are using something else. You should try the `--with-low-memory` option even if you have so much memory and swap space that you think you can't possibly have run out. This problem has been observed to occur even on systems with generous hardware configurations, and the `--with-low-memory` option usually fixes it.

- By default, `configure` picks `c++` as the compiler name and GNU `c++` links with `-lg++`. If you are using `gcc`, that behavior can cause problems during configuration such as this:

```
configure: error: installation or configuration problem:
C++ compiler cannot create executables.
```

You might also observe problems during compilation related to `g++`, `libg++`, or `libstdc++`.

One cause of these problems is that you may not have `g++`, or you may have `g++` but not `libg++`, or `libstdc++`. Take a look at the `config.log` file. It should contain the exact reason why your C++ compiler did not work. To work around these problems, you can use `gcc` as your C++ compiler. Try setting the environment variable `CXX` to `"gcc -O3"`. For example:

```
shell> CXX="gcc -O3" ./configure
```

This works because `gcc` compiles C++ source files as well as `g++` does, but does not link in `libg++` or `libstdc++` by default.

Another way to fix these problems is to install `g++`, `libg++`, and `libstdc++`. However, do not use `libg++` or `libstdc++` with MySQL because this only increases the binary size of `mysqld` without

providing any benefits. Some versions of these libraries have also caused strange problems for MySQL users in the past.

- To define flags to be used by your C or C++ compilers, specify them using the CFLAGS and CXXFLAGS environment variables. You can also specify the compiler names this way using CC and CXX. For example:

```
shell> CC=gcc
shell> CFLAGS=-O3
shell> CXX=gcc
shell> CXXFLAGS=-O3
shell> export CC CFLAGS CXX CXXFLAGS
```

  To see what flags you might need to specify, invoke mysql_config with the --cflags option.

- If you get errors such as those shown here when compiling mysqld, configure did not correctly detect the type of the last argument to accept(), getsockname(), or getpeername():

```
cxx: Error: mysqld.cc, line 645: In this statement, the referenced
    type of the pointer value ''length'' is ''unsigned long'',
    which is not compatible with ''int''.
new_sock = accept(sock, (struct sockaddr *)&cAddr, &length);
```

  To fix this, edit the config.h file (which is generated by configure). Look for these lines:

```
/* Define as the base type of the last arg to accept */
#define SOCKET_SIZE_TYPE XXX
```

  Change XXX to size_t or int, depending on your operating system. (You must do this each time you run configure because configure regenerates config.h.)

- If your compile fails with errors such as any of the following, you must upgrade your version of make to GNU make:

```
make: Fatal error in reader: Makefile, line 18:
Badly formed macro assignment
```

  Or:

```
make: file `Makefile' line 18: Must be a separator (:
```

  Or:

```
pthread.h: No such file or directory
```

  Solaris and FreeBSD are known to have troublesome make programs.

  GNU make 3.75 is known to work.

- The sql_yacc.cc file is generated from sql_yacc.yy. Normally, the build process does not need to create sql_yacc.cc because MySQL comes with a pregenerated copy. However, if you do need to re-create it, you might encounter this error:

```
"sql_yacc.yy", line xxx fatal: default action causes potential...
```

This is a sign that your version of `yacc` is deficient. You probably need to install `bison` (the GNU version of `yacc`) and use that instead.

Versions of `bison` older than 1.75 may report this error:

```
sql_yacc.yy:#####: fatal error: maximum table size (32767) exceeded
```

The maximum table size is not actually exceeded; the error is caused by bugs in older versions of `bison`.

- On Debian Linux 3.0, you need to install `gawk` instead of the default `mawk`.

- If you get a compilation error on Linux (for example, SuSE Linux 8.1 or Red Hat Linux 7.3) similar to the following one, you probably do not have `g++` installed:

```
libmysql.c:1329: warning: passing arg 5 of `gethostbyname_r' from
incompatible pointer type
libmysql.c:1329: too few arguments to function `gethostbyname_r'
libmysql.c:1329: warning: assignment makes pointer from integer
without a cast
make[2]: *** [libmysql.lo] Error 1
```

By default, the `configure` script attempts to determine the correct number of arguments by using `g++` (the GNU C++ compiler). This test yields incorrect results if `g++` is not installed. There are two ways to work around this problem:

- Make sure that the GNU C++ `g++` is installed. On some Linux distributions, the required package is called `gpp`; on others, it is named `gcc-c++`.

- Use `gcc` as your C++ compiler by setting the `CXX` environment variable to `gcc`:

```
export CXX="gcc"
```

You must run `configure` again after making either of those changes.

For information about acquiring or updating tools, see the system requirements in Section 2.11, "Installing MySQL from Source".

2.11.6 Compiling and Linking an Optimized mysqld Server

Most of the following tests were performed on Linux with the MySQL benchmarks, but they should give some indication for other operating systems and workloads.

You obtain the fastest executables when you link with `-static`.

By using better compiler and compilation options, you can obtain a 10% to 30% speed increase in applications. This is particularly important if you compile the MySQL server yourself.

When we tested both the Cygnus CodeFusion and Fujitsu compilers, neither was sufficiently bug-free to enable MySQL to be compiled with optimizations enabled.

The standard MySQL binary distributions are compiled with support for all character sets. When you compile MySQL yourself, include support only for the character sets that you are going to use. This is controlled by the `--with-charset` option to `configure`.

Here is a list of some measurements that we have made:

- If you link dynamically (without `-static`), the result is 13% slower on Linux. Note that you still can use a dynamically linked MySQL library for your client applications. It is the server that is most critical for performance.

- For a connection from a client to a server running on the same host, if you connect using TCP/IP rather than a Unix socket file, performance is 7.5% slower. (On Unix, if you connect to the host name `localhost`, MySQL uses a socket file by default.)

- For TCP/IP connections from a client to a server, connecting to a remote server on another host is 8% to 11% slower than connecting to a server on the same host, even for connections faster than 100Mb/s Ethernet.

- When running our benchmark tests using secure connections (all data encrypted with internal SSL support) performance was 55% slower than with unencrypted connections.

- On a Sun UltraSPARC-IIe, a server compiled with Forte 5.0 is 4% faster than one compiled with `gcc` 3.2.

- On a Sun UltraSPARC-IIe, a server compiled with Forte 5.0 is 4% faster in 32-bit mode than in 64-bit mode.

- Compiling on Linux-x86 using `gcc` without frame pointers (`-fomit-frame-pointer` or `-fomit-frame-pointer -ffixed-ebp`) makes `mysqld` 1% to 4% faster.

2.11.7 Installing MySQL from Source on Windows

These instructions describe how to build binaries from source for MySQL 5.1 on Windows. Instructions are provided for building binaries from a standard source distribution or from the Bazaar tree that contains the latest development source.

> **Note**
>
> The instructions here are strictly for users who want to test MySQL on Microsoft Windows from the latest source distribution or from the Bazaar tree. For production use, we do not advise using a MySQL server built by yourself from source. Normally, it is best to use precompiled binary distributions of MySQL that are built specifically for optimal performance on Windows by Oracle Corporation. Instructions for installing binary distributions are available in Section 2.3, "Installing MySQL on Microsoft Windows".

To build MySQL on Windows from source, you must satisfy the following system, compiler, and resource requirements:

- Windows 2000, Windows XP, or newer version.

  Windows Vista is supported when using Visual Studio 2005 provided you have installed the following updates:

  - Microsoft Visual Studio 2005 Professional Edition - ENU Service Pack 1 (KB926601)

  - Security Update for Microsoft Visual Studio 2005 Professional Edition - ENU (KB937061)

  - Update for Microsoft Visual Studio 2005 Professional Edition - ENU (KB932232)

- `CMake`, which can be downloaded from http://www.cmake.org. After installing, modify your `PATH` environment variable to include the directory where `cmake` is located.

- Microsoft Visual C++ 2005 Express Edition, Visual Studio .Net 2003 (7.1), or Visual Studio 2005 (8.0) compiler system.

- If you are using Visual C++ 2005 Express Edition, you must also install an appropriate Platform SDK. More information and links to downloads for various Windows platforms is available from http:// www.microsoft.com/downloads/details.aspx?familyid=0baf2b35-c656-4969-ace8-e4c0c0716adb.

- If you are compiling from a Bazaar tree or making changes to the parser, you need `bison` for Windows, which can be downloaded from http://gnuwin32.sourceforge.net/packages/bison.htm. Download the package labeled "Complete package, excluding sources". After installing the package, modify your `PATH` environment variable to include the directory where `bison` is located.

> **Note**
>
> On Windows, the default location for `bison` is the `C:\Program Files \GnuWin32` directory. Some utilities, including `m4`, may fail to find `bison` because of the space in the directory name. You can resolve this by installing into a directory that does not contain a space; for example `C:\GnuWin32`.

- Cygwin might be necessary if you want to run the test script or package the compiled binaries and support files into a Zip archive. (Cygwin is needed only to test or package the distribution, not to build it.) Cygwin is available from http://cygwin.com.

- 3GB to 5GB of disk space.

You also need a MySQL source distribution for Windows, which can be obtained two ways:

- Obtain a source distribution packaged by Oracle Corporation. These are available from http:// dev.mysql.com/downloads/.

- Package a source distribution yourself from the latest Bazaar developer source tree. For instructions on pulling the latest source files, see Section 2.11.3, "Installing MySQL Using a Development Source Tree".

If you find something not working as expected, or you have suggestions about ways to improve the current build process on Windows, please send a message to the `win32` mailing list. See Section 1.6.1, "MySQL Mailing Lists".

> **Note**
>
> To compile from the source code on Windows you must use the standard source distribution (for example, `mysql-5.1.73.zip`) or `mysql-5.1.73.tar.gz`). You build from the same distribution as used to build MySQL on Unix, Linux and other platforms. Do *not* use the Windows Source distributions as they do not contain the necessary configuration script and other files.

Follow this procedure to build MySQL:

1. If you are installing from a packaged source distribution, create a work directory (for example, `C:\workdir`), and unpack the source distribution there using `WinZip` or another Windows tool that can read `.zip` files. This directory is the work directory in the following instructions.

   > **Note**
   >
   > Commands that are located in the `win` directory should be executed from the top-level source directory. Do not change location into the `win` directory, as the commands will not execute correctly.

2. Start a command shell. If you have not configured the `PATH` and other environment variables for all command shells, you may be able to start a command shell from the **Start Menu** within the Windows Visual Studio menu that contains the necessary environment changes.

3. Within the command shell, navigate to the work directory and run the following command:

```
C:\workdir>win\configure.js options
```

If you have associated the `.js` file extension with an application such as a text editor, then you may need to use the following command to force `configure.js` to be executed as a script:

```
C:\workdir>cscript win\configure.js options
```

These options are available for `configure.js`:

- `WITH_INNOBASE_STORAGE_ENGINE`: Enable the `InnoDB` storage engine.

- `WITH_PARTITION_STORAGE_ENGINE`: Enable user-defined partitioning.

- `WITH_ARCHIVE_STORAGE_ENGINE`: Enable the `ARCHIVE` storage engine.

- `WITH_BLACKHOLE_STORAGE_ENGINE`: Enable the `BLACKHOLE` storage engine.

- `WITH_EXAMPLE_STORAGE_ENGINE`: Enable the `EXAMPLE` storage engine.

- `WITH_FEDERATED_STORAGE_ENGINE`: Enable the `FEDERATED` storage engine.

- `WITH_NDBCLUSTER_STORAGE_ENGINE`: Enable the `NDBCLUSTER` storage engine in the MySQL server; cause binaries for the MySQL Cluster management and data node, management client, and other programs to be built.

  This option is supported only in MySQL Cluster NDB 7.0 and later (`NDBCLUSTER` storage engine versions 6.4.0 and later) using the MySQL Cluster sources. It cannot be used to enable clustering support in other MySQL source trees or distributions.

- `MYSQL_SERVER_SUFFIX=suffix`: Server suffix, default none.

- `COMPILATION_COMMENT=comment`: Server comment, default "Source distribution".

- `MYSQL_TCP_PORT=port`: Server port, default 3306.

- `DISABLE_GRANT_OPTIONS`: Disables the `--bootstrap`, `--skip-grant-tables`, and `--init-file` options for `mysqld`. This option is available as of MySQL 5.1.15.

For example (type the command on one line):

```
C:\workdir>win\configure.js WITH_INNOBASE_STORAGE_ENGINE
             WITH_PARTITION_STORAGE_ENGINE MYSQL_SERVER_SUFFIX=-pro
```

4. From the work directory, execute the `win\build-vs9.bat` (Windows Visual Studio 2008), `win\build-vs8.bat` (Windows Visual Studio 2005), or `win\build-vs71.bat` (Windows Visual Studio 2003) script, depending on the version of Visual Studio you have installed. The script invokes `CMake`, which generates the `mysql.sln` solution file.

   You can also use the corresponding 64-bit file (for example `win\build-vs8_x64.bat` or `win\build-vs9_x64.bat`) to build the 64-bit version of MySQL. However, you cannot build the 64-bit version with Visual Studio Express Edition. You must use Visual Studio 2005 (8.0) or higher.

5. From the work directory, open the generated `mysql.sln` file with Visual Studio and select the proper
    configuration using the **Configuration** menu. The menu provides **Debug**, **Release**, **RelwithDebInfo**,
    MinRelInfo options. Then select **Solution** > **Build** to build the solution.

    Remember the configuration that you use in this step. It is important later when you run the test script
    because that script needs to know which configuration you used.

6. Test the server. The server built using the preceding instructions expects that the MySQL base
    directory and data directory are `C:\mysql` and `C:\mysql\data` by default. If you want to test
    your server using the source tree root directory and its data directory as the base directory and data
    directory, you need to tell the server their path names. You can either do this on the command line
    with the `--basedir` and `--datadir` options, or by placing appropriate options in an option file. (See
    Section 4.2.6, "Using Option Files".) If you have an existing data directory elsewhere that you want to
    use, you can specify its path name instead.

    When the server is running in standalone fashion or as a service based on your configuration, try to
    connect to it from the `mysql` interactive command-line utility.

    You can also run the standard test script, `mysql-test-run.pl`. This script is written in Perl, so you'll
    need either Cygwin or ActiveState Perl to run it. You may also need to install the modules required
    by the script. To run the test script, change location into the `mysql-test` directory under the work
    directory, set the `MTR_VS_CONFIG` environment variable to the configuration you selected earlier (or
    use the `--vs-config` option), and invoke `mysql-test-run.pl`. For example (using Cygwin and the
    `bash` shell):

    ```
    shell> cd mysql-test
    shell> export MTR_VS_CONFIG=debug
    shell> ./mysql-test-run.pl --force --timer
    shell> ./mysql-test-run.pl --force --timer --ps-protocol
    ```

When you are satisfied that the programs you have built are working correctly, stop the server. Now you
can install the distribution. One way to do this is to use the `make_win_bin_dist` script in the `scripts`
directory of the MySQL source distribution (see Section 4.4.2, "`make_win_bin_dist` — Package MySQL
Distribution as Zip Archive"). This is a shell script, so you must have Cygwin installed if you want to use
it. It creates a Zip archive of the built executables and support files that you can unpack in the location at
which you want to install MySQL.

It is also possible to install MySQL by copying directories and files directly:

1. Create the directories where you want to install MySQL. For example, to install into `C:\mysql`, use
    these commands:

    ```
    C:\> mkdir C:\mysql
    C:\> mkdir C:\mysql\bin
    C:\> mkdir C:\mysql\data
    C:\> mkdir C:\mysql\share
    C:\> mkdir C:\mysql\scripts
    ```

    If you want to compile other clients and link them to MySQL, you should also create several additional
    directories:

    ```
    C:\> mkdir C:\mysql\include
    C:\> mkdir C:\mysql\lib
    C:\> mkdir C:\mysql\lib\debug
    C:\> mkdir C:\mysql\lib\opt
    ```

If you want to benchmark MySQL, create this directory:

```
C:\> mkdir C:\mysql\sql-bench
```

Benchmarking requires Perl support for MySQL. See Section 2.15, "Perl Installation Notes".

2. From the work directory, copy into the `C:\mysql` directory the following files and directories:

```
C:\> cd \workdir
C:\workdir> mkdir C:\mysql
C:\workdir> mkdir C:\mysql\bin
C:\workdir> copy client\Release\*.exe C:\mysql\bin
C:\workdir> copy sql\Release\mysqld.exe C:\mysql\bin\mysqld.exe
C:\workdir> xcopy scripts\*.* C:\mysql\scripts /E
C:\workdir> xcopy share\*.* C:\mysql\share /E
```

If you want to compile other clients and link them to MySQL, you should also copy several libraries and header files:

```
C:\workdir> copy lib\Release\mysqlclient.lib C:\mysql\lib\debug
C:\workdir> copy lib\Release\libmysql.* C:\mysql\lib\debug
C:\workdir> copy lib\Release\zlib.* C:\mysql\lib\debug
C:\workdir> copy lib\Release\mysqlclient.lib C:\mysql\lib\opt
C:\workdir> copy lib\Release\libmysql.* C:\mysql\lib\opt
C:\workdir> copy lib\Release\zlib.* C:\mysql\lib\opt
C:\workdir> copy include\*.h C:\mysql\include
C:\workdir> copy libmysql\libmysql.def C:\mysql\include
```

> **Note**
>
> If you have compiled a Debug solution, rather than a Release solution, install it by replacing `Release` with `Debug` in the source file names just shown.

If you want to benchmark MySQL, you should also do this:

```
C:\workdir> xcopy sql-bench\*.* C:\mysql\bench /E
```

After installation, set up and start the server in the same way as for binary Windows distributions. This includes creating the system tables by running `mysql_install_db`. For more information, see Section 2.3, "Installing MySQL on Microsoft Windows".

2.11.8 Notes on Installing MySQL on Solaris from Source

When building MySQL on Solaris you can use either the Sun Studio or GNU cc compilers. For more information on specific notes and environments, use the following hints.

- When building you should ensure that your `PATH` variable includes the necessary tools, including `ar` for building libraries. Some tools are located in `/usr/ccs/bin`.

- When running `configure`, you should specify the C and C++ compiler explicitly to ensure that the right C compiler combination is used:

```
CC=gcc CXX=g++ ./configure
```

- If you have an UltraSPARC system, you can get 4% better performance by adding `-mcpu=v8 -Wa,-xarch=v8plusa` to the `CFLAGS` and `CXXFLAGS` environment variables.

- If you have Sun's Forte 5.00 (or newer) or Sun Studio compiler, you can run `configure` like this:

```
CC=cc CFLAGS="-Xa -fast -native -xstrconst -mt" \
CXX=CC CXXFLAGS="-noex -mt" \
./configure --prefix=/usr/local/mysql --enable-assembler
```

- To create a 64-bit SPARC binary with Sun's Forte or Sun Studio compiler, use the following configuration options:

```
CC=cc CFLAGS="-Xa -fast -native -xstrconst -mt -xarch=v9" \
CXX=CC CXXFLAGS="-noex -mt -xarch=v9" ASFLAGS="-xarch=v9" \
./configure --prefix=/usr/local/mysql --enable-assembler
```

  To create a 64-bit Solaris binary using `gcc`, add `-m64` to `CFLAGS` and `CXXFLAGS` and remove `--enable-assembler` from the `configure` line.

  In the MySQL benchmarks, we obtained a 4% speed increase on UltraSPARC when using Forte 5.0 in 32-bit mode, as compared to using `gcc` 3.2 with the `-mcpu` flag.

  If you create a 64-bit `mysqld` binary, it is 4% slower than the 32-bit binary, but can handle more threads and memory.

- If you get a problem with `fdatasync` or `sched_yield`, you can fix this by adding `LIBS=-lrt` to the `configure` line

- Solaris does not provide static versions of all system libraries (`libpthreads` and `libdl`), so you cannot compile MySQL with `--static`. If you try to do so, you get one of the following errors:

```
ld: fatal: library -ldl: not found
undefined reference to `dlopen'
cannot find -lrt
```

- If you link your own MySQL client programs, you may see the following error at runtime:

```
ld.so.1: fatal: libmysqlclient.so.#:
open failed: No such file or directory
```

  To avoid this problem, use one of the following methods:

  - Use the `crle` tool to add the directory containing the `libmysqlclient` library file to the list of standard library directories. You need administrator privileges to do this. Make sure you update the library information, rather than replace it with the new path. For example, the following command adds the directory to the list of standard directories searched for libraries.

```
crle -u -l /usr/local/mysql/lib
```

  For 64-bit libraries, add the `-64` option:

```
crle -64 -u -l /usr/local/mysql/lib
```

  - Link clients with the `-Wl,r/full/path/to/libmysqlclient.so` flag rather than with `-Lpath`).

  - Copy `libmysqlclient.so` to `/usr/lib`.

- Add the path name of the directory where `libmysqlclient.so` is located to the `LD_RUN_PATH` environment variable before running your client.

- If you have problems with `configure` trying to link with `-lz` when you do not have `zlib` installed, you have two options:

  - If you want to be able to use the compressed communication protocol, obtain and install `zlib` from `ftp.gnu.org`.

  - To build without `zlib`, run `configure` with the `--with-named-z-libs=no` option when building MySQL.

- If you are using `gcc` and have problems with loading user-defined functions (UDFs) into MySQL, try adding `-lgcc` to the link line for the UDF.

2.11.9 Notes on Installing MySQL on AIX from Source

General notes on building MySQL from source on IBM AIX:

- Automatic `xlC` detection is missing from Autoconf, so a number of variables need to be set before running `configure`. The following example uses the IBM compiler:

```
export CC="xlc_r -ma -O3 -qstrict -qoptimize=3 -qmaxmem=8192 "
export CXX="xlC_r -ma -O3 -qstrict -qoptimize=3 -qmaxmem=8192"
export CFLAGS="-I /usr/local/include"
export LDFLAGS="-L /usr/local/lib"
export CPPFLAGS=$CFLAGS
export CXXFLAGS=$CFLAGS

./configure --prefix=/usr/local \
            --localstatedir=/var/mysql \
            --sbindir='/usr/local/bin' \
            --libexecdir='/usr/local/bin' \
            --enable-thread-safe-client \
            --enable-large-files
```

The preceding options are used to compile the MySQL distribution that can be found at http://www-frec.bull.com/.

- If you change the `-O3` to `-O2` in the preceding `configure` line, you must also remove the `-qstrict` option. This is a limitation in the IBM C compiler.

- If you compile MySQL with `gcc`, you *must* use the `-fno-exceptions` flag because the exception handling in `gcc` is not thread-safe. There are also some known problems with IBM's assembler that may cause it to generate bad code when used with `gcc`.

- If you have problems with signals (MySQL dies unexpectedly under high load), you may have found an OS bug with threads and signals. In this case, you can tell MySQL not to use signals by configuring as follows:

```
CFLAGS=-DDONT_USE_THR_ALARM CXX=gcc \
CXXFLAGS="-felide-constructors -fno-exceptions -fno-rtti \
-DDONT_USE_THR_ALARM" \
./configure --prefix=/usr/local/mysql --with-debug \
    --with-low-memory
```

This does not affect the performance of MySQL, but has the side effect that you cannot kill clients that are "sleeping" on a connection with `mysqladmin kill` or `mysqladmin shutdown`. Instead, the client dies when it issues its next command.

- On some versions of AIX, linking with `libbind.a` makes `getservbyname()` dump core. This is an AIX bug and should be reported to IBM.

2.11.10 Notes on Installing MySQL on HP-UX from Source

General notes on compiling MySQL on HP-UX.

- If you are using HP-UX compiler, you can use the following command (which has been tested with `cc` B.11.11.04):

```
CC=cc CXX=aCC CFLAGS=+DD64 CXXFLAGS=+DD64 ./configure \
    --with-extra-character-set=complex
```

You can ignore any errors of the following type:

```
aCC: warning 901: unknown option: `-3': use +help for online
documentation
```

- If you get the following error from `configure`, verify that you do not have the path to the K&R compiler before the path to the HP-UX C and C++ compiler:

```
checking for cc option to accept ANSI C... no
configure: error: MySQL requires an ANSI C compiler (and a C++ compiler).
Try gcc. See the Installation chapter in the Reference Manual.
```

- Another reason for compile failure is that you did not define the `+DD64` flags as just described.

2.12 Postinstallation Setup and Testing

This section discusses tasks that you should perform after installing MySQL:

- If necessary, initialize the data directory and create the MySQL grant tables. For some MySQL installation methods, data directory initialization may be done for you automatically:

  - Installation on Windows

  - Installation on Linux using a server RPM distribution.

  - Installation using the native packaging system on many platforms, including Debian Linux, Ubuntu Linux, Gentoo Linux, and others.

  - Installation on OS X using a DMG distribution.

  For other platforms and installation types, including installation from generic binary and source distributions, you must initialize the data directory yourself. For instructions, see Section 2.12.1, "Initializing the Data Directory".

- For instructions, see Section 2.12.2, "Starting the Server", and Section 2.12.3, "Testing the Server".

- Assign passwords to any initial accounts in the grant tables, if that was not already done during data directory initialization. Passwords prevent unauthorized access to the MySQL server. You may also wish

to restrict access to test databases. For instructions, see Section 2.12.4, "Securing the Initial MySQL Accounts".

- Optionally, arrange for the server to start and stop automatically when your system starts and stops. For instructions, see Section 2.12.5, "Starting and Stopping MySQL Automatically".

- Optionally, populate time zone tables to enable recognition of named time zones. For instructions, see Section 10.6, "MySQL Server Time Zone Support".

When you are ready to create additional user accounts, you can find information on the MySQL access control system and account management in Section 6.2, "The MySQL Access Privilege System", and Section 6.3, "MySQL User Account Management".

2.12.1 Initializing the Data Directory

After installing MySQL, you must initialize the data directory, including the tables in the `mysql` system database. For some MySQL installation methods, data directory initialization may be done automatically, as described in Section 2.12, "Postinstallation Setup and Testing". For other installation methods, including installation from generic binary and source distributions, you must initialize the data directory yourself.

This section describes how to initialize the data directory on Unix and Unix-like systems. (For Windows, see Section 2.3.8, "Windows Postinstallation Procedures".) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 2.12.3, "Testing the Server".

In the examples shown here, the server runs under the user ID of the `mysql` login account. This assumes that such an account exists. Either create the account if it does not exist, or substitute the name of a different existing login account that you plan to use for running the server. For information about creating the account, see Creating a `mysql` System User and Group, in Section 2.2, "Installing MySQL on Unix/Linux Using Generic Binaries".

1. Change location into the top-level directory of your MySQL installation, represented here by *BASEDIR*:

```
shell> cd BASEDIR
```

BASEDIR is likely to be something like `/usr/local/mysql` or `/usr/local`. The following steps assume that you have changed location to this directory.

You will find several files and subdirectories in the *BASEDIR* directory. The most important for installation purposes are the `bin` and `scripts` subdirectories, which contain the server as well as client and utility programs.

For some distribution types, `mysqld` is installed in the `libexec` directory.

2. If necessary, ensure that the distribution contents are accessible to `mysql`. If you installed the distribution as `mysql`, no further action is required. If you installed the distribution as `root`, its contents will be owned by `root`. Change its ownership to `mysql` by executing the following commands as `root` in the installation directory. The first command changes the owner attribute of the files to the `mysql` user. The second changes the group attribute to the `mysql` group.

```
shell> chown -R mysql .
shell> chgrp -R mysql .
```

3. If necessary, initialize the data directory, including the `mysql` database containing the initial MySQL grant tables that determine how users are permitted to connect to the server.

Typically, data directory initialization need be done only the first time you install MySQL. If you are upgrading an existing installation, you should run `mysql_upgrade` instead (see Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables"). However, the command that initializes the data directory does not overwrite any existing privilege tables, so it should be safe to run in any circumstances.

The exact location of `mysql_install_db` depends on the layout for your given installation. To initialize the grant tables, use one of the following commands, depending on whether `mysql_install_db` is located in the `bin` or `scripts` directory:

```
shell> scripts/mysql_install_db --user=mysql
shell> bin/mysql_install_db --user=mysql
```

It is important to make sure that the database directories and files are owned by the `mysql` login account so that the server has read and write access to them when you run it later. To ensure this if you run `mysql_install_db` as `root`, include the `--user` option as shown. Otherwise, you should execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

The `mysql_install_db` command creates the server's data directory. Under the data directory, it creates directories for the `mysql` database that holds the grant tables and the `test` database that you can use to test MySQL. The program also creates privilege table entries for the initial account or accounts. `test_`. For a complete listing and description of the grant tables, see Section 6.2, "The MySQL Access Privilege System".

It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysql_install_db` does not identify the correct locations for the installation directory or data directory. For example:

```
shell> scripts/mysql_install_db --user=mysql \
          --basedir=/opt/mysql/mysql \
          --datadir=/opt/mysql/mysql/data
```

If you do not want to have the `test` database, you can remove it after starting the server, using the instructions in Section 2.12.4, "Securing the Initial MySQL Accounts".

If you have trouble with `mysql_install_db` at this point, see Section 2.12.1.1, "Problems Running mysql_install_db".

4. After initializing the data directory, you can establish the final installation ownership settings. To leave the installation owned by `mysql`, no action is required here. Otherwise, most of the MySQL installation can be owned by `root` if you like. The exception is that the data directory must be owned by `mysql`. To accomplish this, run the following commands as `root` in the installation directory. For some distribution types, the data directory might be named `var` rather than `data`; adjust the second command accordingly.

```
shell> chown -R root .
shell> chown -R mysql data
```

If the plugin directory (the directory named by the `plugin_dir` system variable) is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making the plugin directory read only to the server or by setting the `secure_file_priv` system variable at server startup to a directory where `SELECT` writes can be performed safely.

5. If you installed MySQL using a source distribution, you may want to optionally copy one of the provided configuration files from the `support-files` directory into your `/etc` directory. There are different sample configuration files for different use cases, server types, and CPU and RAM configurations. To use one of these standard files, copy it to `/etc/my.cnf`, or `/etc/mysql/my.cnf` and edit and check the configuration before starting your MySQL server for the first time.

    You can also create `my.cnf` yourself and place into it the options the server should use at startup. See Section 5.1.2, "Server Configuration Defaults".

    If you do not copy one of the standard configuration files or create your own, the MySQL server starts with its default settings.

6. If you want MySQL to start automatically when you boot your machine, see Section 2.12.5, "Starting and Stopping MySQL Automatically".

Data directory initialization creates time zone tables in the `mysql` database but does not populate them. To do so, use the instructions in Section 10.6, "MySQL Server Time Zone Support".

2.12.1.1 Problems Running mysql_install_db

The purpose of the `mysql_install_db` program is to initialize the data directory, including the tables in the `mysql` system database. It does not overwrite existing MySQL privilege tables, and it does not affect any other data.

To re-create your privilege tables, first stop the `mysqld` server if it is running. Then rename the `mysql` directory under the data directory to save it, and run `mysql_install_db`. Suppose that your current directory is the MySQL installation directory and that `mysql_install_db` is located in the `bin` directory and the data directory is named `data`. To rename the `mysql` database and re-run `mysql_install_db`, use these commands.

```
shell> mv data/mysql data/mysql.old
shell> scripts/mysql_install_db --user=mysql
```

When you run `mysql_install_db`, you might encounter the following problems:

*   **`mysql_install_db` fails to install the grant tables**

    You may find that `mysql_install_db` fails to install the grant tables and terminates after displaying the following messages:

    ```
    Starting mysqld daemon with databases from XXXXXX
    mysqld ended
    ```

    In this case, you should examine the error log file very carefully. The log should be located in the directory XXXXXX named by the error message and should indicate why `mysqld` did not start. If you do not understand what happened, include the log when you post a bug report. See Section 1.7, "How to Report Bugs or Problems".

*   **There is a `mysqld` process running**

    This indicates that the server is running, in which case the grant tables have probably been created already. If so, there is no need to run `mysql_install_db` at all because it needs to be run only once, when you first install MySQL.

*   **Installing a second `mysqld` server does not work when one server is running**

This can happen when you have an existing MySQL installation, but want to put a new installation in a different location. For example, you might have a production installation, but you want to create a second installation for testing purposes. Generally the problem that occurs when you try to run a second server is that it tries to use a network interface that is in use by the first server. In this case, you should see one of the following error messages:

```
Can't start server: Bind on TCP/IP port:
Address already in use
Can't start server: Bind on unix socket...
```

For instructions on setting up multiple servers, see Section 5.5, "Running Multiple MySQL Instances on One Machine".

- **You do not have write access to the `/tmp` directory**

  If you do not have write access to create temporary files or a Unix socket file in the default location (the `/tmp` directory) or the `TMPDIR` environment variable, if it has been set, an error occurs when you run `mysql_install_db` or the `mysqld` server.

  You can specify different locations for the temporary directory and Unix socket file by executing these commands prior to starting `mysql_install_db` or `mysqld`, where *some_tmp_dir* is the full path name to some directory for which you have write permission:

  ```
  shell> TMPDIR=/some_tmp_dir/
  shell> MYSQL_UNIX_PORT=/some_tmp_dir/mysql.sock
  shell> export TMPDIR MYSQL_UNIX_PORT
  ```

  Then you should be able to run `mysql_install_db` and start the server with these commands:

  ```
  shell> scripts/mysql_install_db --user=mysql
  shell> bin/mysqld_safe --user=mysql &
  ```

  If `mysql_install_db` is located in the `bin` directory, modify the first command to `bin/mysql_install_db`.

  See Section B.5.3.6, "How to Protect or Change the MySQL Unix Socket File", and Section 2.14, "Environment Variables".

There are some alternatives to running the `mysql_install_db` program provided in the MySQL distribution:

- If you want the initial privileges to be different from the standard defaults, use account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to change the privileges *after* the grant tables have been set up. In other words, run `mysql_install_db`, and then use `mysql -u root mysql` to connect to the server as the MySQL `root` user so that you can issue the necessary statements. (See Section 13.7.1, "Account Management Statements".)

  To install MySQL on several machines with the same privileges, put the `CREATE USER`, `GRANT`, and `REVOKE` statements in a file and execute the file as a script using `mysql` after running `mysql_install_db`. For example:

  ```
  shell> scripts/mysql_install_db --user=mysql
  shell> bin/mysql -u root < your_script_file
  ```

This enables you to avoid issuing the statements manually on each machine.

- It is possible to re-create the grant tables completely after they have previously been created. You might want to do this if you are just learning how to use `CREATE USER`, `GRANT`, and `REVOKE` and have made so many modifications after running `mysql_install_db` that you want to wipe out the tables and start over.

  To re-create the grant tables, stop the server if it is running and remove the `mysql` database directory. Then run `mysql_install_db` again.

2.12.2 Starting the Server

This section describes how start the server on Unix and Unix-like systems. (For Windows, see Section 2.3.6.4, "Starting MySQL Server on Microsoft Windows for the First Time".) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 2.12.3, "Testing the Server".

Start the MySQL server like this:

```
shell> bin/mysqld_safe --user=mysql &
```

It is important that the MySQL server be run using an unprivileged (non-`root`) login account. To ensure this if you run `mysqld_safe` as `root`, include the `--user` option as shown. Otherwise, execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

For further instructions for running MySQL as an unprivileged user, see Section 6.1.5, "How to Run MySQL as a Normal User".

If the command fails immediately and prints `mysqld ended`, look for information in the error log (which by default is the *host_name*`.err` file in the data directory).

If the server is unable to access the data directory it starts or read the grant tables in the `mysql` database, it writes a message to its error log. Such problems can occur if you neglected to create the grant tables by initializing the data directory before proceeding to this step, or if you ran the command that initializes the data directory without the `--user` option. Remove the `data` directory and run the command with the `--user` option.

If you have other problems starting the server, see Section 2.12.2.1, "Troubleshooting Problems Starting the MySQL Server". For more information about `mysqld_safe`, see Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".

You can set up new accounts using the `bin/mysql_setpermission` script if you install the `DBI` and `DBD::mysql` Perl modules. See Section 4.6.14, "`mysql_setpermission` — Interactively Set Permissions in Grant Tables". For Perl module installation instructions, see Section 2.15, "Perl Installation Notes".

If you would like to use `mysqlaccess` and have the MySQL distribution in some nonstandard location, you must change the location where `mysqlaccess` expects to find the `mysql` client. Edit the `bin/mysqlaccess` script at approximately line 18. Search for a line that looks like this:

```
$MYSQL     = '/usr/local/bin/mysql';    # path to mysql executable
```

Change the path to reflect the location where `mysql` actually is stored on your system. If you do not do this, a `Broken pipe` error will occur when you run `mysqlaccess`.

2.12.2.1 Troubleshooting Problems Starting the MySQL Server

This section provides troubleshooting suggestions for problems starting the server. For additional suggestions for Windows systems, see Section 2.3.7, "Troubleshooting a Microsoft Windows MySQL Server Installation".

If you have problems starting the server, here are some things to try:

- Check the error log to see why the server does not start.

- Specify any special options needed by the storage engines you are using.

- Make sure that the server knows where to find the data directory.

- Make sure that the server can access the data directory. The ownership and permissions of the data directory and its contents must be set such that the server can read and modify them.

- Verify that the network interfaces the server wants to use are available.

Some storage engines have options that control their behavior. You can create a `my.cnf` file and specify startup options for the engines that you plan to use. If you are going to use storage engines that support transactional tables (`InnoDB`, `NDB`), be sure that you have them configured the way you want before starting the server:

If you are using `InnoDB` tables, see Section 14.6.2, "InnoDB Configuration".

If you are using MySQL Cluster, see Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1".

Storage engines will use default option values if you specify none, but it is recommended that you review the available options and specify explicit values for those for which the defaults are not appropriate for your installation.

When the `mysqld` server starts, it changes location to the data directory. This is where it expects to find databases and where it expects to write log files. The server also writes the pid (process ID) file in the data directory.

The data directory location is hardwired in when the server is compiled. This is where the server looks for the data directory by default. If the data directory is located somewhere else on your system, the server will not work properly. You can determine what the default path settings are by invoking `mysqld` with the `--verbose` and `--help` options.

If the default locations do not match the MySQL installation layout on your system, you can override them by specifying options to `mysqld` or `mysqld_safe` on the command line or in an option file.

To specify the location of the data directory explicitly, use the `--datadir` option. However, normally you can tell `mysqld` the location of the base directory under which MySQL is installed and it looks for the data directory there. You can do this with the `--basedir` option.

To check the effect of specifying path options, invoke `mysqld` with those options followed by the `--verbose` and `--help` options. For example, if you change location into the directory where `mysqld` is installed and then run the following command, it shows the effect of starting the server with a base directory of `/usr/local`:

```
shell> ./mysqld --basedir=/usr/local --verbose --help
```

You can specify other options such as `--datadir` as well, but `--verbose` and `--help` must be the last options.

Once you determine the path settings you want, start the server without `--verbose` and `--help`.

If `mysqld` is currently running, you can find out what path settings it is using by executing this command:

```
shell> mysqladmin variables
```

Or:

```
shell> mysqladmin -h host_name variables
```

`host_name` is the name of the MySQL server host.

If you get `Errcode 13` (which means `Permission denied`) when starting `mysqld`, this means that the privileges of the data directory or its contents do not permit server access. In this case, you change the permissions for the involved files and directories so that the server has the right to use them. You can also start the server as `root`, but this raises security issues and should be avoided.

Change location into the data directory and check the ownership of the data directory and its contents to make sure the server has access. For example, if the data directory is `/usr/local/mysql/var`, use this command:

```
shell> ls -la /usr/local/mysql/var
```

If the data directory or its files or subdirectories are not owned by the login account that you use for running the server, change their ownership to that account. If the account is named `mysql`, use these commands:

```
shell> chown -R mysql /usr/local/mysql/var
shell> chgrp -R mysql /usr/local/mysql/var
```

Even with correct ownership, MySQL might fail to start up if there is other security software running on your system that manages application access to various parts of the file system. In this case, reconfigure that software to enable `mysqld` to access the directories it uses during normal operation.

If the server fails to start up correctly, check the error log. Log files are located in the data directory (typically `C:\Program Files\MySQL\MySQL Server 5.1\data` on Windows, `/usr/local/mysql/data` for a Unix/Linux binary distribution, and `/usr/local/var` for a Unix/Linux source distribution). Look in the data directory for files with names of the form `host_name.err` and `host_name.log`, where `host_name` is the name of your server host. Then examine the last few lines of these files. You can use `tail` to display them:

```
shell> tail host_name.err
shell> tail host_name.log
```

The error log should contain information that indicates why the server could not start.

If either of the following errors occur, it means that some other program (perhaps another `mysqld` server) is using the TCP/IP port or Unix socket file that `mysqld` is trying to use:

```
Can't start server: Bind on TCP/IP port: Address already in use
Can't start server: Bind on unix socket...
```

Use `ps` to determine whether you have another `mysqld` server running. If so, shut down the server before starting `mysqld` again. (If another server is running, and you really want to run multiple servers, you can find information about how to do so in Section 5.5, "Running Multiple MySQL Instances on One Machine".)

If no other server is running, try to execute the command `telnet your_host_name tcp_ip_port_number`. (The default MySQL port number is 3306.) Then press Enter a couple of times. If you do not get an error message like `telnet: Unable to connect to remote host: Connection refused`, some other program is using the TCP/IP port that `mysqld` is trying to use. You will need to track down what program this is and disable it, or else tell `mysqld` to listen to a different port with the `--port` option. In this case, you will also need to specify the port number for client programs when connecting to the server using TCP/IP.

Another reason the port might be inaccessible is that you have a firewall running that blocks connections to it. If so, modify the firewall settings to permit access to the port.

If the server starts but you cannot connect to it, you should make sure that you have an entry in `/etc/hosts` that looks like this:

```
127.0.0.1       localhost
```

If you cannot get `mysqld` to start, you can try to make a trace file to find the problem by using the `--debug` option. See Section 22.4.3, "The DBUG Package".

2.12.3 Testing the Server

After the data directory is initialized and you have started the server, perform some simple tests to make sure that it works satisfactorily. This section assumes that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your shell (command interpreter) to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Section 4.2.10, "Setting Environment Variables".

Use `mysqladmin` to verify that the server is running. The following commands provide simple tests to check whether the server is up and responding to connections:

```
shell> bin/mysqladmin version
shell> bin/mysqladmin variables
```

If you cannot connect to the server, specify a `-u root` option to connect as `root`. If you have assigned a password for the `root` account already, you'll also need to specify `-p` on the command line and enter the password when prompted. For example:

```
shell> bin/mysqladmin -u root -p version
Enter password: (enter root password here)
```

The output from `mysqladmin version` varies slightly depending on your platform and version of MySQL, but should be similar to that shown here:

```
shell> bin/mysqladmin version
mysqladmin  Ver 14.12 Distrib 5.1.73, for pc-linux-gnu on i686
...

Server version         5.1.73
Protocol version       10
Connection             Localhost via UNIX socket
UNIX socket            /var/lib/mysql/mysql.sock
Uptime:                14 days 5 hours 5 min 21 sec
```

```
Threads: 1  Questions: 366  Slow queries: 0
Opens: 0  Flush tables: 1  Open tables: 19
Queries per second avg: 0.000
```

To see what else you can do with `mysqladmin`, invoke it with the `--help` option.

Verify that you can shut down the server (include a `-p` option if the `root` account has a password already):

```
shell> bin/mysqladmin -u root shutdown
```

Verify that you can start the server again. Do this by using `mysqld_safe` or by invoking `mysqld` directly. For example:

```
shell> bin/mysqld_safe --user=mysql &
```

If `mysqld_safe` fails, see Section 2.12.2.1, "Troubleshooting Problems Starting the MySQL Server".

Run some simple tests to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use `mysqlshow` to see what databases exist:

```
shell> bin/mysqlshow
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| test               |
+--------------------+
```

The list of installed databases may vary, but will always include the minimum of `mysql` and `information_schema`.

If you specify a database name, `mysqlshow` displays a list of the tables within the database:

```
shell> bin/mysqlshow mysql
Database: mysql
+---------------------------+
|          Tables           |
+---------------------------+
| columns_priv              |
| db                        |
| event                     |
| func                      |
| help_category             |
| help_keyword              |
| help_relation             |
| help_topic                |
| host                      |
| ndb_binlog_index          |
| plugin                    |
| proc                      |
| procs_priv                |
| servers                   |
| tables_priv               |
| time_zone                 |
| time_zone_leap_second     |
| time_zone_name            |
| time_zone_transition      |
| time_zone_transition_type |
```

```
| user                      |
+---------------------------+
```

Use the `mysql` program to select information from a table in the `mysql` database:

```
shell> bin/mysql -e "SELECT User, Host FROM mysql.user" mysql
+------+-----------+
| User | Host      |
+------+-----------+
| root | localhost |
+------+-----------+
```

There is a benchmark suite in the `sql-bench` directory (under the MySQL installation directory) that you can use to compare how MySQL performs on different platforms. The benchmark suite is written in Perl. It requires the Perl DBI module that provides a database-independent interface to the various databases, and some other additional Perl modules:

```
DBI
DBD::mysql
Data::Dumper
Data::ShowTable
```

These modules can be obtained from CPAN (http://www.cpan.org/). See also Section 2.15.1, "Installing Perl on Unix".

The `sql-bench/Results` directory contains the results from many runs against different databases and platforms. To run all tests, execute these commands:

```
shell> cd sql-bench
shell> perl run-all-tests
```

If you do not have the `sql-bench` directory, you probably installed MySQL using RPM files other than the source RPM. (The source RPM includes the `sql-bench` benchmark directory.) In this case, you must first install the benchmark suite before you can use it. There are separate benchmark RPM files named `mysql-bench-VERSION.i386.rpm` that contain benchmark code and data.

If you have a source distribution, there are also tests in its `tests` subdirectory that you can run. For example, to run `auto_increment.tst`, execute this command from the top-level directory of your source distribution:

```
shell> mysql -vvf test < ./tests/auto_increment.tst
```

The expected result of the test can be found in the `./tests/auto_increment.res` file.

At this point, your server is running and you can access it. To tighten security if you have not yet assigned passwords to the initial account or accounts, follow the instructions in Section 2.12.4, "Securing the Initial MySQL Accounts".

For more information about `mysql`, `mysqladmin`, and `mysqlshow`, see Section 4.5.1, "`mysql` — The MySQL Command-Line Tool", Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server", and Section 4.5.6, "`mysqlshow` — Display Database, Table, and Column Information".

2.12.4 Securing the Initial MySQL Accounts

The MySQL installation process involves initializing the data directory, including the `mysql` database containing the grant tables that define MySQL accounts. For details, see Section 2.12, "Postinstallation Setup and Testing".

This section describes how to assign passwords to the initial accounts created during the MySQL installation procedure, if you have not already done so.

The `mysql.user` grant table defines the initial MySQL user accounts and their access privileges:

- Some accounts have the user name `root`. These are superuser accounts that have all privileges and can do anything. If these `root` accounts have empty passwords, anyone can connect to the MySQL server as `root` *without a password* and be granted all privileges.

  - On Windows, `root` accounts are created that permit connections from the local host only. Connections can be made by specifying the host name `localhost` or the IP address `127.0.0.1`. If the user selects the **Enable root access from remote machines** option during installation, the Windows installer creates another `root` account that permits connections from any host.

  - On Unix, each `root` account permits connections from the local host. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, or the actual host name or IP address.

  An attempt to connect to the host `127.0.0.1` normally resolves to the `localhost` account. However, this fails if the server is run with the `--skip-name-resolve` option, so the `127.0.0.1` account is useful in that case.

- If accounts for anonymous users were created, these have an empty user name. The anonymous accounts have no password, so anyone can use them to connect to the MySQL server.

  - On Windows, there is one anonymous account that permits connections from the local host. Connections can be made by specifying a host name of `localhost`. The account has no global privileges. (Before MySQL 5.1.16, it has all global privileges, just like the `root` accounts.)

  - On Unix, each anonymous account permits connections from the local host. Connections can be made by specifying a host name of `localhost` for one of the accounts, or the actual host name or IP address for the other.

To display which accounts exist in the `mysql.user` table and check whether their passwords are empty, use the following statement:

```
mysql> SELECT User, Host, Password FROM mysql.user;
+------+-------------------+----------+
| User | Host              | Password |
+------+-------------------+----------+
| root | localhost         |          |
| root | myhost.example.com |          |
| root | 127.0.0.1         |          |
|      | localhost         |          |
|      | myhost.example.com |          |
+------+-------------------+----------+
```

This output indicates that there are several `root` and anonymous-user accounts, none of which have passwords. The output might differ on your system, but the presence of accounts with empty passwords means that your MySQL installation is unprotected until you do something about it:

- Assign a password to each MySQL `root` account that does not have one.

- To prevent clients from connecting as anonymous users without a password, either assign a password to each anonymous account or remove the accounts.

In addition, the `mysql.db` table contains rows that permit all accounts to access the `test` database and other databases with names that start with `test_`. This is true even for accounts that otherwise have no

special privileges such as the default anonymous accounts. This is convenient for testing but inadvisable on production servers. Administrators who want database access restricted only to accounts that have permissions granted explicitly for that purpose should remove these `mysql.db` table rows.

The following instructions describe how to set up passwords for the initial MySQL accounts, first for the `root` accounts, then for the anonymous accounts. The instructions also cover how to remove anonymous accounts, should you prefer not to permit anonymous access at all, and describe how to remove permissive access to test databases. Replace *new_password* in the examples with the password that you want to use. Replace *host_name* with the name of the server host. You can determine this name from the output of the preceding `SELECT` statement. For the output shown, *host_name* is `myhost.example.com`.

> **Note**
>
> For additional information about setting passwords, see Section 6.3.5, "Assigning Account Passwords". If you forget your `root` password after setting it, see Section B.5.3.2, "How to Reset the Root Password".
>
> To set up additional accounts, see Section 6.3.2, "Adding User Accounts".

You might want to defer setting the passwords until later, to avoid the need to specify them while you perform additional setup or testing. However, be sure to set them before using your installation for production purposes.

> **Note**
>
> On Windows, you can also perform the process described in this section using the Configuration Wizard (see Section 2.3.5.11, "MySQL Server Instance Config Wizard: The Security Options Dialog"). On all platforms, the MySQL distribution includes `mysql_secure_installation`, a command-line utility that automates much of the process of securing a MySQL installation.

Assigning root Account Passwords

A `root` account password can be set several ways. The following discussion demonstrates three methods:

- Use the `SET PASSWORD` statement

- Use the `UPDATE` statement

- Use the `mysqladmin` command-line client program

To assign passwords using `SET PASSWORD`, connect to the server as `root` and issue a `SET PASSWORD` statement for each `root` account listed in the `mysql.user` table.

For Windows, do this:

```
shell> mysql -u root
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'127.0.0.1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'%' = PASSWORD('new_password');
```

The last statement is unnecessary if the `mysql.user` table has no `root` account with a host value of `%`.

For Unix, do this:

```
shell> mysql -u root
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
```

```
mysql> SET PASSWORD FOR 'root'@'127.0.0.1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'host_name' = PASSWORD('new_password');
```

You can also use a single statement that assigns a password to all `root` accounts by using `UPDATE` to modify the `mysql.user` table directly. This method works on any platform:

```
shell> mysql -u root
mysql> UPDATE mysql.user SET Password = PASSWORD('new_password')
    ->       WHERE User = 'root';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the password change remains unnoticed by the server until you restart it.

To assign passwords to the `root` accounts using `mysqladmin`, execute the following commands:

```
shell> mysqladmin -u root password "new_password"
shell> mysqladmin -u root -h host_name password "new_password"
```

Those commands apply both to Windows and to Unix. The double quotation marks around the password are not always necessary, but you should use them if the password contains spaces or other characters that are special to your command interpreter.

The `mysqladmin` method of setting the `root` account passwords does not work for the `'root'@'127.0.0.1'` account. Use the `SET PASSWORD` method shown earlier.

After the `root` passwords have been set, you must supply the appropriate password whenever you connect as `root` to the server. For example, to shut down the server with `mysqladmin`, use this command:

```
shell> mysqladmin -u root -p shutdown
Enter password: (enter root password here)
```

The `mysql` commands in the following instructions include a `-p` option based on the assumption that you have assigned the `root` account passwords using the preceding instructions and must specify that password when connecting to the server.

Assigning Anonymous Account Passwords

To assign passwords to the anonymous accounts, connect to the server as `root`, then use either `SET PASSWORD` or `UPDATE`.

To use `SET PASSWORD` on Windows, do this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
```

To use `SET PASSWORD` on Unix, do this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR ''@'host_name' = PASSWORD('new_password');
```

To set the anonymous-user account passwords with a single `UPDATE` statement, do this (on any platform):

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> UPDATE mysql.user SET Password = PASSWORD('new_password')
    ->     WHERE User = '';
mysql> FLUSH PRIVILEGES;
```

The FLUSH statement causes the server to reread the grant tables. Without it, the password change remains unnoticed by the server until you restart it.

Removing Anonymous Accounts

If you prefer to remove any anonymous accounts rather than assigning them passwords, do so as follows on Windows:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DROP USER ''@'localhost';
```

On Unix, remove the anonymous accounts like this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DROP USER ''@'localhost';
mysql> DROP USER ''@'host_name';
```

Securing Test Databases

By default, the mysql.db table contains rows that permit access by any user to the test database and other databases with names that start with test_. (These rows have an empty User column value, which for access-checking purposes matches any user name.) This means that such databases can be used even by accounts that otherwise possess no privileges. If you want to remove any-user access to test databases, do so as follows:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DELETE FROM mysql.db WHERE Db LIKE 'test%';
mysql> FLUSH PRIVILEGES;
```

The FLUSH statement causes the server to reread the grant tables. Without it, the privilege change remains unnoticed by the server until you restart it.

With the preceding change, only users who have global database privileges or privileges granted explicitly for the test database can use it. However, if you prefer that the database not exist at all, drop it:

```
mysql> DROP DATABASE test;
```

2.12.5 Starting and Stopping MySQL Automatically

This section discusses methods for starting and stopping the MySQL server.

Generally, you start the mysqld server in one of these ways:

- Invoke mysqld directly. This works on any platform.

- On Windows, you can set up a MySQL service that runs automatically when Windows starts. See Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

- On Unix and Unix-like systems, you can invoke `mysqld_safe`, which tries to determine the proper options for `mysqld` and then runs it with those options. See Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".

- On systems that use System V-style run directories (that is, `/etc/init.d` and run-level specific directories), invoke `mysql.server`. This script is used primarily at system startup and shutdown. It usually is installed under the name `mysql`. The `mysql.server` script starts the server by invoking `mysqld_safe`. See Section 4.3.3, "`mysql.server` — MySQL Server Startup Script".

- On OS X, install a launchd daemon to enable automatic MySQL startup at system startup. The daemon starts the server by invoking `mysqld_safe`. For details, see Section 2.4.3, "Installing a MySQL Launch Daemon". A MySQL Preference Pane also provides control for starting and stopping MySQL through the System Preferences. See Section 2.4.5, "Installing and Using the MySQL Preference Pane".

- On Solaris/OpenSolaris, use the service management framework (SMF) system to initiate and control MySQL startup. For more information, see Section 2.6.2, "Installing MySQL on OpenSolaris Using IPS".

The `mysqld_safe` and `mysql.server` scripts, Solaris/OpenSolaris SMF, and the OS X Startup Item (or MySQL Preference Pane) can be used to start the server manually, or automatically at system startup time. `mysql.server` and the Startup Item also can be used to stop the server.

The following table shows which option groups the server and startup scripts read from option files.

Table 2.20 MySQL Startup Scripts and Supported Server Option Groups

Script	Option Groups
`mysqld`	`[mysqld]`, `[server]`, `[mysqld-major_version]`
`mysqld_safe`	`[mysqld]`, `[server]`, `[mysqld_safe]`
`mysql.server`	`[mysqld]`, `[mysql.server]`, `[server]`

`[mysqld-major_version]` means that groups with names like `[mysqld-5.0]` and `[mysqld-5.1]` are read by servers having versions 5.0.x, 5.1.x, and so forth. This feature can be used to specify options that can be read only by servers within a given release series.

For backward compatibility, `mysql.server` also reads the `[mysql_server]` group and `mysqld_safe` also reads the `[safe_mysqld]` group. However, you should update your option files to use the `[mysql.server]` and `[mysqld_safe]` groups instead.

For more information on MySQL configuration files and their structure and contents, see Section 4.2.6, "Using Option Files".

2.13 Upgrading or Downgrading MySQL

This section describes the steps to upgrade or downgrade a MySQL installation.

Upgrading is a common procedure, as you pick up bug fixes within the same MySQL release series or significant features between major MySQL releases. You perform this procedure first on some test systems to make sure everything works smoothly, and then on the production systems.

Downgrading is less common. Typically, you undo an upgrade because of some compatibility or performance issue that occurs on a production system, and was not uncovered during initial upgrade verification on the test systems. As with the upgrade procedure, perform and verify the downgrade procedure on some test systems first, before using it on a production system.

2.13.1 Upgrading MySQL

This section describes how to upgrade to a new MySQL version.

- Supported Upgrade Methods

- Supported Upgrade Paths

- Before You Begin

- Performing an In-place Upgrade

- Performing a Logical Upgrade

- Upgrade Troubleshooting

Supported Upgrade Methods

- *In-place Upgrade*: Involves shutting down the old MySQL version, replacing the old MySQL binaries or packages with the new ones, restarting MySQL on the existing data directory, and running `mysql_upgrade`.

- *Logical Upgrade*: Involves exporting existing data from the old MySQL version using `mysqldump`, installing the new MySQL version, loading the dump file into the new MySQL version, and running `mysql_upgrade`.

  Note

  MySQL recommends a `mysqldump` upgrade when upgrading from a previous release. For example, use this method when upgrading from 5.0 to 5.1.

For in-place and logical upgrade procedures, see Performing an In-place Upgrade, and Performing a Logical Upgrade.

If you run MySQL Server on Windows, see Section 2.3.9, "Upgrading MySQL Server on Microsoft Windows".

Supported Upgrade Paths

Unless otherwise documented, the following upgrade paths are supported:

- Upgrading from a release series version to a newer release series version is supported. For example, upgrading from 5.1.71 to 5.1.72 is supported. Skipping release series versions is also supported. For example, upgrading from 5.1.70 to 5.1.72 is supported.

- Upgrading one release level is supported. For example, upgrading from 5.0 to 5.1 is supported. Upgrading to the latest release series version is recommended before upgrading to the next release level. For example, upgrade to the latest 5.0 release before upgrading to 5.1.

- Upgrading more than one release level is supported, but only if you upgrade one release level at a time. For example, if you currently are running MySQL 4.1 and wish to upgrade to a newer series, upgrade to MySQL 5.0 first before upgrading to MySQL 5.1, and so forth. For information on upgrading to MySQL 5.0 see the *MySQL 5.0 Reference Manual*.

- Direct upgrades that skip a release level (for example, upgrading directly from MySQL 4.1 to 5.1) are not recommended or supported.

The following conditions apply to all upgrade paths:

- Upgrades between General Availability (GA) status releases are supported.

- Upgrades between milestone releases (or from a milestone release to a GA release) are not supported.

- For upgrades between versions of a MySQL release series that has reached GA status, you can move the MySQL format files and data files between different versions on systems with the same architecture. This is not necessarily true for upgrades between milestone releases. Use of milestone releases is at your own risk.

Before You Begin

Before upgrading, review the following information and perform the recommended steps:

- Before upgrading, protect your data by creating a backup of your current databases and log files. The backup should include the `mysql` database, which contains the MySQL system tables. See Section 7.2, "Database Backup Methods".

- Review the Release Notes which provide information about features that are new in the MySQL 5.1 or differ from those found in earlier MySQL releases. Some of these changes may result in incompatibilities.

- Review Section 2.13.1.1, "Changes Affecting Upgrades to 5.1". This section describes changes that may require action before or after upgrading.

- Check Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt", to see whether changes to table formats or to character sets or collations were made between your current version of MySQL and the version to which you are upgrading. If such changes have resulted in an incompatibility between MySQL versions, you will need to upgrade the affected tables using the instructions in Section 2.13.4, "Rebuilding or Repairing Tables or Indexes".

- If you use replication, see Section 16.4.3, "Upgrading a Replication Setup", for information on upgrading your replication setup.

- If you use XA transactions with `InnoDB`, run `XA RECOVER` before upgrading to check for uncommitted XA transactions. If results are returned, either commit or rollback the XA transactions by issuing an `XA COMMIT` or `XA ROLLBACK` statement.

- If your MySQL installation contains a large amount of data that might take a long time to convert after an in-place upgrade, you might find it useful to create a "dummy" database instance for assessing what conversions might be needed and the work involved to perform them. Make a copy of your MySQL instance that contains a full copy of the `mysql` database, plus all other databases without data. Run your upgrade procedure on this dummy instance to see what actions might be needed so that you can better evaluate the work involved when performing actual data conversion on your original database instance.

- Rebuilding and reinstalling the Perl `DBD::mysql` module whenever you install or upgrade to a new release of MySQL is recommended. The same applies to other MySQL interfaces as well, such as PHP `mysql` extensions and the Python `MySQLdb` module.

Performing an In-place Upgrade

This section describes how to perform an in-place upgrade. Review Before you Begin before proceeding.

Note

If you upgrade an installation originally produced by installing multiple RPM packages, upgrade all the packages, not just some. For example, if you previously installed the server and client RPMs, do not upgrade just the server RPM.

To perform an in-place upgrade:

1. Review the changes described in Section 2.13.1.1, "Changes Affecting Upgrades to 5.1" for steps to be performed before upgrading.

2. If you use `InnoDB`, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to `0`. For example:

```
shell> bin/mysql -u root -ppassword --execute="set global innodb_fast_shutdown=0"
```

With a slow shutdown, `InnoDB` performs a full purge and change buffer merge before shutting down, which ensures that data files are fully prepared in case of file format differences between releases.

3. Shut down the old MySQL server. For example:

```
shell> bin/mysqladmin -u root -ppassword shutdown
```

4. Upgrade the MySQL binaries or packages in place (replace the old binaries with the new ones).

5. Start the MySQL 5.1 server, using the existing data directory. For example:

```
shell> bin/mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
```

6. Run `mysql_upgrade`. For example:

```
shell> bin/mysql_upgrade -u root -ppassword
```

`mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL. `mysql_upgrade` also upgrades the system tables so that you can take advantage of new privileges or capabilities.

> **Note**
>
> `mysql_upgrade` does not upgrade the contents of the help tables. For upgrade instructions, see Section 5.1.9, "Server-Side Help".

Performing a Logical Upgrade

This section describes how to perform a logical upgrade. Review Before you Begin before proceeding.

To perform a logical upgrade:

1. Review the changes described in Section 2.13.1.1, "Changes Affecting Upgrades to 5.1" for steps to be performed before upgrading.

2. Export your existing data from the previous MySQL version:

```
shell> mysqldump --add-drop-table --routines --events
    -> --all-databases --force > data-for-upgrade.sql
```

> **Note**
>
> Use the `--routines` and `--events` options with `mysqldump` (as shown above) if your databases include stored programs. The `--all-databases` option includes all databases in the dump, including the `mysql` database that holds the system tables.

3. Shut down the old MySQL server. For example:

```
shell> bin/mysqladmin -u root -ppassword shutdown
```

4. Install MySQL 5.1. For installation instructions, see Chapter 2, *Installing and Upgrading MySQL*.

5. Initialize a new data directory:

```
shell> scripts/mysql_install_db --user=mysql --datadir=/path/to/5.1-datadir
```

6. Start the MySQL 5.1 server, using the new data directory. For example:

```
shell> bin/mysqld_safe --user=mysql --datadir=/path/to/5.1-datadir
```

7. Load the previously created dump file into the new MySQL server. For example:

```
shell> bin/mysql -u root -ppassword --execute="source data-for-upgrade.sql" --force
```

8. Run `mysql_upgrade`. For example:

```
shell> bin/mysql_upgrade -u root -ppassword
```

`mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL. `mysql_upgrade` also upgrades the system tables so that you can take advantage of new privileges or capabilities.

> **Note**
>
> `mysql_upgrade` does not upgrade the contents of the help tables. For upgrade instructions, see Section 5.1.9, "Server-Side Help".

9. If you use `InnoDB`, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to `0`. For example:

```
shell> bin/mysql -u root -ppassword --execute="set global innodb_fast_shutdown=0"
```

10. Shut down and restart the MySQL server to ensure a clean shutdown and startup. For example:

```
shell> bin/mysqladmin -u root -ppassword shutdown
shell> bin/mysqld_safe --user=mysql --datadir=/path/to/5.1-datadir
```

Upgrade Troubleshooting

- If problems occur, such as that the new `mysqld` server does not start or that you cannot connect without a password, verify that you do not have an old `my.cnf` file from your previous installation. You can check this with the `--print-defaults` option (for example, `mysqld --print-defaults`). If this command displays anything other than the program name, you have an active `my.cnf` file that affects server or client operation.

- If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, you probably have used old header or library files when compiling your programs. In this case, check the date for your `mysql.h` file and `libmysqlclient.a` library to verify that they are from the new MySQL distribution. If not, recompile your programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example from `libmysqlclient.so.15` to `libmysqlclient.so.16`.

- If you have created a user-defined function (UDF) with a given name and upgrade MySQL to a version that implements a new built-in function with the same name, the UDF becomes inaccessible. To correct this, use `DROP FUNCTION` to drop the UDF, and then use `CREATE FUNCTION` to re-create the UDF with a different nonconflicting name. The same is true if the new version of MySQL implements a built-

in function with the same name as an existing stored function. See Section 9.2.4, "Function Name Parsing and Resolution", for the rules describing how the server interprets references to different kinds of functions.

2.13.1.1 Changes Affecting Upgrades to 5.1

Before upgrading to MySQL 5.1, review the changes described in this section to identify upgrade issues that apply to your current MySQL installation and applications.

> **Note**
>
> In addition to the changes outlined in this section, review the Release Notes and other important information outlined in Before You Begin.

Changes marked as either **Known issue** or **Incompatible change** are incompatibilities with earlier versions of MySQL, and may require your attention *before you upgrade*. Our aim is to avoid these changes, but occasionally they are necessary to correct problems that would be worse than an incompatibility between releases. If any upgrade issue applicable to your installation involves an incompatibility that requires special handling, follow the instructions given in the incompatibility description. Sometimes this involves dumping and reloading tables, or use of a statement such as `CHECK TABLE` or `REPAIR TABLE`.

For dump and reload instructions, see Section 2.13.4, "Rebuilding or Repairing Tables or Indexes". Any procedure that involves `REPAIR TABLE` with the `USE_FRM` option *must* be done before upgrading. Use of this statement with a version of MySQL different from the one used to create the table (that is, using it after upgrading) may damage the table. See Section 13.7.2.6, "REPAIR TABLE Syntax".

- Configuration Changes

- System Table Changes

- Server Changes

- SQL Changes

- C API Changes

Configuration Changes

- Before MySQL 5.1.11, to build MySQL from source with SSL support enabled, you would invoke `configure` with either the `--with-openssl` or `--with-yassl` option. In MySQL 5.1.11, those options both have been replaced by the `--with-ssl` option. By default, `--with-ssl` causes the bundled yaSSL library to be used. To select OpenSSL instead, give the option as `--with-ssl=path`, where `path` is the directory where the OpenSSL header files and libraries are located.

System Table Changes

- **After upgrading a 5.0 installation to 5.0.10 or above**, it is *necessary* to upgrade your grant tables using `mysql_upgrade`. Otherwise, creating stored procedures and functions might not work. Running `mysql_upgrade` is part of the the in-place and logical upgrade procedures.

Server Changes

- As of MySQL 5.1.9, the `mysqld-max` server is included in binary distributions. There is no separate MySQL-Max distribution. As of MySQL 5.1.12, there is no `mysqld-max` server at all in binary distributions. They contain a server that includes the features previously included in `mysqld-max`.

- **Known issue**: As of MySQL 5.1.70, for new installations, the `url` columns in the `mysql` datatbase help tables are now created as type `TEXT` to accommodate longer URLs. For upgrades, `mysql_upgrade` does *not* update the columns. Modify them manually using these statements:

```
ALTER TABLE mysql.help_category MODIFY url TEXT NOT NULL;
ALTER TABLE mysql.help_topic MODIFY url TEXT NOT NULL;
```

- **Known issue**: `mysql_upgrade` attempts to upgrade tables that are incompatible with the current version of MySQL. (It invokes `mysqlcheck` to check tables and, if necessary, repair them.) However this can fail for storage engines that do not support *REPAIR TABLE*, such as `InnoDB`, and leave tables in a nonupgradable state.

  To work around this problem, use `ALTER TABLE` *tbl_name* `ENGINE=InnoDB` to perform a "null" alter operation that rebuilds the table.

- **Known issue**: After a binary upgrade to MySQL 5.1 from a MySQL 5.0 installation that contains `ARCHIVE` tables:

  - Before MySQL 5.1.42, accessing those tables will cause the server to crash, even if you have run `mysql_upgrade` or `CHECK TABLE ... FOR UPGRADE`.

  - As of MySQL 5.1.42, the server will not open 5.0 `ARCHIVE` tables at all.

  In either case, the solution is to use `mysqldump` to dump all 5.0 `ARCHIVE` tables before upgrading, and reload them into MySQL 5.1 after upgrading. This problem is fixed in MySQL 5.6.4: The server can open `ARCHIVE` tables created in MySQL 5.0. However, it remains the recommended upgrade procedure to dump 5.0 `ARCHIVE` tables before upgrading and reload them after upgrading.

- **Known issue**: The fix for Bug #23491 introduced a problem with `SHOW CREATE VIEW`, which is used by `mysqldump`. This causes an incompatibility when upgrading from versions affected by that bug fix (MySQL 5.0.40 through 5.0.43, MySQL 5.1.18 through 5.1.19): If you use `mysqldump` before upgrading from an affected version and reload the data after upgrading to a higher version, you must drop and recreate your views.

- **Known issue**: Dumps performed by using `mysqldump` to generate a dump file before the upgrade and reloading the file after upgrading are subject to the following problem:

  Before MySQL 5.0.40, `mysqldump` displays `SPATIAL` index definitions using prefix lengths for the indexed columns. These prefix lengths are accepted in MySQL 5.0, but not as of MySQL 5.1. If you use `mysqldump` from versions of MySQL older than 5.0.40, any table containing `SPATIAL` indexes will cause an error when the dump file is reloaded into MySQL 5.1 or higher.

  For example, a table definition might look like this when dumped in MySQL 5.0:

```
CREATE TABLE `t` (
 `g` geometry NOT NULL,
 SPATIAL KEY `g` (`g`(32))
) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

  The `SPATIAL` index definition will not be accepted in MySQL 5.1. To work around this, edit the dump file to remove the prefix:

```
CREATE TABLE `t` (
 `g` geometry NOT NULL,
 SPATIAL KEY `g` (`g`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

Dump files can be large, so it may be preferable to dump table definitions and data separately to make it easier to edit the definitions:

```
shell> mysqldump --no-data other_args > definitions.sql
shell> mysqldump --no-create-info other_args > data.sql
```

Then edit `definitions.sql` before reloading `definitions.sql` and `data.sql`, in that order.

If you upgrade to a version of MySQL 5.0 higher than 5.0.40 before upgrading to MySQL 5.1, this problem does not occur.

- **Known issue**: Before MySQL 5.1.30, the `CHECK TABLE ... FOR UPGRADE` statement did not check for incompatible collation changes made in MySQL 5.1.24. (This also affects `mysqlcheck` and `mysql_upgrade`, which cause that statement to be executed.)

  Prior to the fix made in 5.1.30, a binary upgrade (performed without dumping tables with `mysqldump` before the upgrade and reloading the dump file after the upgrade) would corrupt tables. After the fix, `CHECK TABLE ... FOR UPGRADE` properly detects the problem and warns about tables that need repair.

  However, the fix is not backward compatible and can result in a downgrading problem under these circumstances:

  1. Perform a binary upgrade to a version of MySQL that includes the fix.

  2. Run `CHECK TABLE ... FOR UPGRADE` (or `mysqlcheck` or `mysql_upgrade`) to upgrade tables.

  3. Perform a binary downgrade to a version of MySQL that does not include the fix.

  The solution is to dump tables with `mysqldump` before the downgrade and reload the dump file after the downgrade. Alternatively, drop and recreate affected indexes.

- **Known issue**: MySQL introduces encoding for table names that have non-ASCII characters (see Section 9.2.3, "Mapping of Identifiers to File Names"). After a binary upgrade from MySQL 5.0 to 5.1 or higher, the server recognizes names that have non-ASCII characters and adds a `#mysql50#` prefix to them.

  As of MySQL 5.1.31, `mysql_upgrade` encodes these names by executing the following command:

```
mysqlcheck --all-databases --check-upgrade --fix-db-names --fix-table-names
```

  Prior to MySQL 5.1.31, `mysql_upgrade` does not execute this command, so you should execute it manually if you have database or table names that contain nonalphanumeric characters.

  Prior to MySQL 5.1.23, the `mysqlcheck` command does not perform the name encoding for views. To work around this problem, drop each affected view and recreate it.

  `mysqlcheck` cannot fix names that contain literal instances of the `@` character that is used for encoding special characters. If you have databases or tables that contain this character, use `mysqldump` to dump them before upgrading to MySQL 5.1, and then reload the dump file after upgrading.

- **Known issue**: When upgrading from MySQL 5.0 to versions of 5.1 prior to 5.1.23, running `mysqlcheck` (or `mysql_upgrade`, which runs `mysqlcheck`) to upgrade tables fails for names that must be written as quoted identifiers. To work around this problem, rename each affected table to a name that does not require quoting:

```
RENAME TABLE `tab``le_a` TO table_a;
RENAME TABLE `table b` TO table_b;
```

After renaming the tables, run the `mysql_upgrade` program. Then rename the tables back to their original names:

```
RENAME TABLE table_a TO `tab``le_a`;
RENAME TABLE table_b TO `table b`;
```

- **Known issue**: In connection with view creation, the server created `arc` directories inside database directories and maintained useless copies of `.frm` files there. Creation and renaming procedures of those copies as well as creation of `arc` directories has been discontinued in MySQL 5.1.29.

  This change does cause a problem when downgrading to older server versions which manifests itself under these circumstances:

  1. Create a view `v_orig` in MySQL 5.1.29 or higher.

  2. Rename the view to `v_new` and then back to `v_orig`.

  3. Downgrade to an older 5.1.x server and run `mysql_upgrade`.

  4. Try to rename `v_orig` to `v_new` again. This operation fails.

  As a workaround to avoid this problem, use either of these approaches:

  - Dump your data using `mysqldump` before downgrading and reload the dump file after downgrading.

  - Instead of renaming a view after the downgrade, drop it and recreate it.

- **Incompatible change**: Character set or collation changes may require table indexes to be rebuilt. In MySQL 5.1, these occurred in versions 5.1.21, 5.1.23, and 5.1.24. For details, see Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt".

- **Incompatible change**: Prior to MySQL 5.1.51, if you flushed the logs using `FLUSH LOGS` or `mysqladmin flush-logs` and `mysqld` was writing the error log to a file (for example, if it was started with the `--log-error` option), it renames the current log file with the suffix `-old`, then created a new empty log file. This had the problem that a second log-flushing operation thus caused the original error log file to be lost unless you saved it under a different name. For example, you could use the following commands to save the file:

```
shell> mysqladmin flush-logs
shell> mv host_name.err-old backup-directory
```

To avoid the preceding file-loss problem, no renaming occurs as of MySQL 5.1.51; the server merely closes and reopens the log file. To rename the file, you can do so manually before flushing. Then flushing the logs reopens a new file with the original file name. For example, you can rename the file and create a new one using the following commands:

```
shell> mv host_name.err host_name.err-old
shell> mysqladmin flush-logs
shell> mv host_name.err-old backup-directory
```

- **Incompatible change**: MySQL 5.1 implements support for a plugin API that enables the loading and unloading of components at runtime, without restarting the server. Section 22.2, "The MySQL

Plugin API". The plugin API requires the `mysql.plugin` table. After upgrading from an older version of MySQL, you should run the `mysql_upgrade` command to create this table. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

Plugins are installed in the directory named by the `plugin_dir` system variable. This variable also controls the location from which the server loads user-defined functions (UDFs), which is a change from earlier versions of MySQL. That is, all UDF library files now must be installed in the plugin directory. When upgrading from an older version of MySQL, you must migrate your UDF files to the plugin directory.

- **Incompatible change**: The `table_cache` system variable has been renamed to `table_open_cache`. Any scripts that refer to `table_cache` must be updated to use the new name.

- **Incompatible change**: In MySQL 5.1.36, options for loading plugins such as pluggable storage engines were changed from boolean to tristate format. The implementations overlap, but if you previously used options of the form `--plugin_name=0` or `--plugin_name=1`, you should instead use `--plugin_name=OFF` or `--plugin_name=ON`, respectively. For details, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

- **Incompatible change**: From MySQL 5.1.24 to 5.1.31, the `UPDATE` statement was changed such that assigning `NULL` to a `NOT NULL` column caused an error even when strict SQL mode was not enabled. The original behavior before MySQL 5.1.24 was that such assignments caused an error only in strict SQL mode, and otherwise set the column to the implicit default value for the column data type and generated a warning. (For information about implicit default values, see Section 11.6, "Data Type Default Values".)

  The change caused compatibility problems for applications that relied on the original behavior. It also caused replication problems between servers that had the original behavior and those that did not, for applications that assigned `NULL` to `NOT NULL` columns in `UPDATE` statements without strict SQL mode enabled. The change was reverted in MySQL 5.1.32 so that `UPDATE` again had the original behavior. Problems can still occur if you replicate between servers that have the modified `UPDATE` behavior and those that do not.

- **Incompatible change**: As of MySQL 5.1.29, the default binary logging mode has been changed from `MIXED` to `STATEMENT` for compatibility with MySQL 5.0.

- **Incompatible change**: In MySQL 5.1.25, a change was made to the way that the server handles prepared statements. This affects prepared statements processed at the SQL level (using the `PREPARE` statement) and those processed using the binary client/server protocol (using the `mysql_stmt_prepare()` C API function).

  Previously, changes to metadata of tables or views referred to in a prepared statement could cause a server crash when the statement was next executed, or perhaps an error at execute time with a crash occurring later. For example, this could happen after dropping a table and recreating it with a different definition.

  Now metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. Metadata changes occur for DDL statements such as those that create, drop, alter, rename, or truncate tables, or that analyze, optimize, or repair tables. Repreparation also occurs after referenced tables or views are flushed from the table definition cache, either implicitly to make room for new entries in the cache, or explicitly due to `FLUSH TABLES`.

  Repreparation is automatic, but to the extent that it occurs, performance of prepared statements is diminished.

Table content changes (for example, with `INSERT` or `UPDATE`) do not cause repreparation, nor do `SELECT` statements.

An incompatibility with previous versions of MySQL is that a prepared statement may now return a different set of columns or different column types from one execution to the next. For example, if the prepared statement is `SELECT * FROM t1`, altering `t1` to contain a different number of columns causes the next execution to return a number of columns different from the previous execution.

Older versions of the client library cannot handle this change in behavior. For applications that use prepared statements with the new server, an upgrade to the new client library is strongly recommended.

Along with this change to statement repreparation, the default value of the `table_definition_cache` system variable has been increased from 128 to 256. The purpose of this increase is to lessen the chance that prepared statements will need repreparation due to referred-to tables/views having been flushed from the cache to make room for new entries.

A new status variable, `Com_stmt_reprepare`, has been introduced to track the number of repreparations.

- **Incompatible change**: The `-`, `*`, and `/` operators and the functions `POW()` and `EXP()` could misbehave when used with floating-point numbers. Previously they might return `+INF`, `-INF`, or `NaN` in cases of numeric overflow (including that caused by division by zero) or when invalid arguments were used. As of MySQL 5.1.24, `NULL` is returned in all such cases.

- **Incompatible change**: As of MySQL 5.1.23, within a stored routine, it is no longer permissible to declare a cursor for a `SHOW` or `DESCRIBE` statement. This happened to work in some instances, but is no longer supported. In many cases, a workaround for this change is to use the cursor with a `SELECT` query to read from an `INFORMATION_SCHEMA` table that produces the same information as the `SHOW` statement.

- **Incompatible change**: `SHOW CREATE VIEW` displays view definitions using an `AS alias_name` clause for each column. If a column is created from an expression, the default alias is the expression text, which can be quite long. As of MySQL 5.1.23, aliases for column names in `CREATE VIEW` statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters). As a result, views created from the output of `SHOW CREATE VIEW` fail if any column alias exceeds 64 characters. This can cause problems for replication or loading dump files. For additional information and workarounds, see Section C.4, "Restrictions on Views".

- **Incompatible change**: Several issues were identified for stored programs (stored procedures and functions, triggers, and events) and views containing non-ASCII symbols. These issues involved conversion errors due to incomplete character set information when translating these objects to and from stored format.

  To address these problems, the representation for these objects was changed in MySQL 5.1.21. However, the fixes affect *all* stored programs and views. (For example, you will see warnings about "no creation context.") To avoid warnings from the server about the use of old definitions from any release prior to 5.1.21, you should dump stored programs and views with `mysqldump` after upgrading to 5.1.21 or higher, and then reload them to recreate them with new definitions. Invoke `mysqldump` with a `--default-character-set` option that names the non-ASCII character set that was used for the definitions when the objects were originally created, and the `--routines`, `--events`, and `--triggers` options to dump stored program definitions.

  Upgrading for triggers in particular must be handled carefully, for two reasons:

- The output from `mysqldump` does not contain a `DROP TRIGGER` statement preceding each `CREATE TRIGGER` statement, so reloading the dump file will fail to re-create the triggers unless you manually drop them after generating the dump file and before reloading it.

- If you are upgrading from a very old version of MySQL 5.0 (before 5.0.10), the trigger upgrade procedure is different because triggers for those versions were created using a different namespace (trigger names had to be unique per table, rather than per schema as is true now).

Assuming that you are upgrading from MySQL 5.0.10 to 5.1.20 to MySQL 5.1.21 or later, use the following procedure to upgrade your triggers:

- Use `mysqldump` to generate a dump file that contains the trigger definitions:

```
mysqldump --triggers --no-create-db --no-data
          --no-create-info --all-databases > triggers.sql
```

  You might need to add options to specify connection parameters, such as `--user` or `--password`. Also, if you are updating from a version of MySQL 5.1 older than 5.1.21, you may need to include a `--default-character-set` option that specifies the non-ASCII character set that was used for the definitions when the triggers were originally created.

  Otherwise, invoke `mysqldump` with exactly the preceding options to avoid generating a dump file that will not have the intended effect when reloaded. For example, if you omit the `--no-create-db` option, your databases will be removed and recreated with no contents when you reload the dump file.

- Drop existing triggers. To see which triggers exist, use this statement:

```
SELECT TRIGGER_SCHEMA, EVENT_OBJECT_TABLE, TRIGGER_NAME
FROM INFORMATION_SCHEMA.TRIGGERS;
```

  To generate `DROP TRIGGERS` statements for the triggers, use this statement:

```
SELECT CONCAT('DROP TRIGGER ', TRIGGER_SCHEMA, '.', TRIGGER_NAME, ';')
FROM INFORMATION_SCHEMA.TRIGGERS
INTO OUTFILE '/tmp/drop_triggers.sql';
```

  The statement uses `INTO OUTFILE`, so you must have the `FILE` privilege. The file will be created on the server host. Use a different file name if you like. To be 100% safe, inspect the trigger definitions in the `drop_triggers.sql` file, and perhaps make a backup of the file. Then execute the statements in the file:

```
mysql --force < /tmp/drop_triggers.sql
```

- Recreate the triggers by reloading the dump file created earlier:

```
mysql --force < triggers.sql
```

For upgrades from a version of MySQL older than 5.0.10 to MySQL 5.1.21 or later, use the following procedure to upgrade your triggers:

1. Upgrade to MySQL 5.1 to be able to access trigger information in the `INFORMATION_SCHEMA.TRIGGERS` table. (This should work even for pre-5.0.10 triggers.)

2. Dump all trigger definitions using the following `SELECT` statement:

```
SELECT CONCAT('CREATE TRIGGER ', t.TRIGGER_SCHEMA, '.', t.TRIGGER_NAME,
              ' ', t.ACTION_TIMING, ' ', t.EVENT_MANIPULATION, ' ON ',
              t.EVENT_OBJECT_SCHEMA, '.', t.EVENT_OBJECT_TABLE,
              ' FOR EACH ROW ', t.ACTION_STATEMENT, '//' )
INTO OUTFILE '/tmp/triggers.sql'
FROM INFORMATION_SCHEMA.TRIGGERS AS t;
```

The statement uses `INTO OUTFILE`, so you must have the `FILE` privilege. The file will be created on the server host. Use a different file name if you like. To be 100% safe, inspect the trigger definitions in the `triggers.sql` file, and perhaps make a backup of the file.

3. Stop the server and drop all triggers by removing all `.TRG` files in your database directories. Change location to your data directory and issue this command:

```
shell> rm */*.TRG
```

4. Start the server and re-create all triggers using the `triggers.sql` file:

```
mysql> delimiter // ;
mysql> source /tmp/triggers.sql //
```

5. Use the `SHOW TRIGGERS` statement to check that all triggers were created successfully.

- **Incompatible change**: As of MySQL 5.1.20, `mysqld_safe` supports error logging to `syslog` on systems that support the `logger` command. The new `--syslog` and `--skip-syslog` options can be used instead of the `--log-error` option to control logging behavior, as described in Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".

  In 5.1.21 and up, the default is `--skip-syslog`, which is compatible with the default behavior of writing an error log file for releases prior to 5.1.20.

  In 5.1.20 *only*, the following conditions apply: 1) The default is to use `syslog`, which is not compatible with releases prior to 5.1.20. 2) Logging to `syslog` may fail to operate correctly in some cases. For these reasons, avoid using MySQL 5.1.20.

- **Incompatible change**: As of MySQL 5.1.18, the plugin interface and its handling of system variables was changed. Command-line options such as `--skip-innodb` now cause an error if `InnoDB` is not built-in or plugin-loaded. You should use `--loose-skip-innodb` if you do not want any error even if `InnoDB` is not available. The `--loose` prefix modifier should be used for all command-line options where you are uncertain whether the plugin exists and when you want the operation to proceed even if the option is necessarily ignored due to the absence of the plugin. (For a description of how `--loose` works, see Section 4.2.4, "Using Options on the Command Line".)

- **Incompatible change**: As of MySQL 5.1.15, `InnoDB` rolls back only the last statement on a transaction timeout. A new option, `--innodb_rollback_on_timeout`, causes `InnoDB` to abort and roll back the entire transaction if a transaction timeout occurs (the same behavior as in MySQL 4.1).

- **Incompatible change**: As of MySQL 5.1.15, the following conditions apply to enabling the `read_only` system variable:

  - If you attempt to enable `read_only` while you have any explicit locks (acquired with `LOCK TABLES` or have a pending transaction, an error will occur.

- If other clients hold explicit table locks or have pending transactions, the attempt to enable `read_only` blocks until the locks are released and the transactions end. While the attempt to enable `read_only` is pending, requests by other clients for table locks or to begin transactions also block until `read_only` has been set.

- `read_only` can be enabled while you hold a global read lock (acquired with `FLUSH TABLES WITH READ LOCK`) because that does not involve table locks.

Previously, the attempt to enable `read_only` would return immediately even if explicit locks or transactions were pending, so some data changes could occur for statements executing in the server at the same time.

- **Incompatible change**: The number of function names affected by `IGNORE_SPACE` was reduced significantly in MySQL 5.1.13, from about 200 to about 30. (For details about `IGNORE_SPACE`, see Section 9.2.4, "Function Name Parsing and Resolution".) This change improves the consistency of parser operation. However, it also introduces the possibility of incompatibility for old SQL code that relies on the following conditions:

  - `IGNORE_SPACE` is disabled.

  - The presence or absence of whitespace following a function name is used to distinguish between a built-in function and stored function that have the same name (for example, `PI()` versus `PI ()`).

For functions that are no longer affected by `IGNORE_SPACE` as of MySQL 5.1.13, that strategy no longer works. Either of the following approaches can be used if you have code that is subject to the preceding incompatibility:

  - If a stored function has a name that conflicts with a built-in function, refer to the stored function with a schema name qualifier, regardless of whether whitespace is present. For example, write *schema_name*`.PI()` or *schema_name*`.PI ()`.

  - Alternatively, rename the stored function to use a nonconflicting name and change invocations of the function to use the new name.

- **Incompatible change**: For `utf8` columns, the full-text parser incorrectly considered several nonword punctuation and whitespace characters as word characters, causing some searches to return incorrect results. The fix involves a change to the full-text parser in MySQL 5.1.12, so as of 5.1.12, any tables that have `FULLTEXT` indexes on `utf8` columns must be repaired with `REPAIR TABLE`:

```
REPAIR TABLE tbl_name QUICK;
```

- **Incompatible change**: Storage engines can be pluggable at runtime, so the distinction between disabled and invalid storage engines no longer applies. As of MySQL 5.1.12, this affects the `NO_ENGINE_SUBSTITUTION` SQL mode, as described in Section 5.1.7, "Server SQL Modes".

- **Incompatible change**: The structure of `FULLTEXT` indexes has been changed in MySQL 5.1.6. After upgrading to MySQL 5.1.6 or greater, any tables that have `FULLTEXT` indexes must be repaired with `REPAIR TABLE`:

```
REPAIR TABLE tbl_name QUICK;
```

- **Incompatible change**: In MySQL 5.1.6, when log tables were implemented, the default log destination for the general query and slow query log was `TABLE`. As of MySQL 5.1.21, this default has been changed to `FILE`, which is compatible with MySQL 5.0, but incompatible with earlier releases of MySQL 5.1. If you are upgrading from MySQL 5.0 to 5.1.21 or higher, no logging option changes should be

necessary. However, if you are upgrading from 5.1.6 through 5.1.20 to 5.1.21 or higher and were using `TABLE` logging, use the `--log-output=TABLE` option explicitly to preserve your server's table-logging behavior.

- **Incompatible change**: In very old versions of MySQL (prior to 4.1), the `TIMESTAMP` data type supported a display width, which was silently ignored beginning with MySQL 4.1. This is deprecated in MySQL 5.1, and removed altogether in MySQL 5.5. These changes in behavior can lead to two problem scenarios when trying to use `TIMESTAMP(N)` columns with a MySQL 5.5 or later server:

  - When importing a dump file (for example, one created using `mysqldump`) created in a MySQL 5.0 or earlier server into a server from a newer release series, a `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP(N)` causes the import to fail with a syntax error.

    To fix this problem, edit the dump file in a text editor to replace any instances of `TIMESTAMP(N)` with `TIMESTAMP` prior to importing the file. Be sure to use a plain text editor for this, and not a word processor; otherwise, the result is almost certain to be unusable for importing into the MySQL server.

  You should try to handle potential issues of these types proactively by updating with `ALTER TABLE` any `TIMESTAMP(N)` columns in your databases so that they use `TIMESTAMP` instead, before performing any upgrades.

- **Incompatible change**: For `ENUM` columns that had enumeration values containing commas, the commas were mapped to `0xff` internally. However, this rendered the commas indistinguishable from true `0xff` characters in the values. This no longer occurs. However, the fix requires that you dump and reload any tables that have `ENUM` columns containing true `0xff` in their values: Dump the tables using `mysqldump` with the current server before upgrading from a version of MySQL 5.1 older than 5.1.15 to version 5.1.15 or newer.

- As of MySQL 5.1.12, the `lc_time_names` system variable specifies the locale that controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()` and `MONTHNAME()` functions. See Section 10.7, "MySQL Server Locale Support".

- As of MySQL 5.1.9, `mysqld_safe` no longer implicitly invokes `mysqld-max` if it exists. Instead, it invokes `mysqld` unless a `--mysqld` or `--mysqld-version` option is given to specify another server explicitly. If you previously relied on the implicit invocation of `mysqld-max`, you should use an appropriate option now. As of MySQL 5.1.12, there is no longer any separate `mysqld-max` server, so no change should be necessary.

SQL Changes

- **Known issue**: Prior to MySQL 5.1.17, the parser accepted invalid code in SQL condition handlers, leading to server crashes or unexpected execution behavior in stored programs. Specifically, the parser permitted a condition handler to refer to labels for blocks that enclose the handler declaration. This was incorrect because block label scope does not include the code for handlers declared within the labeled block.

  As of 5.1.17, the parser rejects this invalid construct, but if you perform a binary upgrade (without dumping and reloading your databases), existing handlers that contain the construct still are invalid and should be rewritten *even if they appear to function as you expect.*

  To find affected handlers, use `mysqldump` to dump all stored procedures and functions, triggers, and events. Then attempt to reload them into an upgraded server. Handlers that contain illegal label references will be rejected.

For more information about condition handlers and writing them to avoid invalid jumps, see Section 13.6.7.2, "DECLARE ... HANDLER Syntax".

- **Incompatible change**: The parser accepted statements that contained `/* ... */` that were not properly closed with `*/`, such as `SELECT 1 /* + 2`. As of MySQL 5.1.23, statements that contain unclosed `/*`-comments now are rejected with a syntax error.

  This fix has the potential to cause incompatibilities. Because of Bug #26302, which caused the trailing `*/` to be truncated from comments in views, stored routines, triggers, and events, it is possible that objects of those types may have been stored with definitions that now will be rejected as syntactically invalid. Such objects should be dropped and re-created so that their definitions do not contain truncated comments.

- **Incompatible change**: Multiple-table `DELETE` statements containing ambiguous aliases could have unintended side effects such as deleting rows from the wrong table. Examples:

  ```
  DELETE FROM t1 AS a2 USING t1 AS a1 INNER JOIN t2 AS a2;
  DELETE t1 AS a2 FROM t1 AS a1 INNER JOIN t2 AS a2;
  ```

  To avoid ambiguity, declaration of aliases other than in the `table_references` part of the statement should be avoided:

  ```
  DELETE FROM t1 USING t1 AS a1 INNER JOIN t2 AS a2;
  DELETE t1 FROM t1 AS a1 INNER JOIN t2 AS a2;
  ```

  As of MySQL 5.1.23, alias declarations outside the `table_references` part of the statement are disallowed for the `USING` variant of multiple-table `DELETE` syntax. (In MySQL 5.5, alias declarations outside `table_references` are disallowed for all multiple-table `DELETE` statements.) Statements containing aliases that are no longer permitted must be rewritten.

- **Incompatible change**: As of MySQL 5.1.8, `TYPE = engine_name` is still accepted as a synonym for the `ENGINE = engine_name` table option but generates a warning. You should note that this option is not available in MySQL 5.1.7, and **is removed altogether in MySQL 5.5 and produces a syntax error**.

  `TYPE` has been deprecated since MySQL 4.0.

- **Incompatible change**: MySQL 5.1.6 introduces the `TRIGGER` privilege. Previously, the `SUPER` privilege was needed to create or drop triggers. Now those operations require the `TRIGGER` privilege. This is a security improvement because you no longer need to grant users the `SUPER` privilege to enable them to create triggers. However, the requirement that the account named in a trigger's `DEFINER` clause must have the `SUPER` privilege has changed to a requirement for the `TRIGGER` privilege. When upgrading from a previous version of MySQL 5.0 or 5.1 to MySQL 5.1.6 or newer, be sure to update your grant tables by running `mysql_upgrade`. This will assign the `TRIGGER` privilege to all accounts that had the `SUPER` privilege. If you fail to update the grant tables, triggers may fail when activated. After updating the grant tables, you can revoke the `SUPER` privilege from those accounts that no longer otherwise require it.

- Some keywords may be reserved in MySQL 5.1 that were not reserved in MySQL 5.0. See Section 9.3, "Keywords and Reserved Words".

- The `BACKUP TABLE`, and `RESTORE TABLE` statements are deprecated. `mysqldump` or `mysqlhotcopy` can be used as alternatives.

- The `LOAD DATA FROM MASTER` and `LOAD TABLE FROM MASTER` statements are deprecated. See Section 13.4.2.2, "LOAD DATA FROM MASTER Syntax", for recommended alternatives.

- The `INSTALL PLUGIN` and `UNINSTALL PLUGIN` statements that are used for the plugin API are new. So is the `WITH PARSER` clause for `FULLTEXT` index creation that associates a parser plugin with a full-text index. Section 22.2, "The MySQL Plugin API".

SC API Changes

- **Incompatible change**: As of MySQL 5.1.7, the `mysql_stmt_attr_get()` C API function returns a boolean rather than an unsigned int for `STMT_ATTR_UPDATE_MAX_LENGTH`. (Bug #16144)

2.13.2 Downgrading MySQL

This section describes how to downgrade to an older MySQL version.

- Supported Downgrade Methods

- Supported Downgrade Paths

- Before You Begin

- Performing an In-place Downgrade

- Performing a Logical Downgrade

- Downgrade Troubleshooting

Supported Downgrade Methods

Supported downgrade methods include:

- *In-place Downgrade*: Involves shutting down the new MySQL version, replacing the new MySQL binaries or packages with the old ones, and restarting the old MySQL version on the new data files. In-place downgrades are supported for downgrades between GA versions within the same release series. For example, in-place downgrades are supported for downgrades from 5.1.73 to 5.1.72.

- *Logical Downgrade*: Involves using `mysqldump` to dump all tables from the new MySQL version, and then loading the dump file into the old MySQL version. Logical downgrades are supported for downgrades between GA versions within the same release series and for downgrades between release levels. For example, logical downgrades are supported for downgrades from 5.1.73 to 5.1.72 and for downgrades from 5.1 to 5.0.

Supported Downgrade Paths

Unless otherwise documented, the following downgrade paths are supported:

- Downgrading from a release series version to an older release series version is supported using all downgrade methods. For example, downgrading from 5.1.73 to 5.1.72 is supported. Skipping release series versions is also supported. For example, downgrading from 5.1.73 to 5.1.71 is supported.

- Downgrading one release level is supported using the *logical downgrade* method. For example, downgrading from 5.1 to 5.0 is supported.

- Downgrading more than one release level is supported using the *logical downgrade* method, but only if you downgrade one release level at a time. For example, you can downgrade from 5.1 to 5.0, and then to 4.1.

The following conditions apply to all downgrade paths:

- Downgrades between General Availability (GA) status releases are supported.

- Downgrades between milestone releases (or from a GA release to a milestone release) are not supported.

Before You Begin

Before downgrading, the following steps are recommended:

- Review the Release Notes for the MySQL version you are downgrading from to ensure that there are no features or fixes that you really need.

- Review Section 2.13.2.1, "Changes Affecting Downgrades from MySQL 5.1". This section describes changes that may require action before or after downgrading.

> **Note**
>
> The downgrade procedures described in the following sections assume you are downgrading with data files created or modified by the newer MySQL version. However, if you did not modify your data after upgrading, downgrading using backups taken *before* upgrading to the new MySQL version is recommended. Many of the changes described in Section 2.13.2.1, "Changes Affecting Downgrades from MySQL 5.1" that require action before or after downgrading are not applicable when downgrading using backups taken *before* upgrading to the new MySQL version.

- Always back up your current databases and log files before downgrading. The backup should include the `mysql` database, which contains the MySQL system tables. See Section 7.2, "Database Backup Methods".

- Use of new features, new configuration options, or new configuration option values that are not supported by a previous release may cause downgrade errors or failures. Before downgrading, it is recommended that you reverse changes resulting from the use of new features and remove configuration settings that are not supported by the release you are downgrading to.

- Check Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt", to see whether changes to table formats or to character sets or collations were made between your current version of MySQL and the version to which you are downgrading. If such changes have resulted in an incompatibility between MySQL versions, downgrade the affected tables using the instructions in Section 2.13.4, "Rebuilding or Repairing Tables or Indexes".

- If you use XA transactions with `InnoDB`, run `XA RECOVER` before downgrading to check for uncommitted XA transactions. If results are returned, either commit or rollback the XA transactions by issuing an `XA COMMIT` or `XA ROLLBACK` statement.

Performing an In-place Downgrade

In-place downgrades are supported for downgrades between GA status releases within the same release series. Review Before you Begin before proceeding.

To perform an in-place downgrade:

1. Review the changes described in Section 2.13.2.1, "Changes Affecting Downgrades from MySQL 5.1" for steps to be performed before downgrading.

2. If you use `InnoDB`, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to `0`. For example:

```
shell> bin/mysql -u root -ppassword --execute="set global innodb_fast_shutdown=0"
```

With a slow shutdown, `InnoDB` performs a full purge and change buffer merge before shutting down, which ensures that data files are fully prepared in case of file format differences between releases.

3. Shut down the newer MySQL server. For example:

```
shell> bin/mysqladmin -u root -ppassword shutdown
```

4. Downgrade the MySQL binaries or packages in-place by replacing the newer binaries or packages with the older ones.

5. Start the older (downgraded) MySQL server, using the existing data directory. For example:

```
shell> bin/mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
```

6. Run `mysql_upgrade`. For example:

```
shell> bin/mysql_upgrade -u root -ppassword
```

Performing a Logical Downgrade

Logical downgrades are supported for downgrades between releases within the same release series and for downgrades to the previous release level. Only downgrades between General Availability (GA) status releases are supported. Review Before you Begin before proceeding.

To perform a logical downgrade:

1. Review the changes described in Section 2.13.2.1, "Changes Affecting Downgrades from MySQL 5.1" for steps to be performed before downgrading.

2. Dump all databases. For example:

```
shell> bin/mysqldump --add-drop-table --skip-events -u root -ppassword --all-databases --force > all_5_
```

3. Shut down the newer MySQL server. For example:

```
shell> bin/mysqladmin -u root -ppassword shutdown
```

4. Initialize an older MySQL instance, with a new data directory. For example:

```
shell> scripts/mysql_install_db --user=mysql
```

5. Start the older MySQL server, using the new data directory. For example:

```
shell> bin/mysqld_safe --user=mysql --datadir=/path/to/new-datadir
```

6. Load the dump file into the older MySQL server. For example:

```
shell> bin/mysql -u root -ppassword --execute="source all_5_1_databases_dump.sql" --force
```

7. Run `mysql_upgrade`. For example:

```
shell> bin/mysql_upgrade -u root -ppassword
```

8. If you use `InnoDB`, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to `0`. For example:

```
shell> bin/mysql -u root -ppassword --execute="set global innodb_fast_shutdown=0"
```

9. Shut down and restart the MySQL server to ensure a clean shutdown and startup. For example:

```
shell> bin/mysqladmin -u root -ppassword shutdown
shell> bin/mysqld_safe --user=mysql --datadir=/path/to/new-datadir
```

Downgrade Troubleshooting

If you downgrade from one release series to another, there may be incompatibilities in table storage formats. In this case, use `mysqldump` to dump your tables before downgrading. After downgrading, reload the dump file using `mysql` or `mysqlimport` to re-create your tables. For examples, see Section 2.13.5, "Copying MySQL Databases to Another Machine".

A typical symptom of a downward-incompatible table format change when you downgrade is that you cannot open tables. In that case, use the following procedure:

1. Stop the older MySQL server that you are downgrading to.

2. Restart the newer MySQL server you are downgrading from.

3. Dump any tables that were inaccessible to the older server by using `mysqldump` to create a dump file.

4. Stop the newer MySQL server and restart the older one.

5. Reload the dump file into the older server. Your tables should be accessible.

2.13.2.1 Changes Affecting Downgrades from MySQL 5.1

Before downgrading from MySQL 5.1, review the changes described in this section. Some changes may require action before or after downgrading.

- **Partitioning.** MySQL 5.0 does not support user-defined partitioning. If a table was created as a partitioned table in 5.1 (or if an table created in a previous version of MySQL was altered to include partitions after an upgrade to 5.1), the table is accessible after downgrade only if you do one of the following:

  - Export the table using `mysqldump` and then drop it in MySQL 5.1; import the table again following the downgrade to MySQL 5.0.

  - Prior to the downgrade, remove the table's partitioning using `ALTER TABLE table_name REMOVE PARTITIONING`.

- **Event Scheduler.** MySQL 5.0 does not support scheduled events. If your databases contain scheduled event definitions, you should prevent them from being dumped when you use `mysqldump` by using the `--skip-events` option. (See Section 4.5.4, "`mysqldump` — A Database Backup Program".)

- **Stored routines.** MySQL 5.1.21 added a number of new columns to the `mysql.proc` table in which stored routine definitions are stored. If you are downgrading from MySQL 5.1.21 or later to MySQL 5.0, you cannot import the MySQL 5.1 routine definitions into MySQL 5.0.46 or earlier using the dump of `mysql.proc` created by `mysqldump` (such as when using the `--all-databases` option). Instead, you should run `mysqldump --routines` prior to performing the downgrade and run the stored routines DDL statements following the downgrade.

  See Bug #11986, Bug #30029, and Bug #30660, for more information.

- **Triggers.** Trigger creation requires the `TRIGGER` privilege as of MySQL 5.1. In MySQL 5.0, there is no `TRIGGER` privilege and `SUPER` is required instead. If you downgrade from MySQL 5.1 to 5.0, you will need to give the `SUPER` privilege to those accounts that had the `TRIGGER` privilege in 5.1.

2.13.2.2 Downgrading from MySQL Enterprise Edition to MySQL Community Server

This section describes the steps required to downgrade from MySQL Enterprise Edition to MySQL Community Edition. This can be done at any time, and is required at the expiration of a MySQL Enterprise Edition subscription if you wish to continue using MySQL Server.

When you perform such a downgrade, all commercially licensed components of the MySQL Enterprise Edition subscription must be uninstalled. These components and related considerations are described in the rest of this section.

> **Note**
>
> The issues described in this section are in addition to any that may be encountered as a result of any upgrade or downgrade of the MySQL Server version (such as between MySQL 5.1 and 5.0). Information about upgrading and downgrading between MySQL release series can be found elsewhere in this chapter; see Section 2.13.1, "Upgrading MySQL", and Section 2.13.2, "Downgrading MySQL".

MySQL Enterprise Database Server.   All commercial versions of MySQL Database Server must be uninstalled.

Commercially licensed extensions.   All commercially licensed MySQL Enterprise Database Server extensions must be uninstalled, including the *MySQL High Availability* extension. Following uninstallation of this extension, automated failover is no longer available.

MySQL Enterprise Backup.   MySQL Enterprise Backup must be uninstalled. Uninstalling this application has the effects listed here:

- Automated backup scripts no longer work.

- Existing backup images taken with MySQL Enterprise Backup can no longer be used for recovery.

- Third-party integration with multimedia systems such as NetBackup, Tivoli, and Oracle Secure Backup no longer works.

MySQL Enterprise Monitor, MySQL Query Analyzer, agents.   MySQL Enterprise Monitor, MySQL Query Analyzer, and all server-side agents must be uninstalled. Uninstalling these applications and agents has the following effects:

- Automated SNMP and SMTP alerts no longer work.

- All historical MySQL, OS monitoring, query, and performance metrics as well as all trending data are lost.

- All environment-specific monitoring templates, custom advisors, graphs and scripts are also lost.

2.13.3 Checking Whether Tables or Indexes Must Be Rebuilt

A binary upgrade or downgrade is one that installs one version of MySQL "in place" over an existing version, without dumping and reloading tables:

1. Stop the server for the existing version if it is running.

2. Install a different version of MySQL. This is an upgrade if the new version is higher than the original version, a downgrade if the version is lower.

3. Start the server for the new version.

In many cases, the tables from the previous version of MySQL can be used without problem by the new version. However, sometimes changes occur that require tables or table indexes to be rebuilt, as described in this section. If you have tables that are affected by any of the issues described here, rebuild the tables or indexes as necessary using the instructions given in Section 2.13.4, "Rebuilding or Repairing Tables or Indexes".

Table Incompatibilities

After a binary upgrade to MySQL 5.1 from a MySQL 5.0 installation that contains `ARCHIVE` tables:

- Before MySQL 5.1.42, accessing those tables will cause the server to crash, even if you have run `mysql_upgrade` or `CHECK TABLE ... FOR UPGRADE`.

- As of MySQL 5.1.42, the server will not open 5.0 `ARCHIVE` tables at all.

In either case, the solution is to use `mysqldump` to dump all 5.0 `ARCHIVE` tables before upgrading, and reload them into MySQL 5.1 after upgrading. This problem is fixed in MySQL 5.6.4: The server can open `ARCHIVE` tables created in MySQL 5.0. However, it remains the recommended upgrade procedure to dump 5.0 `ARCHIVE` tables before upgrading and reload them after upgrading.

Index Incompatibilities

If you perform a binary upgrade without dumping and reloading tables, you cannot upgrade directly from MySQL 4.1 to 5.1 or higher. This occurs due to an incompatible change in the `MyISAM` table index format in MySQL 5.0. Upgrade from MySQL 4.1 to 5.0 and repair all `MyISAM` tables. Then upgrade from MySQL 5.0 to 5.1 and check and repair your tables.

Modifications to the handling of character sets or collations might change the character sort order, which causes the ordering of entries in any index that uses an affected character set or collation to be incorrect. Such changes result in several possible problems:

- Comparison results that differ from previous results

- Inability to find some index values due to misordered index entries

- Misordered `ORDER BY` results

- Tables that `CHECK TABLE` reports as being in need of repair

The solution to these problems is to rebuild any indexes that use an affected character set or collation, either by dropping and re-creating the indexes, or by dumping and reloading the entire table. In some cases, it is possible to alter affected columns to use a different collation. For information about rebuilding indexes, see Section 2.13.4, "Rebuilding or Repairing Tables or Indexes".

To check whether a table has indexes that must be rebuilt, consult the following list. It indicates which versions of MySQL introduced character set or collation changes that require indexes to be rebuilt. Each entry indicates the version in which the change occurred and the character sets or collations that the change affects. If the change is associated with a particular bug report, the bug number is given.

The list applies both for binary upgrades and downgrades. For example, Bug #27877 was fixed in MySQL 5.1.24, so it applies to upgrades from versions older than 5.1.24 to 5.1.24 or newer, and to downgrades from 5.1.24 or newer to versions older than 5.1.24.

In many cases, you can use `CHECK TABLE ... FOR UPGRADE` to identify tables for which index rebuilding is required. It will report this message:

```
Table upgrade required.
```

```
Please do "REPAIR TABLE `tbl_name`" or dump/reload to fix it!
```

In these cases, you can also use `mysqlcheck --check-upgrade` or `mysql_upgrade`, which execute `CHECK TABLE`. However, the use of `CHECK TABLE` applies only after upgrades, not downgrades. Also, `CHECK TABLE` is not applicable to all storage engines. For details about which storage engines `CHECK TABLE` supports, see Section 13.7.2.3, "CHECK TABLE Syntax".

These changes cause index rebuilding to be necessary:

- MySQL 5.1.24 (Bug #27877)

  Affects indexes that use the `utf8_general_ci` or `ucs2_general_ci` collation for columns that contain `'ß'` LATIN SMALL LETTER SHARP S (German). The bug fix corrected an error in the original collations but introduced an incompatibility such that `'ß'` compares equal to characters with which it previously compared different.

  Affected tables can be detected by `CHECK TABLE ... FOR UPGRADE` as of MySQL 5.1.30 (see Bug #40053).

  A workaround for this issue is implemented as of MySQL 5.1.62, 5.5.21, and 5.6.5. The workaround involves altering affected columns to use the `utf8_general_mysql500_ci` and `ucs2_general_mysql500_ci` collations, which preserve the original pre-5.1.24 ordering of `utf8_general_ci` and `ucs2_general_ci`.

- MySQL 5.0.48, 5.1.23 (Bug #27562)

  Affects indexes that use the `ascii_general_ci` collation for columns that contain any of these characters: `'`'` GRAVE ACCENT, `'['` LEFT SQUARE BRACKET, `'\'` REVERSE SOLIDUS, `']'` RIGHT SQUARE BRACKET, `'~'` TILDE

  Affected tables can be detected by `CHECK TABLE ... FOR UPGRADE` as of MySQL 5.1.29 (see Bug #39585).

- MySQL 5.0.48, 5.1.21 (Bug #29461)

  Affects indexes for columns that use any of these character sets: `eucjpms`, `euc_kr`, `gb2312`, `latin7`, `macce`, `ujis`

  Affected tables can be detected by `CHECK TABLE ... FOR UPGRADE` as of MySQL 5.1.29 (see Bug #39585).

2.13.4 Rebuilding or Repairing Tables or Indexes

This section describes how to rebuild a table. This can be necessitated by changes to MySQL such as how data types are handled or changes to character set handling. For example, an error in a collation might have been corrected, necessitating a table rebuild to update the indexes for character columns that use the collation. (For examples, see Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt".) It might also be that a table repair or upgrade should be done as indicated by a table check operation such as that performed by `CHECK TABLE`, `mysqlcheck`, or `mysql_upgrade`.

Methods for rebuilding a table include dumping and reloading it, or using `ALTER TABLE` or `REPAIR TABLE`.

> **Note**
>
> If you are rebuilding tables because a different version of MySQL will not handle them after a binary (in-place) upgrade or downgrade, you must use the dump-

> and-reload method. Dump the tables *before* upgrading or downgrading using your original version of MySQL. Then reload the tables *after* upgrading or downgrading.
>
> If you use the dump-and-reload method of rebuilding tables only for the purpose of rebuilding indexes, you can perform the dump either before or after upgrading or downgrading. Reloading still must be done afterward.

To rebuild a table by dumping and reloading it, use `mysqldump` to create a dump file and `mysql` to reload the file:

```
shell> mysqldump db_name t1 > dump.sql
shell> mysql db_name < dump.sql
```

To rebuild all the tables in a single database, specify the database name without any following table name:

```
shell> mysqldump db_name > dump.sql
shell> mysql db_name < dump.sql
```

To rebuild all tables in all databases, use the `--all-databases` option:

```
shell> mysqldump --all-databases > dump.sql
shell> mysql < dump.sql
```

To rebuild a table with `ALTER TABLE`, use a "null" alteration; that is, an `ALTER TABLE` statement that "changes" the table to use the storage engine that it already has. For example, if `t1` is a `MyISAM` table, use this statement:

```
mysql> ALTER TABLE t1 ENGINE = MyISAM;
```

If you are not sure which storage engine to specify in the `ALTER TABLE` statement, use `SHOW CREATE TABLE` to display the table definition.

If you must rebuild a table because a table checking operation indicates that the table is corrupt or needs an upgrade, you can use `REPAIR TABLE` if that statement supports the table's storage engine. For example, to repair a `MyISAM` table, use this statement:

```
mysql> REPAIR TABLE t1;
```

For storage engines such as `InnoDB` that `REPAIR TABLE` does not support, use `mysqldump` to create a dump file and `mysql` to reload the file, as described earlier.

For specifics about which storage engines `REPAIR TABLE` supports, see Section 13.7.2.6, "REPAIR TABLE Syntax".

`mysqlcheck --repair` provides command-line access to the `REPAIR TABLE` statement. This can be a more convenient means of repairing tables because you can use the `--databases` or `--all-databases` option to repair all tables in specific databases or all databases, respectively:

```
shell> mysqlcheck --repair --databases db_name ...
shell> mysqlcheck --repair --all-databases
```

For incompatibilities introduced in MySQL 5.1.24 by the fix for Bug #27877 that corrected the `utf8_general_ci` and `ucs2_general_ci` collations, a workaround is implemented as of MySQL 5.1.62, 5.5.21, and 5.6.5. Upgrade to one of those versions, then convert each affected table using

one of the following methods. In each case, the workaround altering affected columns to use the `utf8_general_mysql500_ci` and `ucs2_general_mysql500_ci` collations, which preserve the original pre-5.1.24 ordering of `utf8_general_ci` and `ucs2_general_ci`.

- To convert an affected table after a binary upgrade that leaves the table files in place, alter the table to use the new collation. Suppose that the table `t1` contains one or more problematic `utf8` columns. To convert the table at the table level, use a statement like this:

```
ALTER TABLE t1
CONVERT TO CHARACTER SET utf8 COLLATE utf8_general_mysql500_ci;
```

  To apply the change on a column-specific basis, use a statement like this (be sure to repeat the column definition as originally specified except for the `COLLATE` clause):

```
ALTER TABLE t1
MODIFY c1 CHAR(N) CHARACTER SET utf8 COLLATE utf8_general_mysql500_ci;
```

- To upgrade the table using a dump and reload procedure, dump the table using `mysqldump`, modify the `CREATE TABLE` statement in the dump file to use the new collation, and reload the table.

After making the appropriate changes, `CHECK TABLE` should report no error.

2.13.5 Copying MySQL Databases to Another Machine

You can copy the `.frm`, `.MYI`, and `.MYD` files for `MyISAM` tables between different architectures that support the same floating-point format. (MySQL takes care of any byte-swapping issues.) See Section 14.5, "The MyISAM Storage Engine".

In cases where you need to transfer databases between different architectures, you can use `mysqldump` to create a file containing SQL statements. You can then transfer the file to the other machine and feed it as input to the `mysql` client.

Use `mysqldump --help` to see what options are available.

The easiest (although not the fastest) way to move a database between two machines is to run the following commands on the machine on which the database is located:

```
shell> mysqladmin -h 'other_hostname' create db_name
shell> mysqldump db_name | mysql -h 'other_hostname' db_name
```

If you want to copy a database from a remote machine over a slow network, you can use these commands:

```
shell> mysqladmin create db_name
shell> mysqldump -h 'other_hostname' --compress db_name | mysql db_name
```

You can also store the dump in a file, transfer the file to the target machine, and then load the file into the database there. For example, you can dump a database to a compressed file on the source machine like this:

```
shell> mysqldump --quick db_name | gzip > db_name.gz
```

Transfer the file containing the database contents to the target machine and run these commands there:

```
shell> mysqladmin create db_name
shell> gunzip < db_name.gz | mysql db_name
```

You can also use mysqldump and mysqlimport to transfer the database. For large tables, this is much faster than simply using mysqldump. In the following commands, *DUMPDIR* represents the full path name of the directory you use to store the output from mysqldump.

First, create the directory for the output files and dump the database:

```
shell> mkdir DUMPDIR
shell> mysqldump --tab=DUMPDIR db_name
```

Then transfer the files in the *DUMPDIR* directory to some corresponding directory on the target machine and load the files into MySQL there:

```
shell> mysqladmin create db_name            # create database
shell> cat DUMPDIR/*.sql | mysql db_name    # create tables in database
shell> mysqlimport db_name DUMPDIR/*.txt    # load data into tables
```

Do not forget to copy the mysql database because that is where the grant tables are stored. You might have to run commands as the MySQL root user on the new machine until you have the mysql database in place.

After you import the mysql database on the new machine, execute mysqladmin flush-privileges so that the server reloads the grant table information.

2.14 Environment Variables

This section lists environment variables that are used directly or indirectly by MySQL. Most of these can also be found in other places in this manual.

Options on the command line take precedence over values specified in option files and environment variables, and values in option files take precedence over values in environment variables. In many cases, it is preferable to use an option file instead of environment variables to modify the behavior of MySQL. See Section 4.2.6, "Using Option Files".

To set an environment variable within sh, ksh, bash, or zsh shells you can use the following commands:

```
shell> ENVVAR=value
shell> export ENVVAR
```

The export is required if you want other sub-commands to inherit that value during execution. On more recent shells you can combine the export and setting processes, like this:

```
shell> export set ENVVAR=value
```

For the csh, or tcsh shells, use the setenv command:

```
shell> setenv ENVVAR value
```

Within the Windows Command Prompt use the set command to specify the value of a variable:

```
shell> set ENVVAR=value
```

On Unix, Linux, OS X, and Windows, the set command without parameters will display the list of currently set variables.

Table 2.21 MySQL Related Environment Variables

Variable	Description
`CXX`	The name of your C++ compiler (for running `configure`).
`CC`	The name of your C compiler (for running `configure`).
`CFLAGS`	Flags for your C compiler (for running `configure`).
`CXXFLAGS`	Flags for your C++ compiler (for running `configure`).
`DBI_USER`	The default user name for Perl DBI.
`DBI_TRACE`	Trace options for Perl DBI.
`HOME`	The default path for the `mysql` history file is `$HOME/.mysql_history`.
`LD_RUN_PATH`	Used to specify the location of `libmysqlclient.so`.
`MYSQL_DEBUG`	Debug trace options when debugging.
`MYSQL_GROUP_SUFFIX`	Option group suffix value (like specifying `--defaults-group-suffix`).
`MYSQL_HISTFILE`	The path to the `mysql` history file. If this variable is set, its value overrides the default for `$HOME/.mysql_history`.
`MYSQL_HOME`	The path to the directory in which the server-specific `my.cnf` file resides.
`MYSQL_HOST`	The default host name used by the `mysql` command-line client.
`MYSQL_PS1`	The command prompt to use in the `mysql` command-line client.
`MYSQL_PWD`	The default password when connecting to `mysqld`. Using this is insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security".
`MYSQL_TCP_PORT`	The default TCP/IP port number.
`MYSQL_UNIX_PORT`	The default Unix socket file name; used for connections to `localhost`.
`PATH`	Used by the shell to find MySQL programs.
`TMPDIR`	The directory in which temporary files are created.
`TZ`	This should be set to your local time zone. See Section B.5.3.7, "Time Zone Problems".
`UMASK`	The user-file creation mode when creating files. See note following table.
`UMASK_DIR`	The user-directory creation mode when creating directories. See note following table.
`USER`	The default user name on Windows and NetWare when connecting to `mysqld`.

For information about the `mysql` history file, see Section 4.5.1.3, "mysql Logging".

The default `UMASK` and `UMASK_DIR` values are `0660` and `0700`, respectively. MySQL assumes that the value for `UMASK` or `UMASK_DIR` is in octal if it starts with a zero. For example, setting `UMASK=0600` is equivalent to `UMASK=384` because 0600 octal is 384 decimal.

The `UMASK` and `UMASK_DIR` variables, despite their names, are used as modes, not masks:

- If `UMASK` is set, `mysqld` uses `($UMASK | 0600)` as the mode for file creation, so that newly created files have a mode in the range from 0600 to 0666 (all values octal).

- If `UMASK_DIR` is set, `mysqld` uses `($UMASK_DIR | 0700)` as the base mode for directory creation, which then is AND-ed with `~(~$UMASK & 0666)`, so that newly created directories have a mode in the range from 0700 to 0777 (all values octal). The AND operation may remove read and write permissions from the directory mode, but not execute permissions.

2.15 Perl Installation Notes

The Perl `DBI` module provides a generic interface for database access. You can write a `DBI` script that works with many different database engines without change. To use `DBI`, you must install the `DBI` module, as well as a DataBase Driver (DBD) module for each type of database server you want to access. For MySQL, this driver is the `DBD::mysql` module.

Perl, and the `DBD::MySQL` module for `DBI` must be installed if you want to run the MySQL benchmark scripts; see Section 8.13.2, "The MySQL Benchmark Suite". They are also required for the MySQL Cluster `ndb_size.pl` utility; see Section 17.4.24, "`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator".

> **Note**
>
> Perl support is not included with MySQL distributions. You can obtain the necessary modules from http://search.cpan.org for Unix, or by using the ActiveState `ppm` program on Windows. The following sections describe how to do this.

The `DBI`/`DBD` interface requires Perl 5.6.0, and 5.6.1 or later is preferred. DBI *does not work* if you have an older version of Perl. You should use `DBD::mysql` 4.009 or higher. Although earlier versions are available, they do not support the full functionality of MySQL 5.1.

2.15.1 Installing Perl on Unix

MySQL Perl support requires that you have installed MySQL client programming support (libraries and header files). Most installation methods install the necessary files. If you install MySQL from RPM files on Linux, be sure to install the developer RPM as well. The client programs are in the client RPM, but client programming support is in the developer RPM.

The files you need for Perl support can be obtained from the CPAN (Comprehensive Perl Archive Network) at http://search.cpan.org.

The easiest way to install Perl modules on Unix is to use the `CPAN` module. For example:

```
shell> perl -MCPAN -e shell
cpan> install DBI
cpan> install DBD::mysql
```

The `DBD::mysql` installation runs a number of tests. These tests attempt to connect to the local MySQL server using the default user name and password. (The default user name is your login name on Unix, and `ODBC` on Windows. The default password is "no password.") If you cannot connect to the server with those values (for example, if your account has a password), the tests fail. You can use `force install DBD::mysql` to ignore the failed tests.

`DBI` requires the `Data::Dumper` module. It may be installed; if not, you should install it before installing `DBI`.

It is also possible to download the module distributions in the form of compressed `tar` archives and build the modules manually. For example, to unpack and build a DBI distribution, use a procedure such as this:

1. Unpack the distribution into the current directory:

   ```
   shell> gunzip < DBI-VERSION.tar.gz | tar xvf -
   ```

   This command creates a directory named `DBI-VERSION`.

2. Change location into the top-level directory of the unpacked distribution:

```
shell> cd DBI-VERSION
```

3. Build the distribution and compile everything:

```
shell> perl Makefile.PL
shell> make
shell> make test
shell> make install
```

The `make test` command is important because it verifies that the module is working. Note that when you run that command during the `DBD::mysql` installation to exercise the interface code, the MySQL server must be running or the test fails.

It is a good idea to rebuild and reinstall the `DBD::mysql` distribution whenever you install a new release of MySQL. This ensures that the latest versions of the MySQL client libraries are installed correctly.

If you do not have access rights to install Perl modules in the system directory or if you want to install local Perl modules, the following reference may be useful: http://learn.perl.org/faq/perlfaq8.html#How-do-I-keep-my-own-module-library-directory-

2.15.2 Installing ActiveState Perl on Windows

On Windows, you should do the following to install the MySQL `DBD` module with ActiveState Perl:

1. Get ActiveState Perl from http://www.activestate.com/Products/ActivePerl/ and install it.

2. Open a console window.

3. If necessary, set the `HTTP_proxy` variable. For example, you might try a setting like this:

```
C:\> set HTTP_proxy=my.proxy.com:3128
```

4. Start the PPM program:

```
C:\> C:\perl\bin\ppm.pl
```

5. If you have not previously done so, install `DBI`:

```
ppm> install DBI
```

6. If this succeeds, run the following command:

```
ppm> install DBD-mysql
```

This procedure should work with ActiveState Perl 5.6 or newer.

If you cannot get the procedure to work, you should install the ODBC driver instead and connect to the MySQL server through ODBC:

```
use DBI;
$dbh= DBI->connect("DBI:ODBC:$dsn",$user,$password) ||
  die "Got error $DBI::errstr when connecting to $dsn\n";
```

2.15.3 Problems Using the Perl DBI/DBD Interface

If Perl reports that it cannot find the `../mysql/mysql.so` module, the problem is probably that Perl cannot locate the `libmysqlclient.so` shared library. You should be able to fix this problem by one of the following methods:

- Copy `libmysqlclient.so` to the directory where your other shared libraries are located (probably `/usr/lib` or `/lib`).

- Modify the `-L` options used to compile `DBD::mysql` to reflect the actual location of `libmysqlclient.so`.

- On Linux, you can add the path name of the directory where `libmysqlclient.so` is located to the `/etc/ld.so.conf` file.

- Add the path name of the directory where `libmysqlclient.so` is located to the `LD_RUN_PATH` environment variable. Some systems use `LD_LIBRARY_PATH` instead.

Note that you may also need to modify the `-L` options if there are other libraries that the linker fails to find. For example, if the linker cannot find `libc` because it is in `/lib` and the link command specifies `-L/usr/lib`, change the `-L` option to `-L/lib` or add `-L/lib` to the existing link command.

If you get the following errors from `DBD::mysql`, you are probably using `gcc` (or using an old binary compiled with `gcc`):

```
/usr/bin/perl: can't resolve symbol '__moddi3'
/usr/bin/perl: can't resolve symbol '__divdi3'
```

Add `-L/usr/lib/gcc-lib/... -lgcc` to the link command when the `mysql.so` library gets built (check the output from `make` for `mysql.so` when you compile the Perl client). The `-L` option should specify the path name of the directory where `libgcc.a` is located on your system.

Another cause of this problem may be that Perl and MySQL are not both compiled with `gcc`. In this case, you can solve the mismatch by compiling both with `gcc`.

You may see the following error from `DBD::mysql` when you run the tests:

```
t/00base............install_driver(mysql) failed:
Can't load '../blib/arch/auto/DBD/mysql/mysql.so' for module DBD::mysql:
../blib/arch/auto/DBD/mysql/mysql.so: undefined symbol:
uncompress at /usr/lib/perl5/5.00503/i586-linux/DynaLoader.pm line 169.
```

This means that you need to include the `-lz` compression library on the link line. That can be done by changing the following line in the file `lib/DBD/mysql/Install.pm`:

```
$sysliblist .= " -lm";
```

Change that line to:

```
$sysliblist .= " -lm -lz";
```

After this, you *must* run `make realclean` and then proceed with the installation from the beginning.

Chapter 3 Tutorial

Table of Contents

This chapter provides a tutorial introduction to MySQL by showing how to use the `mysql` client program to create and use a simple database. `mysql` (sometimes referred to as the "terminal monitor" or just "monitor") is an interactive program that enables you to connect to a MySQL server, run queries, and view the results. `mysql` may also be used in batch mode: you place your queries in a file beforehand, then tell `mysql` to execute the contents of the file. Both ways of using `mysql` are covered here.

To see a list of options provided by `mysql`, invoke it with the `--help` option:

```
shell> mysql --help
```

This chapter assumes that `mysql` is installed on your machine and that a MySQL server is available to which you can connect. If this is not true, contact your MySQL administrator. (If *you* are the administrator, you need to consult the relevant portions of this manual, such as Chapter 5, *MySQL Server Administration*.)

This chapter describes the entire process of setting up and using a database. If you are interested only in accessing an existing database, you may want to skip over the sections that describe how to create the database and the tables it contains.

Because this chapter is tutorial in nature, many details are necessarily omitted. Consult the relevant sections of the manual for more information on the topics covered here.

3.1 Connecting to and Disconnecting from the Server

To connect to the server, you will usually need to provide a MySQL user name when you invoke `mysql` and, most likely, a password. If the server runs on a machine other than the one where you log in, you will

also need to specify a host name. Contact your administrator to find out what connection parameters you should use to connect (that is, what host, user name, and password to use). Once you know the proper parameters, you should be able to connect like this:

```
shell> mysql -h host -u user -p
Enter password: ********
```

`host` and `user` represent the host name where your MySQL server is running and the user name of your MySQL account. Substitute appropriate values for your setup. The `********` represents your password; enter it when `mysql` displays the `Enter password:` prompt.

If that works, you should see some introductory information followed by a `mysql>` prompt:

```
shell> mysql -h host -u user -p
Enter password: ********
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 25338 to server version: 5.1.73-standard

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql>
```

The `mysql>` prompt tells you that `mysql` is ready for you to enter SQL statements.

If you are logging in on the same machine that MySQL is running on, you can omit the host, and simply use the following:

```
shell> mysql -u user -p
```

If, when you attempt to log in, you get an error message such as `ERROR 2002 (HY000): Can't connect to local MySQL server through socket '/tmp/mysql.sock' (2)`, it means that the MySQL server daemon (Unix) or service (Windows) is not running. Consult the administrator or see the section of Chapter 2, *Installing and Upgrading MySQL* that is appropriate to your operating system.

For help with other problems often encountered when trying to log in, see Section B.5.2, "Common Errors When Using MySQL Programs".

Some MySQL installations permit users to connect as the anonymous (unnamed) user to the server running on the local host. If this is the case on your machine, you should be able to connect to that server by invoking `mysql` without any options:

```
shell> mysql
```

After you have connected successfully, you can disconnect any time by typing `QUIT` (or `\q`) at the `mysql>` prompt:

```
mysql> QUIT
Bye
```

On Unix, you can also disconnect by pressing Control+D.

Most examples in the following sections assume that you are connected to the server. They indicate this by the `mysql>` prompt.

3.2 Entering Queries

Make sure that you are connected to the server, as discussed in the previous section. Doing so does not in itself select any database to work with, but that is okay. At this point, it is more important to find out a little about how to issue queries than to jump right in creating tables, loading data into them, and retrieving data from them. This section describes the basic principles of entering queries, using several queries you can try out to familiarize yourself with how `mysql` works.

Here is a simple query that asks the server to tell you its version number and the current date. Type it in as shown here following the `mysql>` prompt and press Enter:

```
mysql> SELECT VERSION(), CURRENT_DATE;
+----------------+--------------+
| VERSION()      | CURRENT_DATE |
+----------------+--------------+
| 5.1.2-alpha-log | 2005-10-11  |
+----------------+--------------+
1 row in set (0.01 sec)
mysql>
```

This query illustrates several things about `mysql`:

- A query normally consists of an SQL statement followed by a semicolon. (There are some exceptions where a semicolon may be omitted. `QUIT`, mentioned earlier, is one of them. We'll get to others later.)

- When you issue a query, `mysql` sends it to the server for execution and displays the results, then prints another `mysql>` prompt to indicate that it is ready for another query.

- `mysql` displays query output in tabular form (rows and columns). The first row contains labels for the columns. The rows following are the query results. Normally, column labels are the names of the columns you fetch from database tables. If you're retrieving the value of an expression rather than a table column (as in the example just shown), `mysql` labels the column using the expression itself.

- `mysql` shows how many rows were returned and how long the query took to execute, which gives you a rough idea of server performance. These values are imprecise because they represent wall clock time (not CPU or machine time), and because they are affected by factors such as server load and network latency. (For brevity, the "rows in set" line is sometimes not shown in the remaining examples in this chapter.)

Keywords may be entered in any lettercase. The following queries are equivalent:

```
mysql> SELECT VERSION(), CURRENT_DATE;
mysql> select version(), current_date;
mysql> SeLeCt vErSiOn(), current_DATE;
```

Here is another query. It demonstrates that you can use `mysql` as a simple calculator:

```
mysql> SELECT SIN(PI()/4), (4+1)*5;
+------------------+---------+
| SIN(PI()/4)      | (4+1)*5 |
+------------------+---------+
| 0.70710678118655 |      25 |
+------------------+---------+
1 row in set (0.02 sec)
```

The queries shown thus far have been relatively short, single-line statements. You can even enter multiple statements on a single line. Just end each one with a semicolon:

```
mysql> SELECT VERSION(); SELECT NOW();
```

```
+-----------------+
| VERSION()       |
+-----------------+
| 5.1.2-alpha-log |
+-----------------+
1 row in set (0.00 sec)


+---------------------+
| NOW()               |
+---------------------+
| 2005-10-11 15:15:00 |
+---------------------+
1 row in set (0.00 sec)
```

A query need not be given all on a single line, so lengthy queries that require several lines are not a problem. `mysql` determines where your statement ends by looking for the terminating semicolon, not by looking for the end of the input line. (In other words, `mysql` accepts free-format input: it collects input lines but does not execute them until it sees the semicolon.)

Here is a simple multiple-line statement:

```
mysql> SELECT
    -> USER()
    -> ,
    -> CURRENT_DATE;
+---------------+--------------+
| USER()        | CURRENT_DATE |
+---------------+--------------+
| jon@localhost | 2005-10-11   |
+---------------+--------------+
```

In this example, notice how the prompt changes from `mysql>` to `->` after you enter the first line of a multiple-line query. This is how `mysql` indicates that it has not yet seen a complete statement and is waiting for the rest. The prompt is your friend, because it provides valuable feedback. If you use that feedback, you can always be aware of what `mysql` is waiting for.

If you decide you do not want to execute a query that you are in the process of entering, cancel it by typing `\c`:

```
mysql> SELECT
    -> USER()
    -> \c
mysql>
```

Here, too, notice the prompt. It switches back to `mysql>` after you type `\c`, providing feedback to indicate that `mysql` is ready for a new query.

The following table shows each of the prompts you may see and summarizes what they mean about the state that `mysql` is in.

Prompt	Meaning
`mysql>`	Ready for new query
`->`	Waiting for next line of multiple-line query
`'>`	Waiting for next line, waiting for completion of a string that began with a single quote ("`'`")
`">`	Waiting for next line, waiting for completion of a string that began with a double quote ("`"`")
`` `> ``	Waiting for next line, waiting for completion of an identifier that began with a backtick ("`` ` ``")
`/*>`	Waiting for next line, waiting for completion of a comment that began with `/*`

Multiple-line statements commonly occur by accident when you intend to issue a query on a single line, but forget the terminating semicolon. In this case, `mysql` waits for more input:

```
mysql> SELECT USER()
    ->
```

If this happens to you (you think you've entered a statement but the only response is a `->` prompt), most likely `mysql` is waiting for the semicolon. If you don't notice what the prompt is telling you, you might sit there for a while before realizing what you need to do. Enter a semicolon to complete the statement, and `mysql` executes it:

```
mysql> SELECT USER()
    -> ;
+---------------+
| USER()        |
+---------------+
| jon@localhost |
+---------------+
```

The `'>` and `">` prompts occur during string collection (another way of saying that MySQL is waiting for completion of a string). In MySQL, you can write strings surrounded by either """ or """ characters (for example, `'hello'` or `"goodbye"`), and `mysql` lets you enter strings that span multiple lines. When you see a `'>` or `">` prompt, it means that you have entered a line containing a string that begins with a """ or """ quote character, but have not yet entered the matching quote that terminates the string. This often indicates that you have inadvertently left out a quote character. For example:

```
mysql> SELECT * FROM my_table WHERE name = 'Smith AND age < 30;
    '>
```

If you enter this `SELECT` statement, then press **Enter** and wait for the result, nothing happens. Instead of wondering why this query takes so long, notice the clue provided by the `'>` prompt. It tells you that `mysql` expects to see the rest of an unterminated string. (Do you see the error in the statement? The string `'Smith` is missing the second single quotation mark.)

At this point, what do you do? The simplest thing is to cancel the query. However, you cannot just type `\c` in this case, because `mysql` interprets it as part of the string that it is collecting. Instead, enter the closing quote character (so `mysql` knows you've finished the string), then type `\c`:

```
mysql> SELECT * FROM my_table WHERE name = 'Smith AND age < 30;
    '> '\c
mysql>
```

The prompt changes back to `mysql>`, indicating that `mysql` is ready for a new query.

The `` `> `` prompt is similar to the `'>` and `">` prompts, but indicates that you have begun but not completed a backtick-quoted identifier.

It is important to know what the `'>`, `">`, and `` `> `` prompts signify, because if you mistakenly enter an unterminated string, any further lines you type appear to be ignored by `mysql`—including a line containing `QUIT`. This can be quite confusing, especially if you do not know that you need to supply the terminating quote before you can cancel the current query.

3.3 Creating and Using a Database

Once you know how to enter SQL statements, you are ready to access a database.

Suppose that you have several pets in your home (your menagerie) and you would like to keep track of various types of information about them. You can do so by creating tables to hold your data and loading them with the desired information. Then you can answer different sorts of questions about your animals by retrieving data from the tables. This section shows you how to perform the following operations:

• Create a database

• Create a table

• Load data into the table

• Retrieve data from the table in various ways

• Use multiple tables

The menagerie database is simple (deliberately), but it is not difficult to think of real-world situations in which a similar type of database might be used. For example, a database like this could be used by a farmer to keep track of livestock, or by a veterinarian to keep track of patient records. A menagerie distribution containing some of the queries and sample data used in the following sections can be obtained from the MySQL Web site. It is available in both compressed `tar` file and Zip formats at http://dev.mysql.com/doc/.

Use the `SHOW` statement to find out what databases currently exist on the server:

```
mysql> SHOW DATABASES;
+----------+
| Database |
+----------+
| mysql    |
| test     |
| tmp      |
+----------+
```

The `mysql` database describes user access privileges. The `test` database often is available as a workspace for users to try things out.

The list of databases displayed by the statement may be different on your machine; `SHOW DATABASES` does not show databases that you have no privileges for if you do not have the `SHOW DATABASES` privilege. See Section 13.7.5.15, "SHOW DATABASES Syntax".

If the `test` database exists, try to access it:

```
mysql> USE test
Database changed
```

`USE`, like `QUIT`, does not require a semicolon. (You can terminate such statements with a semicolon if you like; it does no harm.) The `USE` statement is special in another way, too: it must be given on a single line.

You can use the `test` database (if you have access to it) for the examples that follow, but anything you create in that database can be removed by anyone else with access to it. For this reason, you should probably ask your MySQL administrator for permission to use a database of your own. Suppose that you want to call yours `menagerie`. The administrator needs to execute a statement like this:

```
mysql> GRANT ALL ON menagerie.* TO 'your_mysql_name'@'your_client_host';
```

where `your_mysql_name` is the MySQL user name assigned to you and `your_client_host` is the host from which you connect to the server.

3.3.1 Creating and Selecting a Database

If the administrator creates your database for you when setting up your permissions, you can begin using it. Otherwise, you need to create it yourself:

```
mysql> CREATE DATABASE menagerie;
```

Under Unix, database names are case sensitive (unlike SQL keywords), so you must always refer to your database as `menagerie`, not as `Menagerie`, `MENAGERIE`, or some other variant. This is also true for table names. (Under Windows, this restriction does not apply, although you must refer to databases and tables using the same lettercase throughout a given query. However, for a variety of reasons, the recommended best practice is always to use the same lettercase that was used when the database was created.)

> **Note**
>
> If you get an error such as `ERROR 1044 (42000): Access denied for user 'micah'@'localhost' to database 'menagerie'` when attempting to create a database, this means that your user account does not have the necessary privileges to do so. Discuss this with the administrator or see Section 6.2, "The MySQL Access Privilege System".

Creating a database does not select it for use; you must do that explicitly. To make `menagerie` the current database, use this statement:

```
mysql> USE menagerie
Database changed
```

Your database needs to be created only once, but you must select it for use each time you begin a `mysql` session. You can do this by issuing a `USE` statement as shown in the example. Alternatively, you can select the database on the command line when you invoke `mysql`. Just specify its name after any connection parameters that you might need to provide. For example:

```
shell> mysql -h host -u user -p menagerie
Enter password: ********
```

> **Important**
>
> `menagerie` in the command just shown is **not** your password. If you want to supply your password on the command line after the `-p` option, you must do so with no intervening space (for example, as `-pmypassword`, not as `-p mypassword`). However, putting your password on the command line is not recommended, because doing so exposes it to snooping by other users logged in on your machine.

> **Note**
>
> You can see at any time which database is currently selected using `SELECT DATABASE()`.

3.3.2 Creating a Table

Creating the database is the easy part, but at this point it is empty, as `SHOW TABLES` tells you:

```
mysql> SHOW TABLES;
Empty set (0.00 sec)
```

The harder part is deciding what the structure of your database should be: what tables you need and what columns should be in each of them.

You want a table that contains a record for each of your pets. This can be called the `pet` table, and it should contain, as a bare minimum, each animal's name. Because the name by itself is not very interesting, the table should contain other information. For example, if more than one person in your family keeps pets, you might want to list each animal's owner. You might also want to record some basic descriptive information such as species and sex.

How about age? That might be of interest, but it is not a good thing to store in a database. Age changes as time passes, which means you'd have to update your records often. Instead, it is better to store a fixed value such as date of birth. Then, whenever you need age, you can calculate it as the difference between the current date and the birth date. MySQL provides functions for doing date arithmetic, so this is not difficult. Storing birth date rather than age has other advantages, too:

- You can use the database for tasks such as generating reminders for upcoming pet birthdays. (If you think this type of query is somewhat silly, note that it is the same question you might ask in the context of a business database to identify clients to whom you need to send out birthday greetings in the current week or month, for that computer-assisted personal touch.)

- You can calculate age in relation to dates other than the current date. For example, if you store death date in the database, you can easily calculate how old a pet was when it died.

You can probably think of other types of information that would be useful in the `pet` table, but the ones identified so far are sufficient: name, owner, species, sex, birth, and death.

Use a `CREATE TABLE` statement to specify the layout of your table:

```
mysql> CREATE TABLE pet (name VARCHAR(20), owner VARCHAR(20),
    -> species VARCHAR(20), sex CHAR(1), birth DATE, death DATE);
```

`VARCHAR` is a good choice for the `name`, `owner`, and `species` columns because the column values vary in length. The lengths in those column definitions need not all be the same, and need not be `20`. You can normally pick any length from `1` to `65535`, whatever seems most reasonable to you. If you make a poor choice and it turns out later that you need a longer field, MySQL provides an `ALTER TABLE` statement.

Several types of values can be chosen to represent sex in animal records, such as `'m'` and `'f'`, or perhaps `'male'` and `'female'`. It is simplest to use the single characters `'m'` and `'f'`.

The use of the `DATE` data type for the `birth` and `death` columns is a fairly obvious choice.

Once you have created a table, `SHOW TABLES` should produce some output:

```
mysql> SHOW TABLES;
+---------------------+
| Tables in menagerie |
+---------------------+
| pet                 |
+---------------------+
```

To verify that your table was created the way you expected, use a `DESCRIBE` statement:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
```

```
| owner   | varchar(20) | YES |     | NULL    |       |
| species | varchar(20) | YES |     | NULL    |       |
| sex     | char(1)     | YES |     | NULL    |       |
| birth   | date        | YES |     | NULL    |       |
| death   | date        | YES |     | NULL    |       |
+---------+-------------+-----+-----+---------+-------+
```

You can use `DESCRIBE` any time, for example, if you forget the names of the columns in your table or what types they have.

For more information about MySQL data types, see Chapter 11, *Data Types*.

3.3.3 Loading Data into a Table

After creating your table, you need to populate it. The `LOAD DATA` and `INSERT` statements are useful for this.

Suppose that your pet records can be described as shown here. (Observe that MySQL expects dates in `'YYYY-MM-DD'` format; this may be different from what you are used to.)

name	owner	species	sex	birth	death
Fluffy	Harold	cat	f	1993-02-04	
Claws	Gwen	cat	m	1994-03-17	
Buffy	Harold	dog	f	1989-05-13	
Fang	Benny	dog	m	1990-08-27	
Bowser	Diane	dog	m	1979-08-31	1995-07-29
Chirpy	Gwen	bird	f	1998-09-11	
Whistler	Gwen	bird		1997-12-09	
Slim	Benny	snake	m	1996-04-29	

Because you are beginning with an empty table, an easy way to populate it is to create a text file containing a row for each of your animals, then load the contents of the file into the table with a single statement.

You could create a text file `pet.txt` containing one record per line, with values separated by tabs, and given in the order in which the columns were listed in the `CREATE TABLE` statement. For missing values (such as unknown sexes or death dates for animals that are still living), you can use `NULL` values. To represent these in your text file, use `\N` (backslash, capital-N). For example, the record for Whistler the bird would look like this (where the whitespace between values is a single tab character):

```
Whistler        Gwen    bird    \N      1997-12-09      \N
```

To load the text file `pet.txt` into the `pet` table, use this statement:

```
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet;
```

If you created the file on Windows with an editor that uses `\r\n` as a line terminator, you should use this statement instead:

```
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet
    -> LINES TERMINATED BY '\r\n';
```

(On an Apple machine running OS X, you would likely want to use `LINES TERMINATED BY '\r'`.)

You can specify the column value separator and end of line marker explicitly in the `LOAD DATA` statement if you wish, but the defaults are tab and linefeed. These are sufficient for the statement to read the file `pet.txt` properly.

If the statement fails, it is likely that your MySQL installation does not have local file capability enabled by default. See Section 6.1.6, "Security Issues with LOAD DATA LOCAL", for information on how to change this.

When you want to add new records one at a time, the `INSERT` statement is useful. In its simplest form, you supply values for each column, in the order in which the columns were listed in the `CREATE TABLE` statement. Suppose that Diane gets a new hamster named "Puffball." You could add a new record using an `INSERT` statement like this:

```
mysql> INSERT INTO pet
    -> VALUES ('Puffball','Diane','hamster','f','1999-03-30',NULL);
```

String and date values are specified as quoted strings here. Also, with `INSERT`, you can insert `NULL` directly to represent a missing value. You do not use `\N` like you do with `LOAD DATA`.

From this example, you should be able to see that there would be a lot more typing involved to load your records initially using several `INSERT` statements rather than a single `LOAD DATA` statement.

3.3.4 Retrieving Information from a Table

The `SELECT` statement is used to pull information from a table. The general form of the statement is:

```
SELECT what_to_select
FROM which_table
WHERE conditions_to_satisfy;
```

`what_to_select` indicates what you want to see. This can be a list of columns, or `*` to indicate "all columns." `which_table` indicates the table from which you want to retrieve data. The `WHERE` clause is optional. If it is present, `conditions_to_satisfy` specifies one or more conditions that rows must satisfy to qualify for retrieval.

3.3.4.1 Selecting All Data

The simplest form of `SELECT` retrieves everything from a table:

```
mysql> SELECT * FROM pet;
+----------+--------+---------+------+------------+------------+
| name     | owner  | species | sex  | birth      | death      |
+----------+--------+---------+------+------------+------------+
| Fluffy   | Harold | cat     | f    | 1993-02-04 | NULL       |
| Claws    | Gwen   | cat     | m    | 1994-03-17 | NULL       |
| Buffy    | Harold | dog     | f    | 1989-05-13 | NULL       |
| Fang     | Benny  | dog     | m    | 1990-08-27 | NULL       |
| Bowser   | Diane  | dog     | m    | 1979-08-31 | 1995-07-29 |
| Chirpy   | Gwen   | bird    | f    | 1998-09-11 | NULL       |
| Whistler | Gwen   | bird    | NULL | 1997-12-09 | NULL       |
| Slim     | Benny  | snake   | m    | 1996-04-29 | NULL       |
| Puffball | Diane  | hamster | f    | 1999-03-30 | NULL       |
+----------+--------+---------+------+------------+------------+
```

This form of `SELECT` is useful if you want to review your entire table, for example, after you've just loaded it with your initial data set. For example, you may happen to think that the birth date for Bowser doesn't seem quite right. Consulting your original pedigree papers, you find that the correct birth year should be 1989, not 1979.

There are at least two ways to fix this:

- Edit the file `pet.txt` to correct the error, then empty the table and reload it using `DELETE` and `LOAD DATA`:

```
mysql> DELETE FROM pet;
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet;
```

However, if you do this, you must also re-enter the record for Puffball.

- Fix only the erroneous record with an `UPDATE` statement:

```
mysql> UPDATE pet SET birth = '1989-08-31' WHERE name = 'Bowser';
```

The `UPDATE` changes only the record in question and does not require you to reload the table.

3.3.4.2 Selecting Particular Rows

As shown in the preceding section, it is easy to retrieve an entire table. Just omit the `WHERE` clause from the `SELECT` statement. But typically you don't want to see the entire table, particularly when it becomes large. Instead, you're usually more interested in answering a particular question, in which case you specify some constraints on the information you want. Let's look at some selection queries in terms of questions about your pets that they answer.

You can select only particular rows from your table. For example, if you want to verify the change that you made to Bowser's birth date, select Bowser's record like this:

```
mysql> SELECT * FROM pet WHERE name = 'Bowser';
+--------+-------+---------+------+------------+------------+
| name   | owner | species | sex  | birth      | death      |
+--------+-------+---------+------+------------+------------+
| Bowser | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+-------+---------+------+------------+------------+
```

The output confirms that the year is correctly recorded as 1989, not 1979.

String comparisons normally are case-insensitive, so you can specify the name as `'bowser'`, `'BOWSER'`, and so forth. The query result is the same.

You can specify conditions on any column, not just `name`. For example, if you want to know which animals were born during or after 1998, test the `birth` column:

```
mysql> SELECT * FROM pet WHERE birth >= '1998-1-1';
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
+----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Puffball | Diane | hamster | f    | 1999-03-30 | NULL  |
+----------+-------+---------+------+------------+-------+
```

You can combine conditions, for example, to locate female dogs:

```
mysql> SELECT * FROM pet WHERE species = 'dog' AND sex = 'f';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
```

```
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The preceding query uses the `AND` logical operator. There is also an `OR` operator:

```
mysql> SELECT * FROM pet WHERE species = 'snake' OR species = 'bird';
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
+----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL  |
| Slim     | Benny | snake   | m    | 1996-04-29 | NULL  |
+----------+-------+---------+------+------------+-------+
```

`AND` and `OR` may be intermixed, although `AND` has higher precedence than `OR`. If you use both operators, it is a good idea to use parentheses to indicate explicitly how conditions should be grouped:

```
mysql> SELECT * FROM pet WHERE (species = 'cat' AND sex = 'm')
    -> OR (species = 'dog' AND sex = 'f');
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

3.3.4.3 Selecting Particular Columns

If you do not want to see entire rows from your table, just name the columns in which you are interested, separated by commas. For example, if you want to know when your animals were born, select the `name` and `birth` columns:

```
mysql> SELECT name, birth FROM pet;
+----------+------------+
| name     | birth      |
+----------+------------+
| Fluffy   | 1993-02-04 |
| Claws    | 1994-03-17 |
| Buffy    | 1989-05-13 |
| Fang     | 1990-08-27 |
| Bowser   | 1989-08-31 |
| Chirpy   | 1998-09-11 |
| Whistler | 1997-12-09 |
| Slim     | 1996-04-29 |
| Puffball | 1999-03-30 |
+----------+------------+
```

To find out who owns pets, use this query:

```
mysql> SELECT owner FROM pet;
+--------+
| owner  |
+--------+
| Harold |
| Gwen   |
| Harold |
| Benny  |
| Diane  |
| Gwen   |
| Gwen   |
| Benny  |
```

```
| Diane  |
+--------+
```

Notice that the query simply retrieves the `owner` column from each record, and some of them appear more than once. To minimize the output, retrieve each unique output record just once by adding the keyword `DISTINCT`:

```
mysql> SELECT DISTINCT owner FROM pet;
+--------+
| owner  |
+--------+
| Benny  |
| Diane  |
| Gwen   |
| Harold |
+--------+
```

You can use a `WHERE` clause to combine row selection with column selection. For example, to get birth dates for dogs and cats only, use this query:

```
mysql> SELECT name, species, birth FROM pet
    -> WHERE species = 'dog' OR species = 'cat';
+--------+---------+------------+
| name   | species | birth      |
+--------+---------+------------+
| Fluffy | cat     | 1993-02-04 |
| Claws  | cat     | 1994-03-17 |
| Buffy  | dog     | 1989-05-13 |
| Fang   | dog     | 1990-08-27 |
| Bowser | dog     | 1989-08-31 |
+--------+---------+------------+
```

3.3.4.4 Sorting Rows

You may have noticed in the preceding examples that the result rows are displayed in no particular order. It is often easier to examine query output when the rows are sorted in some meaningful way. To sort a result, use an `ORDER BY` clause.

Here are animal birthdays, sorted by date:

```
mysql> SELECT name, birth FROM pet ORDER BY birth;
+----------+------------+
| name     | birth      |
+----------+------------+
| Buffy    | 1989-05-13 |
| Bowser   | 1989-08-31 |
| Fang     | 1990-08-27 |
| Fluffy   | 1993-02-04 |
| Claws    | 1994-03-17 |
| Slim     | 1996-04-29 |
| Whistler | 1997-12-09 |
| Chirpy   | 1998-09-11 |
| Puffball | 1999-03-30 |
+----------+------------+
```

On character type columns, sorting—like all other comparison operations—is normally performed in a case-insensitive fashion. This means that the order is undefined for columns that are identical except for their case. You can force a case-sensitive sort for a column by using `BINARY` like so: `ORDER BY BINARY col_name`.

The default sort order is ascending, with smallest values first. To sort in reverse (descending) order, add the `DESC` keyword to the name of the column you are sorting by:

```
mysql> SELECT name, birth FROM pet ORDER BY birth DESC;
+----------+------------+
| name     | birth      |
+----------+------------+
| Puffball | 1999-03-30 |
| Chirpy   | 1998-09-11 |
| Whistler | 1997-12-09 |
| Slim     | 1996-04-29 |
| Claws    | 1994-03-17 |
| Fluffy   | 1993-02-04 |
| Fang     | 1990-08-27 |
| Bowser   | 1989-08-31 |
| Buffy    | 1989-05-13 |
+----------+------------+
```

You can sort on multiple columns, and you can sort different columns in different directions. For example, to sort by type of animal in ascending order, then by birth date within animal type in descending order (youngest animals first), use the following query:

```
mysql> SELECT name, species, birth FROM pet
    -> ORDER BY species, birth DESC;
+----------+---------+------------+
| name     | species | birth      |
+----------+---------+------------+
| Chirpy   | bird    | 1998-09-11 |
| Whistler | bird    | 1997-12-09 |
| Claws    | cat     | 1994-03-17 |
| Fluffy   | cat     | 1993-02-04 |
| Fang     | dog     | 1990-08-27 |
| Bowser   | dog     | 1989-08-31 |
| Buffy    | dog     | 1989-05-13 |
| Puffball | hamster | 1999-03-30 |
| Slim     | snake   | 1996-04-29 |
+----------+---------+------------+
```

The `DESC` keyword applies only to the column name immediately preceding it (`birth`); it does not affect the `species` column sort order.

3.3.4.5 Date Calculations

MySQL provides several functions that you can use to perform calculations on dates, for example, to calculate ages or extract parts of dates.

To determine how many years old each of your pets is, use the `TIMESTAMPDIFF()` function. Its arguments are the unit in which you want the result expressed, and the two date for which to take the difference. The following query shows, for each pet, the birth date, the current date, and the age in years. An *alias* (`age`) is used to make the final output column label more meaningful.

```
mysql> SELECT name, birth, CURDATE(),
    -> TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
    -> FROM pet;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
```

```
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
+----------+------------+------------+------+
```

The query works, but the result could be scanned more easily if the rows were presented in some order.
This can be done by adding an `ORDER BY name` clause to sort the output by name:

```
mysql> SELECT name, birth, CURDATE(),
    -> TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
    -> FROM pet ORDER BY name;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
+----------+------------+------------+------+
```

To sort the output by `age` rather than `name`, just use a different `ORDER BY` clause:

```
mysql> SELECT name, birth, CURDATE(),
    -> TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
    -> FROM pet ORDER BY age;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
+----------+------------+------------+------+
```

A similar query can be used to determine age at death for animals that have died. You determine which
animals these are by checking whether the `death` value is `NULL`. Then, for those with non-`NULL` values,
compute the difference between the `death` and `birth` values:

```
mysql> SELECT name, birth, death,
    -> TIMESTAMPDIFF(YEAR,birth,death) AS age
    -> FROM pet WHERE death IS NOT NULL ORDER BY age;
+--------+------------+------------+------+
| name   | birth      | death      | age  |
+--------+------------+------------+------+
| Bowser | 1989-08-31 | 1995-07-29 |    5 |
+--------+------------+------------+------+
```

The query uses `death IS NOT NULL` rather than `death <> NULL` because `NULL` is a special value that
cannot be compared using the usual comparison operators. This is discussed later. See Section 3.3.4.6,
"Working with NULL Values".

What if you want to know which animals have birthdays next month? For this type of calculation, year and day are irrelevant; you simply want to extract the month part of the `birth` column. MySQL provides several functions for extracting parts of dates, such as `YEAR()`, `MONTH()`, and `DAYOFMONTH()`. `MONTH()` is the appropriate function here. To see how it works, run a simple query that displays the value of both `birth` and `MONTH(birth)`:

```
mysql> SELECT name, birth, MONTH(birth) FROM pet;
+----------+------------+--------------+
| name     | birth      | MONTH(birth) |
+----------+------------+--------------+
| Fluffy   | 1993-02-04 |            2 |
| Claws    | 1994-03-17 |            3 |
| Buffy    | 1989-05-13 |            5 |
| Fang     | 1990-08-27 |            8 |
| Bowser   | 1989-08-31 |            8 |
| Chirpy   | 1998-09-11 |            9 |
| Whistler | 1997-12-09 |           12 |
| Slim     | 1996-04-29 |            4 |
| Puffball | 1999-03-30 |            3 |
+----------+------------+--------------+
```

Finding animals with birthdays in the upcoming month is also simple. Suppose that the current month is April. Then the month value is 4 and you can look for animals born in May (month 5) like this:

```
mysql> SELECT name, birth FROM pet WHERE MONTH(birth) = 5;
+-------+------------+
| name  | birth      |
+-------+------------+
| Buffy | 1989-05-13 |
+-------+------------+
```

There is a small complication if the current month is December. You cannot merely add one to the month number (12) and look for animals born in month 13, because there is no such month. Instead, you look for animals born in January (month 1).

You can write the query so that it works no matter what the current month is, so that you do not have to use the number for a particular month. `DATE_ADD()` enables you to add a time interval to a given date. If you add a month to the value of `CURDATE()`, then extract the month part with `MONTH()`, the result produces the month in which to look for birthdays:

```
mysql> SELECT name, birth FROM pet
    -> WHERE MONTH(birth) = MONTH(DATE_ADD(CURDATE(),INTERVAL 1 MONTH));
```

A different way to accomplish the same task is to add 1 to get the next month after the current one after using the modulo function (`MOD`) to wrap the month value to 0 if it is currently 12:

```
mysql> SELECT name, birth FROM pet
    -> WHERE MONTH(birth) = MOD(MONTH(CURDATE()), 12) + 1;
```

`MONTH()` returns a number between 1 and 12. And `MOD(something,12)` returns a number between 0 and 11. So the addition has to be after the `MOD()`, otherwise we would go from November (11) to January (1).

3.3.4.6 Working with NULL Values

The `NULL` value can be surprising until you get used to it. Conceptually, `NULL` means "a missing unknown value" and it is treated somewhat differently from other values.

To test for `NULL`, use the `IS NULL` and `IS NOT NULL` operators, as shown here:

```
mysql> SELECT 1 IS NULL, 1 IS NOT NULL;
+-----------+---------------+
| 1 IS NULL | 1 IS NOT NULL |
+-----------+---------------+
|         0 |             1 |
+-----------+---------------+
```

You cannot use arithmetic comparison operators such as `=`, `<`, or `<>` to test for `NULL`. To demonstrate this for yourself, try the following query:

```
mysql> SELECT 1 = NULL, 1 <> NULL, 1 < NULL, 1 > NULL;
+----------+-----------+----------+----------+
| 1 = NULL | 1 <> NULL | 1 < NULL | 1 > NULL |
+----------+-----------+----------+----------+
|     NULL |      NULL |     NULL |     NULL |
+----------+-----------+----------+----------+
```

Because the result of any arithmetic comparison with `NULL` is also `NULL`, you cannot obtain any meaningful results from such comparisons.

In MySQL, `0` or `NULL` means false and anything else means true. The default truth value from a boolean operation is `1`.

This special treatment of `NULL` is why, in the previous section, it was necessary to determine which animals are no longer alive using `death IS NOT NULL` instead of `death <> NULL`.

Two `NULL` values are regarded as equal in a `GROUP BY`.

When doing an `ORDER BY`, `NULL` values are presented first if you do `ORDER BY ... ASC` and last if you do `ORDER BY ... DESC`.

A common error when working with `NULL` is to assume that it is not possible to insert a zero or an empty string into a column defined as `NOT NULL`, but this is not the case. These are in fact values, whereas `NULL` means "not having a value." You can test this easily enough by using `IS [NOT] NULL` as shown:

```
mysql> SELECT 0 IS NULL, 0 IS NOT NULL, '' IS NULL, '' IS NOT NULL;
+-----------+---------------+------------+----------------+
| 0 IS NULL | 0 IS NOT NULL | '' IS NULL | '' IS NOT NULL |
+-----------+---------------+------------+----------------+
|         0 |             1 |          0 |              1 |
+-----------+---------------+------------+----------------+
```

Thus it is entirely possible to insert a zero or empty string into a `NOT NULL` column, as these are in fact `NOT NULL`. See Section B.5.4.3, "Problems with NULL Values".

3.3.4.7 Pattern Matching

MySQL provides standard SQL pattern matching as well as a form of pattern matching based on extended regular expressions similar to those used by Unix utilities such as `vi`, `grep`, and `sed`.

SQL pattern matching enables you to use "`_`" to match any single character and "`%`" to match an arbitrary number of characters (including zero characters). In MySQL, SQL patterns are case-insensitive by default. Some examples are shown here. You do not use `=` or `<>` when you use SQL patterns; use the `LIKE` or `NOT LIKE` comparison operators instead.

To find names beginning with "`b`":

```
mysql> SELECT * FROM pet WHERE name LIKE 'b%';
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

To find names ending with "fy":

```
mysql> SELECT * FROM pet WHERE name LIKE '%fy';
+--------+--------+---------+------+------------+-------+
| name   | owner  | species | sex  | birth      | death |
+--------+--------+---------+------+------------+-------+
| Fluffy | Harold | cat     | f    | 1993-02-04 | NULL  |
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL  |
+--------+--------+---------+------+------------+-------+
```

To find names containing a "w":

```
mysql> SELECT * FROM pet WHERE name LIKE '%w%';
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

To find names containing exactly five characters, use five instances of the "_" pattern character:

```
mysql> SELECT * FROM pet WHERE name LIKE '_____';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The other type of pattern matching provided by MySQL uses extended regular expressions. When you test for a match for this type of pattern, use the REGEXP and NOT REGEXP operators (or RLIKE and NOT RLIKE, which are synonyms).

The following list describes some characteristics of extended regular expressions:

- "." matches any single character.

- A character class "[...]" matches any character within the brackets. For example, "[abc]" matches "a", "b", or "c". To name a range of characters, use a dash. "[a-z]" matches any letter, whereas "[0-9]" matches any digit.

- "*" matches zero or more instances of the thing preceding it. For example, "x*" matches any number of "x" characters, "[0-9]*" matches any number of digits, and ".*" matches any number of anything.

- A REGEXP pattern match succeeds if the pattern matches anywhere in the value being tested. (This differs from a LIKE pattern match, which succeeds only if the pattern matches the entire value.)

- To anchor a pattern so that it must match the beginning or end of the value being tested, use "^" at the beginning or "$" at the end of the pattern.

To demonstrate how extended regular expressions work, the LIKE queries shown previously are rewritten here to use REGEXP.

To find names beginning with "b", use "^" to match the beginning of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^b';
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

If you really want to force a REGEXP comparison to be case sensitive, use the BINARY keyword to make one of the strings a binary string. This query matches only lowercase "b" at the beginning of a name:

```
mysql> SELECT * FROM pet WHERE name REGEXP BINARY '^b';
```

To find names ending with "fy", use "$" to match the end of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP 'fy$';
+--------+--------+---------+------+------------+-------+
| name   | owner  | species | sex  | birth      | death |
+--------+--------+---------+------+------------+-------+
| Fluffy | Harold | cat     | f    | 1993-02-04 | NULL  |
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL  |
+--------+--------+---------+------+------------+-------+
```

To find names containing a "w", use this query:

```
mysql> SELECT * FROM pet WHERE name REGEXP 'w';
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

Because a regular expression pattern matches if it occurs anywhere in the value, it is not necessary in the previous query to put a wildcard on either side of the pattern to get it to match the entire value like it would be if you used an SQL pattern.

To find names containing exactly five characters, use "^" and "$" to match the beginning and end of the name, and five instances of "." in between:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^.....$';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

You could also write the previous query using the $\{n\}$ ("repeat-n-times") operator:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^.{5}$';
```

```
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

Section 12.5.2, "Regular Expressions", provides more information about the syntax for regular expressions.

3.3.4.8 Counting Rows

Databases are often used to answer the question, "How often does a certain type of data occur in a table?" For example, you might want to know how many pets you have, or how many pets each owner has, or you might want to perform various kinds of census operations on your animals.

Counting the total number of animals you have is the same question as "How many rows are in the pet table?" because there is one record per pet. COUNT(*) counts the number of rows, so the query to count your animals looks like this:

```
mysql> SELECT COUNT(*) FROM pet;
+----------+
| COUNT(*) |
+----------+
|        9 |
+----------+
```

Earlier, you retrieved the names of the people who owned pets. You can use COUNT() if you want to find out how many pets each owner has:

```
mysql> SELECT owner, COUNT(*) FROM pet GROUP BY owner;
+--------+----------+
| owner  | COUNT(*) |
+--------+----------+
| Benny  |        2 |
| Diane  |        2 |
| Gwen   |        3 |
| Harold |        2 |
+--------+----------+
```

The preceding query uses GROUP BY to group all records for each owner. The use of COUNT() in conjunction with GROUP BY is useful for characterizing your data under various groupings. The following examples show different ways to perform animal census operations.

Number of animals per species:

```
mysql> SELECT species, COUNT(*) FROM pet GROUP BY species;
+---------+----------+
| species | COUNT(*) |
+---------+----------+
| bird    |        2 |
| cat     |        2 |
| dog     |        3 |
| hamster |        1 |
| snake   |        1 |
+---------+----------+
```

Number of animals per sex:

```
mysql> SELECT sex, COUNT(*) FROM pet GROUP BY sex;
```

```
+------+----------+
| sex  | COUNT(*) |
+------+----------+
| NULL |        1 |
| f    |        4 |
| m    |        4 |
+------+----------+
```

(In this output, NULL indicates that the sex is unknown.)

Number of animals per combination of species and sex:

```
mysql> SELECT species, sex, COUNT(*) FROM pet GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | NULL |        1 |
| bird    | f    |        1 |
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
```

You need not retrieve an entire table when you use COUNT(). For example, the previous query, when performed just on dogs and cats, looks like this:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    -> WHERE species = 'dog' OR species = 'cat'
    -> GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
+---------+------+----------+
```

Or, if you wanted the number of animals per sex only for animals whose sex is known:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    -> WHERE sex IS NOT NULL
    -> GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | f    |        1 |
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
```

If you name columns to select in addition to the COUNT() value, a GROUP BY clause should be present that names those same columns. Otherwise, the following occurs:

- If the ONLY_FULL_GROUP_BY SQL mode is enabled, an error occurs:

```
mysql> SET sql_mode = 'ONLY_FULL_GROUP_BY';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT owner, COUNT(*) FROM pet;
ERROR 1140 (42000): Mixing of GROUP columns (MIN(),MAX(),COUNT()...)
with no GROUP columns is illegal if there is no GROUP BY clause
```

- If ONLY_FULL_GROUP_BY is not enabled, the query is processed by treating all rows as a single group, but the value selected for each named column is indeterminate. The server is free to select the value from any row:

```
mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT owner, COUNT(*) FROM pet;
+--------+----------+
| owner  | COUNT(*) |
+--------+----------+
| Harold |        8 |
+--------+----------+
1 row in set (0.00 sec)
```

See also Section 12.17.3, "MySQL Handling of GROUP BY".

3.3.4.9 Using More Than one Table

The pet table keeps track of which pets you have. If you want to record other information about them, such as events in their lives like visits to the vet or when litters are born, you need another table. What should this table look like? It needs to contain the following information:

- The pet name so that you know which animal each event pertains to.

- A date so that you know when the event occurred.

- A field to describe the event.

- An event type field, if you want to be able to categorize events.

Given these considerations, the CREATE TABLE statement for the event table might look like this:

```
mysql> CREATE TABLE event (name VARCHAR(20), date DATE,
    -> type VARCHAR(15), remark VARCHAR(255));
```

As with the pet table, it is easiest to load the initial records by creating a tab-delimited text file containing the following information.

name	date	type	remark
Fluffy	1995-05-15	litter	4 kittens, 3 female, 1 male
Buffy	1993-06-23	litter	5 puppies, 2 female, 3 male
Buffy	1994-06-19	litter	3 puppies, 3 female
Chirpy	1999-03-21	vet	needed beak straightened
Slim	1997-08-03	vet	broken rib
Bowser	1991-10-12	kennel	

name	date	type	remark
Fang	1991-10-12	kennel	
Fang	1998-08-28	birthday	Gave him a new chew toy
Claws	1998-03-17	birthday	Gave him a new flea collar
Whistler	1998-12-09	birthday	First birthday

Load the records like this:

```
mysql> LOAD DATA LOCAL INFILE 'event.txt' INTO TABLE event;
```

Based on what you have learned from the queries that you have run on the `pet` table, you should be able to perform retrievals on the records in the `event` table; the principles are the same. But when is the `event` table by itself insufficient to answer questions you might ask?

Suppose that you want to find out the ages at which each pet had its litters. We saw earlier how to calculate ages from two dates. The litter date of the mother is in the `event` table, but to calculate her age on that date you need her birth date, which is stored in the `pet` table. This means the query requires both tables:

```
mysql> SELECT pet.name,
    -> TIMESTAMPDIFF(YEAR,birth,date) AS age,
    -> remark
    -> FROM pet INNER JOIN event
    ->   ON pet.name = event.name
    -> WHERE event.type = 'litter';
+--------+------+----------------------------+
| name   | age  | remark                     |
+--------+------+----------------------------+
| Fluffy |    2 | 4 kittens, 3 female, 1 male |
| Buffy  |    4 | 5 puppies, 2 female, 3 male |
| Buffy  |    5 | 3 puppies, 3 female        |
+--------+------+----------------------------+
```

There are several things to note about this query:

- The `FROM` clause joins two tables because the query needs to pull information from both of them.

- When combining (joining) information from multiple tables, you need to specify how records in one table can be matched to records in the other. This is easy because they both have a `name` column. The query uses an `ON` clause to match up records in the two tables based on the `name` values.

  The query uses an `INNER JOIN` to combine the tables. An `INNER JOIN` permits rows from either table to appear in the result if and only if both tables meet the conditions specified in the `ON` clause. In this example, the `ON` clause specifies that the `name` column in the `pet` table must match the `name` column in the `event` table. If a name appears in one table but not the other, the row will not appear in the result because the condition in the `ON` clause fails.

- Because the `name` column occurs in both tables, you must be specific about which table you mean when referring to the column. This is done by prepending the table name to the column name.

You need not have two different tables to perform a join. Sometimes it is useful to join a table to itself, if you want to compare records in a table to other records in that same table. For example, to find breeding pairs among your pets, you can join the `pet` table with itself to produce candidate pairs of males and females of like species:

```
mysql> SELECT p1.name, p1.sex, p2.name, p2.sex, p1.species
    -> FROM pet AS p1 INNER JOIN pet AS p2
    ->   ON p1.species = p2.species AND p1.sex = 'f' AND p2.sex = 'm';
+--------+------+--------+------+---------+
| name   | sex  | name   | sex  | species |
+--------+------+--------+------+---------+
| Fluffy | f    | Claws  | m    | cat     |
| Buffy  | f    | Fang   | m    | dog     |
| Buffy  | f    | Bowser | m    | dog     |
+--------+------+--------+------+---------+
```

In this query, we specify aliases for the table name to refer to the columns and keep straight which instance of the table each column reference is associated with.

3.4 Getting Information About Databases and Tables

What if you forget the name of a database or table, or what the structure of a given table is (for example, what its columns are called)? MySQL addresses this problem through several statements that provide information about the databases and tables it supports.

You have previously seen SHOW DATABASES, which lists the databases managed by the server. To find out which database is currently selected, use the DATABASE() function:

```
mysql> SELECT DATABASE();
+------------+
| DATABASE() |
+------------+
| menagerie  |
+------------+
```

If you have not yet selected any database, the result is NULL.

To find out what tables the default database contains (for example, when you are not sure about the name of a table), use this statement:

```
mysql> SHOW TABLES;
+---------------------+
| Tables_in_menagerie |
+---------------------+
| event               |
| pet                 |
+---------------------+
```

The name of the column in the output produced by this statement is always Tables_in_*db_name*, where *db_name* is the name of the database. See Section 13.7.5.39, "SHOW TABLES Syntax", for more information.

If you want to find out about the structure of a table, the DESCRIBE statement is useful; it displays information about each of a table's columns:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
```

```
| death   | date        | YES  |     | NULL     |       |
+---------+-------------+------+-----+---------+-------+
```

`Field` indicates the column name, `Type` is the data type for the column, `NULL` indicates whether the column can contain `NULL` values, `Key` indicates whether the column is indexed, and `Default` specifies the column's default value. `Extra` displays special information about columns: If a column was created with the `AUTO_INCREMENT` option, the value will be `auto_increment` rather than empty.

`DESC` is a short form of `DESCRIBE`. See Section 13.8.1, "DESCRIBE Syntax", for more information.

You can obtain the `CREATE TABLE` statement necessary to create an existing table using the `SHOW CREATE TABLE` statement. See Section 13.7.5.12, "SHOW CREATE TABLE Syntax".

If you have indexes on a table, `SHOW INDEX FROM tbl_name` produces information about them. See Section 13.7.5.23, "SHOW INDEX Syntax", for more about this statement.

3.5 Using mysql in Batch Mode

In the previous sections, you used `mysql` interactively to enter statements and view the results. You can also run `mysql` in batch mode. To do this, put the statements you want to run in a file, then tell `mysql` to read its input from the file:

```
shell> mysql < batch-file
```

If you are running `mysql` under Windows and have some special characters in the file that cause problems, you can do this:

```
C:\> mysql -e "source batch-file"
```

If you need to specify connection parameters on the command line, the command might look like this:

```
shell> mysql -h host -u user -p < batch-file
Enter password: ********
```

When you use `mysql` this way, you are creating a script file, then executing the script.

If you want the script to continue even if some of the statements in it produce errors, you should use the `--force` command-line option.

Why use a script? Here are a few reasons:

* If you run a query repeatedly (say, every day or every week), making it a script enables you to avoid retyping it each time you execute it.

* You can generate new queries from existing ones that are similar by copying and editing script files.

* Batch mode can also be useful while you're developing a query, particularly for multiple-line statements or multiple-statement sequences. If you make a mistake, you don't have to retype everything. Just edit your script to correct the error, then tell `mysql` to execute it again.

* If you have a query that produces a lot of output, you can run the output through a pager rather than watching it scroll off the top of your screen:

  ```
  shell> mysql < batch-file | more
  ```

- You can catch the output in a file for further processing:

```
shell> mysql < batch-file > mysql.out
```

- You can distribute your script to other people so that they can also run the statements.

- Some situations do not allow for interactive use, for example, when you run a query from a `cron` job. In this case, you must use batch mode.

The default output format is different (more concise) when you run `mysql` in batch mode than when you use it interactively. For example, the output of `SELECT DISTINCT species FROM pet` looks like this when `mysql` is run interactively:

```
+---------+
| species |
+---------+
| bird    |
| cat     |
| dog     |
| hamster |
| snake   |
+---------+
```

In batch mode, the output looks like this instead:

```
species
bird
cat
dog
hamster
snake
```

If you want to get the interactive output format in batch mode, use `mysql -t`. To echo to the output the statements that are executed, use `mysql -v`.

You can also use scripts from the `mysql` prompt by using the `source` command or `\.` command:

```
mysql> source filename;
mysql> \. filename
```

See Section 4.5.1.5, "Executing SQL Statements from a Text File", for more information.

3.6 Examples of Common Queries

Here are examples of how to solve some common problems with MySQL.

Some of the examples use the table `shop` to hold the price of each article (item number) for certain traders (dealers). Supposing that each trader has a single fixed price per article, then (`article`, `dealer`) is a primary key for the records.

Start the command-line tool `mysql` and select a database:

```
shell> mysql your-database-name
```

(In most MySQL installations, you can use the database named `test`).

You can create and populate the example table with these statements:

```
CREATE TABLE shop (
    article INT(4) UNSIGNED ZEROFILL DEFAULT '0000' NOT NULL,
    dealer  CHAR(20)                 DEFAULT ''     NOT NULL,
    price   DOUBLE(16,2)             DEFAULT '0.00' NOT NULL,
    PRIMARY KEY(article, dealer));
INSERT INTO shop VALUES
    (1,'A',3.45),(1,'B',3.99),(2,'A',10.99),(3,'B',1.45),
    (3,'C',1.69),(3,'D',1.25),(4,'D',19.95);
```

After issuing the statements, the table should have the following contents:

```
SELECT * FROM shop;

+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0001 | A      |  3.45 |
|    0001 | B      |  3.99 |
|    0002 | A      | 10.99 |
|    0003 | B      |  1.45 |
|    0003 | C      |  1.69 |
|    0003 | D      |  1.25 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

3.6.1 The Maximum Value for a Column

"What is the highest item number?"

```
SELECT MAX(article) AS article FROM shop;

+---------+
| article |
+---------+
|       4 |
+---------+
```

3.6.2 The Row Holding the Maximum of a Certain Column

Task: Find the number, dealer, and price of the most expensive article.

This is easily done with a subquery:

```
SELECT article, dealer, price
FROM   shop
WHERE  price=(SELECT MAX(price) FROM shop);

+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

Other solutions are to use a LEFT JOIN or to sort all rows descending by price and get only the first row using the MySQL-specific LIMIT clause:

```
SELECT s1.article, s1.dealer, s1.price
```

```
FROM shop s1
LEFT JOIN shop s2 ON s1.price < s2.price
WHERE s2.article IS NULL;

SELECT article, dealer, price
FROM shop
ORDER BY price DESC
LIMIT 1;
```

Note

If there were several most expensive articles, each with a price of 19.95, the `LIMIT` solution would show only one of them.

3.6.3 Maximum of Column per Group

Task: Find the highest price per article.

```
SELECT article, MAX(price) AS price
FROM   shop
GROUP BY article;

+---------+-------+
| article | price |
+---------+-------+
|    0001 |  3.99 |
|    0002 | 10.99 |
|    0003 |  1.69 |
|    0004 | 19.95 |
+---------+-------+
```

3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column

Task: For each article, find the dealer or dealers with the most expensive price.

This problem can be solved with a subquery like this one:

```
SELECT article, dealer, price
FROM   shop s1
WHERE  price=(SELECT MAX(s2.price)
             FROM shop s2
             WHERE s1.article = s2.article);

+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0001 | B      |  3.99 |
|    0002 | A      | 10.99 |
|    0003 | C      |  1.69 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

The preceding example uses a correlated subquery, which can be inefficient (see Section 13.2.9.7, "Correlated Subqueries"). Other possibilities for solving the problem are to use an uncorrelated subquery in the `FROM` clause or a `LEFT JOIN`.

Uncorrelated subquery:

```
SELECT s1.article, dealer, s1.price
FROM shop s1
```

```
JOIN (
  SELECT article, MAX(price) AS price
  FROM shop
  GROUP BY article) AS s2
  ON s1.article = s2.article AND s1.price = s2.price;
```

LEFT JOIN:

```
SELECT s1.article, s1.dealer, s1.price
FROM shop s1
LEFT JOIN shop s2 ON s1.article = s2.article AND s1.price < s2.price
WHERE s2.article IS NULL;
```

The LEFT JOIN works on the basis that when `s1.price` is at its maximum value, there is no `s2.price` with a greater value and the `s2` rows values will be NULL. See Section 13.2.8.2, "JOIN Syntax".

3.6.5 Using User-Defined Variables

You can employ MySQL user variables to remember results without having to store them in temporary variables in the client. (See Section 9.4, "User-Defined Variables".)

For example, to find the articles with the highest and lowest price you can do this:

```
mysql> SELECT @min_price:=MIN(price),@max_price:=MAX(price) FROM shop;
mysql> SELECT * FROM shop WHERE price=@min_price OR price=@max_price;
+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0003 | D      |  1.25 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

Note

It is also possible to store the name of a database object such as a table or a column in a user variable and then to use this variable in an SQL statement; however, this requires the use of a prepared statement. See Section 13.5, "SQL Syntax for Prepared Statements", for more information.

3.6.6 Using Foreign Keys

In MySQL, InnoDB tables support checking of foreign key constraints. See Section 14.6, "The InnoDB Storage Engine", and Section 1.8.2.4, "Foreign Key Differences".

A foreign key constraint is not required merely to join two tables. For storage engines other than InnoDB, it is possible when defining a column to use a REFERENCES *tbl_name(col_name)* clause, which has no actual effect, and *serves only as a memo or comment to you that the column which you are currently defining is intended to refer to a column in another table*. It is extremely important to realize when using this syntax that:

- MySQL does not perform any sort of CHECK to make sure that *col_name* actually exists in *tbl_name* (or even that *tbl_name* itself exists).

- MySQL does not perform any sort of action on *tbl_name* such as deleting rows in response to actions taken on rows in the table which you are defining; in other words, this syntax induces no ON DELETE or ON UPDATE behavior whatsoever. (Although you can write an ON DELETE or ON UPDATE clause as part of the REFERENCES clause, it is also ignored.)

- This syntax creates a *column*; it does **not** create any sort of index or key.

You can use a column so created as a join column, as shown here:

```
CREATE TABLE person (
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,
    name CHAR(60) NOT NULL,
    PRIMARY KEY (id)
);

CREATE TABLE shirt (
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,
    style ENUM('t-shirt', 'polo', 'dress') NOT NULL,
    color ENUM('red', 'blue', 'orange', 'white', 'black') NOT NULL,
    owner SMALLINT UNSIGNED NOT NULL REFERENCES person(id),
    PRIMARY KEY (id)
);

INSERT INTO person VALUES (NULL, 'Antonio Paz');

SELECT @last := LAST_INSERT_ID();

INSERT INTO shirt VALUES
(NULL, 'polo', 'blue', @last),
(NULL, 'dress', 'white', @last),
(NULL, 't-shirt', 'blue', @last);

INSERT INTO person VALUES (NULL, 'Lilliana Angelovska');

SELECT @last := LAST_INSERT_ID();

INSERT INTO shirt VALUES
(NULL, 'dress', 'orange', @last),
(NULL, 'polo', 'red', @last),
(NULL, 'dress', 'blue', @last),
(NULL, 't-shirt', 'white', @last);

SELECT * FROM person;
+----+---------------------+
| id | name                |
+----+---------------------+
|  1 | Antonio Paz         |
|  2 | Lilliana Angelovska |
+----+---------------------+

SELECT * FROM shirt;
+----+---------+--------+-------+
| id | style   | color  | owner |
+----+---------+--------+-------+
|  1 | polo    | blue   |     1 |
|  2 | dress   | white  |     1 |
|  3 | t-shirt | blue   |     1 |
|  4 | dress   | orange |     2 |
|  5 | polo    | red    |     2 |
|  6 | dress   | blue   |     2 |
|  7 | t-shirt | white  |     2 |
+----+---------+--------+-------+


SELECT s.* FROM person p INNER JOIN shirt s
   ON s.owner = p.id
 WHERE p.name LIKE 'Lilliana%'
   AND s.color <> 'white';

+----+-------+--------+-------+
| id | style | color  | owner |
```

```
+----+-------+--------+-------+
|  4 | dress | orange |     2 |
|  5 | polo  | red    |     2 |
|  6 | dress | blue   |     2 |
+----+-------+--------+-------+
```

When used in this fashion, the REFERENCES clause is not displayed in the output of SHOW CREATE TABLE or DESCRIBE:

```
SHOW CREATE TABLE shirt\G
*************************** 1. row ***************************
Table: shirt
Create Table: CREATE TABLE `shirt` (
`id` smallint(5) unsigned NOT NULL auto_increment,
`style` enum('t-shirt','polo','dress') NOT NULL,
`color` enum('red','blue','orange','white','black') NOT NULL,
`owner` smallint(5) unsigned NOT NULL,
PRIMARY KEY  (`id`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

The use of REFERENCES in this way as a comment or "reminder" in a column definition works with MyISAM tables.

3.6.7 Searching on Two Keys

An OR using a single key is well optimized, as is the handling of AND.

The one tricky case is that of searching on two different keys combined with OR:

```
SELECT field1_index, field2_index FROM test_table
WHERE field1_index = '1' OR  field2_index = '1'
```

This case is optimized. See Section 8.2.1.4, "Index Merge Optimization".

You can also solve the problem efficiently by using a UNION that combines the output of two separate SELECT statements. See Section 13.2.8.3, "UNION Syntax".

Each SELECT searches only one key and can be optimized:

```
SELECT field1_index, field2_index
    FROM test_table WHERE field1_index = '1'
UNION
SELECT field1_index, field2_index
    FROM test_table WHERE field2_index = '1';
```

3.6.8 Calculating Visits Per Day

The following example shows how you can use the bit group functions to calculate the number of days per month a user has visited a Web page.

```
CREATE TABLE t1 (year YEAR(4), month INT(2) UNSIGNED ZEROFILL,
            day INT(2) UNSIGNED ZEROFILL);
INSERT INTO t1 VALUES(2000,1,1),(2000,1,20),(2000,1,30),(2000,2,2),
            (2000,2,23),(2000,2,23);
```

The example table contains year-month-day values representing visits by users to the page. To determine how many different days in each month these visits occur, use this query:

```
SELECT year,month,BIT_COUNT(BIT_OR(1<<day)) AS days FROM t1
       GROUP BY year,month;
```

Which returns:

```
+------+-------+------+
| year | month | days |
+------+-------+------+
| 2000 |    01 |    3 |
| 2000 |    02 |    2 |
+------+-------+------+
```

The query calculates how many different days appear in the table for each year/month combination, with automatic removal of duplicate entries.

3.6.9 Using AUTO_INCREMENT

The AUTO_INCREMENT attribute can be used to generate a unique identity for new rows:

```
CREATE TABLE animals (
     id MEDIUMINT NOT NULL AUTO_INCREMENT,
     name CHAR(30) NOT NULL,
     PRIMARY KEY (id)
) ENGINE=INNODB;

INSERT INTO animals (name) VALUES
    ('dog'),('cat'),('penguin'),
    ('lax'),('whale'),('ostrich');

SELECT * FROM animals;
```

Which returns:

```
+----+---------+
| id | name    |
+----+---------+
|  1 | dog     |
|  2 | cat     |
|  3 | penguin |
|  4 | lax     |
|  5 | whale   |
|  6 | ostrich |
+----+---------+
```

No value was specified for the AUTO_INCREMENT column, so MySQL assigned sequence numbers automatically. You can also explicitly assign 0 to the column to generate sequence numbers. If the column is declared NOT NULL, it is also possible to assign NULL to the column to generate sequence numbers. When you insert any other value into an AUTO_INCREMENT column, the column is set to that value and the sequence is reset so that the next automatically generated value follows sequentially from the largest column value.

You can retrieve the most recent automatically generated AUTO_INCREMENT value with the LAST_INSERT_ID() SQL function or the mysql_insert_id() C API function. These functions are connection-specific, so their return values are not affected by another connection which is also performing inserts.

Use the smallest integer data type for the AUTO_INCREMENT column that is large enough to hold the maximum sequence value you will need. When the column reaches the upper limit of the data type, the next attempt to generate a sequence number fails. Use the UNSIGNED attribute if possible to allow a

greater range. For example, if you use `TINYINT`, the maximum permissible sequence number is 127. For `TINYINT UNSIGNED`, the maximum is 255. See Section 11.2.1, "Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT" for the ranges of all the integer types.

> **Note**
>
> For a multiple-row insert, `LAST_INSERT_ID()` and `mysql_insert_id()` actually return the `AUTO_INCREMENT` key from the *first* of the inserted rows. This enables multiple-row inserts to be reproduced correctly on other servers in a replication setup.

To start with an `AUTO_INCREMENT` value other than 1, set that value with `CREATE TABLE` or `ALTER TABLE`, like this:

```
mysql> ALTER TABLE tbl AUTO_INCREMENT = 100;
```

InnoDB Notes

For information about `AUTO_INCREMENT` usage specific to `InnoDB`, see Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB".

MyISAM Notes

- For `MyISAM` tables, you can specify `AUTO_INCREMENT` on a secondary column in a multiple-column index. In this case, the generated value for the `AUTO_INCREMENT` column is calculated as `MAX(auto_increment_column) + 1 WHERE prefix=given-prefix`. This is useful when you want to put data into ordered groups.

```
CREATE TABLE animals (
    grp ENUM('fish','mammal','bird') NOT NULL,
    id MEDIUMINT NOT NULL AUTO_INCREMENT,
    name CHAR(30) NOT NULL,
    PRIMARY KEY (grp,id)
) ENGINE=MyISAM;

INSERT INTO animals (grp,name) VALUES
    ('mammal','dog'),('mammal','cat'),
    ('bird','penguin'),('fish','lax'),('mammal','whale'),
    ('bird','ostrich');

SELECT * FROM animals ORDER BY grp,id;
```

Which returns:

```
+--------+----+---------+
| grp    | id | name    |
+--------+----+---------+
| fish   |  1 | lax     |
| mammal |  1 | dog     |
| mammal |  2 | cat     |
| mammal |  3 | whale   |
| bird   |  1 | penguin |
| bird   |  2 | ostrich |
+--------+----+---------+
```

In this case (when the `AUTO_INCREMENT` column is part of a multiple-column index), `AUTO_INCREMENT` values are reused if you delete the row with the biggest `AUTO_INCREMENT` value in any group. This happens even for `MyISAM` tables, for which `AUTO_INCREMENT` values normally are not reused.

- If the `AUTO_INCREMENT` column is part of multiple indexes, MySQL generates sequence values using the index that begins with the `AUTO_INCREMENT` column, if there is one. For example, if the `animals` table contained indexes `PRIMARY KEY (grp, id)` and `INDEX (id)`, MySQL would ignore the `PRIMARY KEY` for generating sequence values. As a result, the table would contain a single sequence, not a sequence per `grp` value.

Further Reading

More information about `AUTO_INCREMENT` is available here:

- How to assign the `AUTO_INCREMENT` attribute to a column: Section 13.1.17, "CREATE TABLE Syntax", and Section 13.1.7, "ALTER TABLE Syntax".

- How `AUTO_INCREMENT` behaves depending on the `NO_AUTO_VALUE_ON_ZERO` SQL mode: Section 5.1.7, "Server SQL Modes".

- How to use the `LAST_INSERT_ID()` function to find the row that contains the most recent `AUTO_INCREMENT` value: Section 12.14, "Information Functions".

- Setting the `AUTO_INCREMENT` value to be used: Section 5.1.4, "Server System Variables".

- Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB"

- `AUTO_INCREMENT` and replication: Section 16.4.1.1, "Replication and AUTO_INCREMENT".

- Server-system variables related to `AUTO_INCREMENT` (`auto_increment_increment` and `auto_increment_offset`) that can be used for replication: Section 5.1.4, "Server System Variables".

3.7 Using MySQL with Apache

There are programs that let you authenticate your users from a MySQL database and also let you write your log files into a MySQL table.

You can change the Apache logging format to be easily readable by MySQL by putting the following into the Apache configuration file:

```
LogFormat \
        "\"%h\",%{%Y%m%d%H%M%S}t,%>s,\"%b\",\"%{Content-Type}o\",  \
        \"%U\",\"%{Referer}i\",\"%{User-Agent}i\""
```

To load a log file in that format into MySQL, you can use a statement something like this:

```
LOAD DATA INFILE '/local/access_log' INTO TABLE tbl_name
FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"' ESCAPED BY '\\'
```

The named table should be created to have columns that correspond to those that the `LogFormat` line writes to the log file.

Chapter 4 MySQL Programs

Table of Contents

This chapter provides a brief overview of the MySQL command-line programs provided by Oracle Corporation. It also discusses the general syntax for specifying options when you run these programs. Most programs have options that are specific to their own operation, but the option syntax is similar for all of them. Finally, the chapter provides more detailed descriptions of individual programs, including which options they recognize.

4.1 Overview of MySQL Programs

There are many different programs in a MySQL installation. This section provides a brief overview of them. Later sections provide a more detailed description of each one, with the exception of MySQL Cluster programs. Each program's description indicates its invocation syntax and the options that it supports. Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*, describes programs specific to MySQL Cluster.

Most MySQL distributions include all of these programs, except for those programs that are platform-specific. (For example, the server startup scripts are not used on Windows.) The exception is that RPM distributions are more specialized. There is one RPM for the server, another for client programs, and so forth. If you appear to be missing one or more programs, see Chapter 2, *Installing and Upgrading MySQL*, for information on types of distributions and what they contain. It may be that you have a distribution that does not include all programs and you need to install an additional package.

Each MySQL program takes many different options. Most programs provide a `--help` option that you can use to get a description of the program's different options. For example, try `mysql --help`.

You can override default option values for MySQL programs by specifying options on the command line or in an option file. See Section 4.2, "Using MySQL Programs", for general information on invoking programs and specifying program options.

The MySQL server, `mysqld`, is the main program that does most of the work in a MySQL installation. The server is accompanied by several related scripts that assist you in starting and stopping the server:

- `mysqld`

  The SQL daemon (that is, the MySQL server). To use client programs, `mysqld` must be running, because clients gain access to databases by connecting to the server. See Section 4.3.1, "`mysqld` — The MySQL Server".

- `mysqld_safe`

  A server startup script. `mysqld_safe` attempts to start `mysqld`. See Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".

- `mysql.server`

A server startup script. This script is used on systems that use System V-style run directories containing scripts that start system services for particular run levels. It invokes `mysqld_safe` to start the MySQL server. See Section 4.3.3, "`mysql.server` — MySQL Server Startup Script".

- `mysqld_multi`

  A server startup script that can start or stop multiple servers installed on the system. See Section 4.3.4, "`mysqld_multi` — Manage Multiple MySQL Servers". An alternative to `mysqld_multi` is `mysqlmanager`, the MySQL Instance Manager. See Section 4.6.10, "`mysqlmanager` — The MySQL Instance Manager".

There are several programs that perform setup operations during MySQL installation or upgrading:

- `comp_err`

  This program is used during the MySQL build/installation process. It compiles error message files from the error source files. See Section 4.4.1, "`comp_err` — Compile MySQL Error Message File".

- `make_binary_distribution`

  This program makes a binary release of a compiled MySQL. This could be sent by FTP to `/pub/mysql/upload/` on `ftp.mysql.com` for the convenience of other MySQL users.

- `make_win_bin_dist`

  This program is used on Windows. It packages a MySQL distribution for installation after the source distribution has been built. See Section 4.4.2, "`make_win_bin_dist` — Package MySQL Distribution as Zip Archive".

- `mysql_fix_privilege_tables`

  This program is used after a MySQL upgrade operation. It updates the grant tables with any changes that have been made in newer versions of MySQL. See Section 4.4.4, "`mysql_fix_privilege_tables` — Upgrade MySQL System Tables".

  Note: As of MySQL 5.1.7, this program has been superseded by `mysql_upgrade` and should no longer be used.

- `mysql_install_db`

  This program initializes the MySQL data directory, creates the `mysql` database, and initializes its grant tables with default privileges. It is usually executed only once, when first installing MySQL on a system. See Section 4.4.5, "`mysql_install_db` — Initialize MySQL Data Directory", and Section 2.12, "Postinstallation Setup and Testing".

- `mysql_secure_installation`

  This program enables you to improve the security of your MySQL installation. See Section 4.4.6, "`mysql_secure_installation` — Improve MySQL Installation Security".

- `mysql_tzinfo_to_sql`

  This program loads the time zone tables in the `mysql` database using the contents of the host system *zoneinfo* database (the set of files describing time zones). See Section 4.4.7, "`mysql_tzinfo_to_sql` — Load the Time Zone Tables".

- `mysql_upgrade`

This program is used after a MySQL upgrade operation. It checks tables for incompatibilities and repairs them if necessary, and updates the grant tables with any changes that have been made in newer versions of MySQL. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

MySQL client programs:

- `mysql`

  The command-line tool for interactively entering SQL statements or executing them from a file in batch mode. See Section 4.5.1, "`mysql` — The MySQL Command-Line Tool".

- `mysqladmin`

  A client that performs administrative operations, such as creating or dropping databases, reloading the grant tables, flushing tables to disk, and reopening log files. `mysqladmin` can also be used to retrieve version, process, and status information from the server. See Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".

- `mysqlcheck`

  A table-maintenance client that checks, repairs, analyzes, and optimizes tables. See Section 4.5.3, "`mysqlcheck` — A Table Maintenance Program".

- `mysqldump`

  A client that dumps a MySQL database into a file as SQL, text, or XML. See Section 4.5.4, "`mysqldump` — A Database Backup Program".

- `mysqlimport`

  A client that imports text files into their respective tables using `LOAD DATA INFILE`. See Section 4.5.5, "`mysqlimport` — A Data Import Program".

- `mysqlshow`

  A client that displays information about databases, tables, columns, and indexes. See Section 4.5.6, "`mysqlshow` — Display Database, Table, and Column Information".

- `mysqlslap`

  A client that is designed to emulate client load for a MySQL server and report the timing of each stage. It works as if multiple clients are accessing the server. See Section 4.5.7, "`mysqlslap` — Load Emulation Client".

MySQL administrative and utility programs:

- `innochecksum`

  An offline `InnoDB` offline file checksum utility. See Section 4.6.1, "`innochecksum` — Offline InnoDB File Checksum Utility".

- `myisam_ftdump`

  A utility that displays information about full-text indexes in `MyISAM` tables. See Section 4.6.2, "`myisam_ftdump` — Display Full-Text Index information".

- `myisamchk`

A utility to describe, check, optimize, and repair `MyISAM` tables. See Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility".

- `myisamlog`

  A utility that processes the contents of a `MyISAM` log file. See Section 4.6.4, "`myisamlog` — Display MyISAM Log File Contents".

- `myisampack`

  A utility that compresses `MyISAM` tables to produce smaller read-only tables. See Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables".

- `mysqlaccess`

  A script that checks the access privileges for a host name, user name, and database combination. See Section 4.6.6, "`mysqlaccess` — Client for Checking Access Privileges".

- `mysqlbinlog`

  A utility for reading statements from a binary log. The log of executed statements contained in the binary log files can be used to help recover from a crash. See Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files".

- `mysqldumpslow`

  A utility to read and summarize the contents of a slow query log. See Section 4.6.8, "`mysqldumpslow` — Summarize Slow Query Log Files".

- `mysqlhotcopy`

  A utility that quickly makes backups of `MyISAM` tables while the server is running. See Section 4.6.9, "`mysqlhotcopy` — A Database Backup Program".

- `mysqlmanager`

  The MySQL Instance Manager, a program for monitoring and managing MySQL servers. See Section 4.6.10, "`mysqlmanager` — The MySQL Instance Manager".

  > **Important**
  >
  > MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

- `mysql_convert_table_format`

  A utility that converts tables in a database to use a given storage engine. See Section 4.6.11, "`mysql_convert_table_format` — Convert Tables to Use a Given Storage Engine".

- `mysql_find_rows`

  A utility that reads files containing SQL statements (such as update logs) and extracts statements that match a given regular expression. See Section 4.6.12, "`mysql_find_rows` — Extract SQL Statements from Files".

- `mysql_fix_extensions`

A utility that converts the extensions for `MyISAM` table files to lowercase. This can be useful after transferring the files from a system with case-insensitive file names to a system with case-sensitive file names. See Section 4.6.13, "`mysql_fix_extensions` — Normalize Table File Name Extensions".

- `mysql_setpermission`

  A utility for interactively setting permissions in the MySQL grant tables. See Section 4.6.14, "`mysql_setpermission` — Interactively Set Permissions in Grant Tables".

- `mysql_waitpid`

  A utility that kills the process with a given process ID. See Section 4.6.15, "`mysql_waitpid` — Kill Process and Wait for Its Termination".

- `mysql_zap`

  A utility that kills processes that match a pattern. See Section 4.6.16, "`mysql_zap` — Kill Processes That Match a Pattern".

MySQL program-development utilities:

- `msql2mysql`

  A shell script that converts `mSQL` programs to MySQL. It doesn't handle every case, but it gives a good start when converting. See Section 4.7.1, "`msql2mysql` — Convert mSQL Programs for Use with MySQL".

- `mysql_config`

  A shell script that produces the option values needed when compiling MySQL programs. See Section 4.7.2, "`mysql_config` — Display Options for Compiling Clients".

- `my_print_defaults`

  A utility that shows which options are present in option groups of option files. See Section 4.7.3, "`my_print_defaults` — Display Options from Option Files".

- `resolve_stack_dump`

  A utility program that resolves a numeric stack trace dump to symbols. See Section 4.7.4, "`resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols".

Miscellaneous utilities:

- `perror`

  A utility that displays the meaning of system or MySQL error codes. See Section 4.8.1, "`perror` — Explain Error Codes".

- `replace`

  A utility program that performs string replacement in the input text. See Section 4.8.2, "`replace` — A String-Replacement Utility".

- `resolveip`

  A utility program that resolves a host name to an IP address or vice versa. See Section 4.8.3, "`resolveip` — Resolve Host name to IP Address or Vice Versa".

Oracle Corporation also provides the MySQL Workbench GUI tool, which is used to administer MySQL servers and databases, to create, execute, and evaluate queries, and to migrate schemas and data from other relational database management systems for use with MySQL. Additional GUI tools include MySQL Notifier and MySQL for Excel.

MySQL client programs that communicate with the server using the MySQL client/server library use the following environment variables.

Environment Variable	Meaning
MYSQL_UNIX_PORT	The default Unix socket file; used for connections to localhost
MYSQL_TCP_PORT	The default port number; used for TCP/IP connections
MYSQL_PWD	The default password
MYSQL_DEBUG	Debug trace options when debugging
TMPDIR	The directory where temporary tables and files are created

For a full list of environment variables used by MySQL programs, see Section 2.14, "Environment Variables".

Use of MYSQL_PWD is insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security".

4.2 Using MySQL Programs

4.2.1 Invoking MySQL Programs

To invoke a MySQL program from the command line (that is, from your shell or command prompt), enter the program name followed by any options or other arguments needed to instruct the program what you want it to do. The following commands show some sample program invocations. "shell>" represents the prompt for your command interpreter; it is not part of what you type. The particular prompt you see depends on your command interpreter. Typical prompts are $ for sh, ksh, or bash, % for csh or tcsh, and C:\> for the Windows command.com or cmd.exe command interpreters.

```
shell> mysql --user=root test
shell> mysqladmin extended-status variables
shell> mysqlshow --help
shell> mysqldump -u root personnel
```

Arguments that begin with a single or double dash ("-", "--") specify program options. Options typically indicate the type of connection a program should make to the server or affect its operational mode. Option syntax is described in Section 4.2.3, "Specifying Program Options".

Nonoption arguments (arguments with no leading dash) provide additional information to the program. For example, the mysql program interprets the first nonoption argument as a database name, so the command mysql --user=root test indicates that you want to use the test database.

Later sections that describe individual programs indicate which options a program supports and describe the meaning of any additional nonoption arguments.

Some options are common to a number of programs. The most frequently used of these are the --host (or -h), --user (or -u), and --password (or -p) options that specify connection parameters. They indicate the host where the MySQL server is running, and the user name and password of your MySQL account. All MySQL client programs understand these options; they enable you to specify which server to connect to and the account to use on that server. Other connection options are --port (or -P) to specify a TCP/IP port number and --socket (or -S) to specify a Unix socket file on Unix (or named pipe name on

Windows). For more information on options that specify connection options, see Section 4.2.2, "Connecting to the MySQL Server".

You may find it necessary to invoke MySQL programs using the path name to the `bin` directory in which they are installed. This is likely to be the case if you get a "program not found" error whenever you attempt to run a MySQL program from any directory other than the `bin` directory. To make it more convenient to use MySQL, you can add the path name of the `bin` directory to your `PATH` environment variable setting. That enables you to run a program by typing only its name, not its entire path name. For example, if `mysql` is installed in `/usr/local/mysql/bin`, you can run the program by invoking it as `mysql`, and it is not necessary to invoke it as `/usr/local/mysql/bin/mysql`.

Consult the documentation for your command interpreter for instructions on setting your `PATH` variable. The syntax for setting environment variables is interpreter-specific. (Some information is given in Section 4.2.10, "Setting Environment Variables".) After modifying your `PATH` setting, open a new console window on Windows or log in again on Unix so that the setting goes into effect.

4.2.2 Connecting to the MySQL Server

This section describes how to establish a connection to the MySQL server. For additional information if you are unable to connect, see Section 6.2.7, "Troubleshooting Problems Connecting to MySQL".

For a client program to be able to connect to the MySQL server, it must use the proper connection parameters, such as the name of the host where the server is running and the user name and password of your MySQL account. Each connection parameter has a default value, but you can override them as necessary using program options specified either on the command line or in an option file.

The examples here use the `mysql` client program, but the principles apply to other clients such as `mysqldump`, `mysqladmin`, or `mysqlshow`.

This command invokes `mysql` without specifying any connection parameters explicitly:

```
shell> mysql
```

Because there are no parameter options, the default values apply:

- The default host name is `localhost`. On Unix, this has a special meaning, as described later.

- The default user name is `ODBC` on Windows or your Unix login name on Unix.

- No password is sent if neither `-p` nor `--password` is given.

- For `mysql`, the first nonoption argument is taken as the name of the default database. If there is no such option, `mysql` does not select a default database.

To specify the host name and user name explicitly, as well as a password, supply appropriate options on the command line:

```
shell> mysql --host=localhost --user=myname --password=mypass mydb
shell> mysql -h localhost -u myname -pmypass mydb
```

For password options, the password value is optional:

- If you use a `-p` or `--password` option and specify the password value, there must be *no space* between `-p` or `--password=` and the password following it.

- If you use a `-p` or `--password` option but do not specify the password value, the client program prompts you to enter the password. The password is not displayed as you enter it. This is more

secure than giving the password on the command line. Other users on your system may be able to see a password specified on the command line by executing a command such as `ps auxw`. See Section 6.1.2.1, "End-User Guidelines for Password Security".

As just mentioned, including the password value on the command line can be a security risk. To avoid this problem, specify the `--password` or `-p` option without any following password value:

```
shell> mysql --host=localhost --user=myname --password mydb
shell> mysql -h localhost -u myname -p mydb
```

When the password option has no password value, the client program prints a prompt and waits for you to enter the password. (In these examples, `mydb` is *not* interpreted as a password because it is separated from the preceding password option by a space.)

On some systems, the library routine that MySQL uses to prompt for a password automatically limits the password to eight characters. That is a problem with the system library, not with MySQL. Internally, MySQL does not have any limit for the length of the password. To work around the problem, change your MySQL password to a value that is eight or fewer characters long, or put your password in an option file.

On Unix, MySQL programs treat the host name `localhost` specially, in a way that is likely different from what you expect compared to other network-based programs. For connections to `localhost`, MySQL programs attempt to connect to the local server by using a Unix socket file. This occurs even if a `--port` or `-P` option is given to specify a port number. To ensure that the client makes a TCP/IP connection to the local server, use `--host` or `-h` to specify a host name value of `127.0.0.1`, or the IP address or name of the local server. You can also specify the connection protocol explicitly, even for `localhost`, by using the `--protocol=TCP` option. For example:

```
shell> mysql --host=127.0.0.1
shell> mysql --protocol=TCP
```

The `--protocol` option enables you to establish a particular type of connection even when the other options would normally default to some other protocol.

On Windows, you can force a MySQL client to use a named-pipe connection by specifying the `--pipe` or `--protocol=PIPE` option, or by specifying `.` (period) as the host name. If named-pipe connections are not enabled, an error occurs. Use the `--socket` option to specify the name of the pipe if you do not want to use the default pipe name.

Connections to remote servers always use TCP/IP. This command connects to the server running on `remote.example.com` using the default port number (3306):

```
shell> mysql --host=remote.example.com
```

To specify a port number explicitly, use the `--port` or `-P` option:

```
shell> mysql --host=remote.example.com --port=13306
```

You can specify a port number for connections to a local server, too. However, as indicated previously, connections to `localhost` on Unix will use a socket file by default. You will need to force a TCP/IP connection as already described or any option that specifies a port number will be ignored.

For this command, the program uses a socket file on Unix and the `--port` option is ignored:

```
shell> mysql --port=13306 --host=localhost
```

To cause the port number to be used, invoke the program in either of these ways:

```
shell> mysql --port=13306 --host=127.0.0.1
shell> mysql --port=13306 --protocol=TCP
```

The following list summarizes the options that can be used to control how client programs connect to the server:

- `--host=host_name`, `-h host_name`

  The host where the server is running. The default value is `localhost`.

- `--password[=pass_val]`, `-p[pass_val]`

  The password of the MySQL account. As described earlier, the password value is optional, but if given, there must be *no space* between `-p` or `--password=` and the password following it. The default is to send no password.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. The server must be started with the `--enable-named-pipe` option to enable named-pipe connections.

- `--port=port_num`, `-P port_num`

  The port number to use for the connection, for connections made using TCP/IP. The default port number is 3306.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  This option explicitly specifies a protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For example, connections on Unix to `localhost` are made using a Unix socket file by default:

```
shell> mysql --host=localhost
```

  To force a TCP/IP connection to be used instead, specify a `--protocol` option:

```
shell> mysql --host=localhost --protocol=TCP
```

  The following table shows the permissible `--protocol` option values and indicates the platforms on which each value may be used. The values are not case sensitive.

`--protocol` Value	Connection Protocol	Permissible Operating Systems
`TCP`	TCP/IP connection to local or remote server	All
`SOCKET`	Unix socket file connection to local server	Unix only
`PIPE`	Named-pipe connection to local or remote server	Windows only
`MEMORY`	Shared-memory connection to local server	Windows only

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--socket=file_name`, `-S file_name`

  On Unix, the name of the Unix socket file to use, for connections made using a named pipe to a local server. The default Unix socket file name is `/tmp/mysql.sock`.

  On Windows, the name of the named pipe to use, for connections to a local server. The default Windows pipe name is `MySQL`. The pipe name is not case sensitive.

  The server must be started with the `--enable-named-pipe` option to enable named-pipe connections.

- `--ssl*`

  Options that begin with `--ssl` are used for establishing a secure connection to the server using SSL, if the server is configured with SSL support. For details, see Section 6.4.5, "Command Options for Secure Connections".

- `--user=user_name`, `-u user_name`

  The user name of the MySQL account you want to use. The default user name is `ODBC` on Windows or your Unix login name on Unix.

It is possible to specify different default values to be used when you make a connection so that you need not enter them on the command line each time you invoke a client program. This can be done in a couple of ways:

- You can specify connection parameters in the `[client]` section of an option file. The relevant section of the file might look like this:

```
[client]
host=host_name
user=user_name
password=your_pass
```

  Section 4.2.6, "Using Option Files", discusses option files further.

- You can specify some connection parameters using environment variables. The host can be specified for `mysql` using `MYSQL_HOST`. The MySQL user name can be specified using `USER` (this is for Windows and NetWare only). The password can be specified using `MYSQL_PWD`, although this is insecure; see Section 6.1.2.1, "End-User Guidelines for Password Security". For a list of variables, see Section 2.14, "Environment Variables".

4.2.3 Specifying Program Options

There are several ways to specify options for MySQL programs:

- List the options on the command line following the program name. This is common for options that apply to a specific invocation of the program.

- List the options in an option file that the program reads when it starts. This is common for options that you want the program to use each time it runs.

- List the options in environment variables (see Section 4.2.10, "Setting Environment Variables"). This method is useful for options that you want to apply each time the program runs. In practice, option files are used more commonly for this purpose, but Section 5.5.3, "Running Multiple MySQL Instances on

Unix", discusses one situation in which environment variables can be very helpful. It describes a handy technique that uses such variables to specify the TCP/IP port number and Unix socket file for the server and for client programs.

Options are processed in order, so if an option is specified multiple times, the last occurrence takes precedence. The following command causes `mysql` to connect to the server running on `localhost`:

```
shell> mysql -h example.com -h localhost
```

If conflicting or related options are given, later options take precedence over earlier options. The following command runs `mysql` in "no column names" mode:

```
shell> mysql --column-names --skip-column-names
```

MySQL programs determine which options are given first by examining environment variables, then by processing option files, and then by checking the command line. This means that environment variables have the lowest precedence and command-line options the highest.

You can take advantage of the way that MySQL programs process options by specifying default option values for a program in an option file. That enables you to avoid typing them each time you run the program while enabling you to override the defaults if necessary by using command-line options.

An option can be specified by writing it in full or as any unambiguous prefix. For example, the `--compress` option can be given to `mysqldump` as `--compr`, but not as `--comp` because the latter is ambiguous:

```
shell> mysqldump --comp
mysqldump: ambiguous option '--comp' (compatible, compress)
```

Be aware that the use of option prefixes can cause problems in the event that new options are implemented for a program. A prefix that is unambiguous now might become ambiguous in the future.

4.2.4 Using Options on the Command Line

Program options specified on the command line follow these rules:

- Options are given after the command name.

- An option argument begins with one dash or two dashes, depending on whether it is a short form or long form of the option name. Many options have both short and long forms. For example, `-?` and `--help` are the short and long forms of the option that instructs a MySQL program to display its help message.

- Option names are case sensitive. `-v` and `-V` are both legal and have different meanings. (They are the corresponding short forms of the `--verbose` and `--version` options.)

- Some options take a value following the option name. For example, `-h localhost` or `--host=localhost` indicate the MySQL server host to a client program. The option value tells the program the name of the host where the MySQL server is running.

- For a long option that takes a value, separate the option name and the value by an "=" sign. For a short option that takes a value, the option value can immediately follow the option letter, or there can be a space between: `-hlocalhost` and `-h localhost` are equivalent. An exception to this rule is the option for specifying your MySQL password. This option can be given in long form as `--password=pass_val` or as `--password`. In the latter case (with no password value given), the program prompts you for the password. The password option also may be given in short form as `-`

p*pass_val* or as `-p`. However, for the short form, if the password value is given, it must follow the option letter with *no intervening space*. The reason for this is that if a space follows the option letter, the program has no way to tell whether a following argument is supposed to be the password value or some other kind of argument. Consequently, the following two commands have two completely different meanings:

```
shell> mysql -ptest
shell> mysql -p test
```

The first command instructs `mysql` to use a password value of `test`, but specifies no default database. The second instructs `mysql` to prompt for the password value and to use `test` as the default database.

- Within option names, dash ("`-`") and underscore ("`_`") may be used interchangeably. For example, `--skip-grant-tables` and `--skip_grant_tables` are equivalent. (However, the leading dashes cannot be given as underscores.)

- For options that take a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3. For example, the following command tells `mysqladmin` to ping the server 1024 times, sleeping 10 seconds between each ping:

```
shell> mysqladmin --count=1K --sleep=10 ping
```

Option values that contain spaces must be quoted when given on the command line. For example, the `--execute` (or `-e`) option can be used with `mysql` to pass SQL statements to the server. When this option is used, `mysql` executes the statements in the option value and exits. The statements must be enclosed by quotation marks. For example, you can use the following command to obtain a list of user accounts:

```
shell> mysql -u root -p --execute="SELECT User, Host FROM mysql.user"
Enter password: ******
+------+-----------+
| User | Host      |
+------+-----------+
|      | gigan     |
| root | gigan     |
|      | localhost |
| jon  | localhost |
| root | localhost |
+------+-----------+
shell>
```

Note

The long form (`--execute`) is followed by an equals sign (`=`).

If you wish to use quoted values within a statement, you will either need to escape the inner quotation marks, or use a different type of quotation marks within the statement from those used to quote the statement itself. The capabilities of your command processor dictate your choices for whether you can use single or double quotation marks and the syntax for escaping quote characters. For example, if your command processor supports quoting with single or double quotation marks, you can use double quotation marks around the statement, and single quotation marks for any quoted values within the statement.

Multiple SQL statements may be passed in the option value on the command line, separated by semicolons:

```
shell> mysql -u root -p -e "SELECT VERSION();SELECT NOW()"
Enter password: ******
```

```
+------------------+
| VERSION()        |
+------------------+
| 5.1.74-debug-log |
+------------------+
+--------------------+
| NOW()              |
+--------------------+
| 2015-11-05 20:03:22 |
+--------------------+
```

The `--execute` or `-e` option may also be used to pass commands in an analogous fashion to the `ndb_mgm` management client for MySQL Cluster. See Section 17.2.6, "Safe Shutdown and Restart of MySQL Cluster", for an example.

4.2.5 Program Option Modifiers

Some options are "boolean" and control behavior that can be turned on or off. For example, the `mysql` client supports a `--column-names` option that determines whether or not to display a row of column names at the beginning of query results. By default, this option is enabled. However, you may want to disable it in some instances, such as when sending the output of `mysql` into another program that expects to see only data and not an initial header line.

To disable column names, you can specify the option using any of these forms:

```
--disable-column-names
--skip-column-names
--column-names=0
```

The `--disable` and `--skip` prefixes and the `=0` suffix all have the same effect: They turn the option off.

The "enabled" form of the option may be specified in any of these ways:

```
--column-names
--enable-column-names
--column-names=1
```

If an option is prefixed by `--loose`, a program does not exit with an error if it does not recognize the option, but instead issues only a warning:

```
shell> mysql --loose-no-such-option
mysql: WARNING: unknown option '--loose-no-such-option'
```

The `--loose` prefix can be useful when you run programs from multiple installations of MySQL on the same machine and list options in an option file. An option that may not be recognized by all versions of a program can be given using the `--loose` prefix (or `loose` in an option file). Versions of the program that recognize the option process it normally, and versions that do not recognize it issue a warning and ignore it.

The `--maximum` prefix is available for `mysqld` only and permits a limit to be placed on how large client programs can set session system variables. To do this, use a `--maximum` prefix with the variable name. For example, `--maximum-max_heap_table_size=32M` prevents any client from making the heap table size limit larger than 32M.

The `--maximum` prefix is intended for use with system variables that have a session value. If applied to a system variable that has only a global value, an error occurs. For example, with `--maximum-query_cache_size=4M`, the server produces this error:

```
Maximum value of 'query_cache_size' cannot be set
```

4.2.6 Using Option Files

Most MySQL programs can read startup options from option files (sometimes called configuration files). Option files provide a convenient way to specify commonly used options so that they need not be entered on the command line each time you run a program. For the MySQL server, MySQL provides a number of preconfigured option files.

To determine whether a program reads option files, invoke it with the `--help` option. (For `mysqld`, use `--verbose` and `--help`.) If the program reads option files, the help message indicates which files it looks for and which option groups it recognizes.

> **Note**
>
> A MySQL program started with the `--no-defaults` option reads no option files.

Option files are plain text files, created using any text editor.

MySQL looks for option files in the order described in the following discussion and reads any that exist. If an option file you want to use does not exist, create it with a plain text editor.

> **Note**
>
> Option files used with MySQL Cluster programs are covered in Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1".

On Windows, MySQL programs read startup options from the files shown in the following table, in the specified order (top files are read first, files read later take precedence).

Table 4.1 Option Files Read on Windows Systems

File Name	Purpose
`%PROGRAMDATA%\MySQL \MySQL Server 5.1\my.ini`, `%PROGRAMDATA %\MySQL\MySQL Server 5.1\my.cnf`	Global options
`%WINDIR%\my.ini`, `%WINDIR %\my.cnf`	Global options
`C:\my.ini`, `C:\my.cnf`	Global options
`BASEDIR\my.ini`, `BASEDIR\my.cnf`	Global options
`defaults-extra-file`	The file specified with `--defaults-extra-file`, if any

In the preceding table, `%PROGRAMDATA%` represents the file system directory that contains application data for all users on the host. This path defaults to `C:\ProgramData` on Microsoft Windows Vista and greater, and `C:\Documents and Settings\All Users\Application Data` on older versions of Microsoft Windows.

`%WINDIR%` represents the location of your Windows directory. This is commonly `C:\WINDOWS`. Use the following command to determine its exact location from the value of the `WINDIR` environment variable:

```
C:\> echo %WINDIR%
```

`%APPDATA%` represents the value of the Windows application data directory. Use the following command to determine its exact location from the value of the `APPDATA` environment variable:

```
C:\> echo %APPDATA%
```

`BASEDIR` represents the MySQL base installation directory. When MySQL 5.1 has been installed using the installation and configuration wizards, this is typically `C:\PROGRAMDIR\MySQL\MySQL 5.1 Server` where `PROGRAMDIR` represents the programs directory (usually `Program Files` on English-language versions of Windows). See Section 2.3.5.1, "Starting the MySQL Server Instance Config Wizard".

On Unix and Unix-like systems, MySQL programs read startup options from the files shown in the following table, in the specified order (top files are read first, files read later take precedence).

Note

On Unix platforms, MySQL ignores configuration files that are world-writable. This is intentional as a security measure.

Table 4.2 Option Files Read on Unix and Unix-Like Systems

File Name	Purpose
`/etc/my.cnf`	Global options
`/etc/mysql/my.cnf`	Global options (as of MySQL 5.1.15)
`SYSCONFDIR/my.cnf`	Global options
`$MYSQL_HOME/my.cnf`	Server-specific options (server only)
`defaults-extra-file`	The file specified with `--defaults-extra-file`, if any
`~/.my.cnf`	User-specific options

In the preceding table, `~` represents the current user's home directory (the value of `$HOME`).

`SYSCONFDIR` represents the directory specified with the `--sysconfdir` option to `configure` when MySQL was built. By default, this is the `etc` directory located under the compiled-in installation directory. This location is used as of MySQL 5.1.10. (From 5.1.10 to 5.1.22, it was read last, after `~/.my.cnf`.)

`MYSQL_HOME` is an environment variable containing the path to the directory in which the server-specific `my.cnf` file resides. If `MYSQL_HOME` is not set and you start the server using the `mysqld_safe` program, `mysqld_safe` attempts to set `MYSQL_HOME` as follows:

- Let `BASEDIR` and `DATADIR` represent the path names of the MySQL base directory and data directory, respectively.

- If there is a `my.cnf` file in `DATADIR` but not in `BASEDIR`, `mysqld_safe` sets `MYSQL_HOME` to `DATADIR`.

- Otherwise, if `MYSQL_HOME` is not set and there is no `my.cnf` file in `DATADIR`, `mysqld_safe` sets `MYSQL_HOME` to `BASEDIR`.

In MySQL 5.1, use of `DATADIR` as the location for `my.cnf` is deprecated.

Typically, `DATADIR` is `/usr/local/mysql/data` for a binary installation or `/usr/local/var` for a source installation. This is the data directory location built in when MySQL was compiled, not the location

specified with the `--datadir` option when `mysqld` starts. Use of `--datadir` at runtime has no effect on where the server looks for option files that it reads before processing any options.

If multiple instances of a given option are found, the last instance takes precedence, with one exception: For `mysqld`, the *first* instance of the `--user` option is used as a security precaution, to prevent a user specified in an option file from being overridden on the command line.

The following description of option file syntax applies to files that you edit manually. This excludes `.mylogin.cnf`, which is created using `mysql_config_editor` and is encrypted.

Any long option that may be given on the command line when running a MySQL program can be given in an option file as well. To get the list of available options for a program, run it with the `--help` option. (For `mysqld`, use `--verbose` and `--help`.)

The syntax for specifying options in an option file is similar to command-line syntax (see Section 4.2.4, "Using Options on the Command Line"). However, in an option file, you omit the leading two dashes from the option name and you specify only one option per line. For example, `--quick` and `--host=localhost` on the command line should be specified as `quick` and `host=localhost` on separate lines in an option file. To specify an option of the form `--loose-opt_name` in an option file, write it as `loose-opt_name`.

Empty lines in option files are ignored. Nonempty lines can take any of the following forms:

- `#comment`, `;comment`

  Comment lines start with "`#`" or "`;`". A "`#`" comment can start in the middle of a line as well.

- `[group]`

  `group` is the name of the program or group for which you want to set options. After a group line, any option-setting lines apply to the named group until the end of the option file or another group line is given. Option group names are not case sensitive.

- `opt_name`

  This is equivalent to `--opt_name` on the command line.

- `opt_name=value`

  This is equivalent to `--opt_name=value` on the command line. In an option file, you can have spaces around the "`=`" character, something that is not true on the command line. The value optionally can be enclosed within single quotation marks or double quotation marks, which is useful if the value contains a "`#`" comment character.

Leading and trailing spaces are automatically deleted from option names and values.

You can use the escape sequences "`\b`", "`\t`", "`\n`", "`\r`", "`\\`", and "`\s`" in option values to represent the backspace, tab, newline, carriage return, backslash, and space characters. In option files, these escaping rules apply:

- A backslash followed by a valid escape sequence character is converted to the character represented by the sequence. For example, "`\s`" is converted to a space.

- A backslash not followed by a valid escape sequence character remains unchanged. For example, "`\S`" is retained as is.

The preceding rules mean that a literal backslash can be given as "`\\`", or as "`\`" if it is not followed by a valid escape sequence character.

The rules for escape sequences in option files differ slightly from the rules for escape sequences in string literals in SQL statements. In the latter context, if "*x*" is not a valid escape sequence character, "*x*" becomes "*x*" rather than "*x*". See Section 9.1.1, "String Literals".

The escaping rules for option file values are especially pertinent for Windows path names, which use "\\" as a path name separator. A separator in a Windows path name must be written as "\\\\" if it is followed by an escape sequence character. It can be written as "\\\\" or "\\" if it is not. Alternatively, "/" may be used in Windows path names and will be treated as "\\". Suppose that you want to specify a base directory of `C:\Program Files\MySQL\MySQL Server 5.1` in an option file. This can be done several ways. Some examples:

```
basedir="C:\Program Files\MySQL\MySQL Server 5.1"
basedir="C:\\Program Files\\MySQL\\MySQL Server 5.1"
basedir="C:/Program Files/MySQL/MySQL Server 5.1"
basedir=C:\\Program\sFiles\\MySQL\\MySQL\sServer\s5.1
```

If an option group name is the same as a program name, options in the group apply specifically to that program. For example, the `[mysqld]` and `[mysql]` groups apply to the `mysqld` server and the `mysql` client program, respectively.

The `[client]` option group is read by all client programs (but *not* by `mysqld`). This enables you to specify options that apply to all clients. For example, `[client]` is the appropriate group to use to specify the password for connecting to the server. (But make sure that the option file is accessible only by yourself, so that other people cannot discover your password.) Be sure not to put an option in the `[client]` group unless it is recognized by *all* client programs that you use. Programs that do not understand the option quit after displaying an error message if you try to run them.

Here is a typical global option file:

```
[client]
port=3306
socket=/tmp/mysql.sock

[mysqld]
port=3306
socket=/tmp/mysql.sock
key_buffer_size=16M
max_allowed_packet=8M

[mysqldump]
quick
```

Here is a typical user option file:

```
[client]
# The following password will be sent to all standard MySQL clients
password="my password"

[mysql]
no-auto-rehash
connect_timeout=2

[mysqlhotcopy]
interactive-timeout
```

To create option groups to be read only by `mysqld` servers from specific MySQL release series, use groups with names of `[mysqld-5.0]`, `[mysqld-5.1]`, and so forth. The following group indicates that the `sql_mode` setting should be used only by MySQL servers with 5.1.x version numbers:

```
[mysqld-5.1]
sql_mode=TRADITIONAL
```

It is possible to use `!include` directives in option files to include other option files and `!includedir` to search specific directories for option files. For example, to include the `/home/mydir/myopt.cnf` file, use the following directive:

```
!include /home/mydir/myopt.cnf
```

To search the `/home/mydir` directory and read option files found there, use this directive:

```
!includedir /home/mydir
```

MySQL makes no guarantee about the order in which option files in the directory will be read.

> **Note**
>
> Any files to be found and included using the `!includedir` directive on Unix operating systems *must* have file names ending in `.cnf`. On Windows, this directive checks for files with the `.ini` or `.cnf` extension.

Write the contents of an included option file like any other option file. That is, it should contain groups of options, each preceded by a `[group]` line that indicates the program to which the options apply.

While an included file is being processed, only those options in groups that the current program is looking for are used. Other groups are ignored. Suppose that a `my.cnf` file contains this line:

```
!include /home/mydir/myopt.cnf
```

And suppose that `/home/mydir/myopt.cnf` looks like this:

```
[mysqladmin]
force

[mysqld]
key_buffer_size=16M
```

If `my.cnf` is processed by `mysqld`, only the `[mysqld]` group in `/home/mydir/myopt.cnf` is used. If the file is processed by `mysqladmin`, only the `[mysqladmin]` group is used. If the file is processed by any other program, no options in `/home/mydir/myopt.cnf` are used.

The `!includedir` directive is processed similarly except that all option files in the named directory are read.

4.2.7 Command-Line Options that Affect Option-File Handling

Most MySQL programs that support option files handle the following options. Because these options affect option-file handling, they must be given on the command line and not in an option file. To work properly, each of these options must be given before other options, with these exceptions:

- `--print-defaults` may be used immediately after `--defaults-file` or `--defaults-extra-file`.

- On Windows, if the server is started with the `--defaults-file` and `--install` options, `--install` must be first. See Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

When specifying file names, avoid the use of the "~" shell metacharacter because it might not be interpreted as you expect.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. (For information about the order in which option files are used, see Section 4.2.6, "Using Option Files".) If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, the `mysql` client normally reads the `[client]` and `[mysql]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql` also reads the `[client_other]` and `[mysql_other]` groups.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

4.2.8 Using Options to Set Program Variables

Many MySQL programs have internal variables that can be set at runtime using the `SET` statement. See Section 13.7.4.1, "SET Syntax for Variable Assignment", and Section 5.1.5, "Using System Variables".

Most of these program variables also can be set at server startup by using the same syntax that applies to specifying program options. For example, `mysql` has a `max_allowed_packet` variable that controls the maximum size of its communication buffer. To set the `max_allowed_packet` variable for `mysql` to a value of 16MB, use either of the following commands:

```
shell> mysql --max_allowed_packet=16777216
shell> mysql --max_allowed_packet=16M
```

The first command specifies the value in bytes. The second specifies the value in megabytes. For variables that take a numeric value, the value can be given with a suffix of K, M, or G (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3. (For example, when used to set `max_allowed_packet`, the suffixes indicate units of kilobytes, megabytes, or gigabytes.)

In an option file, variable settings are given without the leading dashes:

```
[mysql]
max_allowed_packet=16777216
```

Or:

```
[mysql]
max_allowed_packet=16M
```

If you like, underscores in a variable name can be specified as dashes. The following option groups are equivalent. Both set the size of the server's key buffer to 512MB:

```
[mysqld]
key_buffer_size=512M

[mysqld]
key-buffer-size=512M
```

A variable can be specified by writing it in full or as any unambiguous prefix. For example, the `max_allowed_packet` variable can be set for `mysql` as `--max_a`, but not as `--max` because the latter is ambiguous:

```
shell> mysql --max=1000000
mysql: ambiguous option '--max=1000000' (max_allowed_packet, max_join_size)
```

Be aware that the use of variable prefixes can cause problems in the event that new variables are implemented for a program. A prefix that is unambiguous now might become ambiguous in the future.

Suffixes for specifying a value multiplier can be used when setting a variable at server startup, but not to set the value with `SET` at runtime. On the other hand, with `SET`, you can assign a variable's value using an expression, which is not true when you set a variable at server startup. For example, the first of the following lines is legal at server startup, but the second is not:

```
shell> mysql --max_allowed_packet=16M
shell> mysql --max_allowed_packet=16*1024*1024
```

Conversely, the second of the following lines is legal at runtime, but the first is not:

```
mysql> SET GLOBAL max_allowed_packet=16M;
mysql> SET GLOBAL max_allowed_packet=16*1024*1024;
```

> **Note**
>
> Before MySQL 4.0.2, the only syntax for setting program variables was `--set-variable=`*option*`=`*value* (or `set-variable=`*option*`=`*value* in option files). Underscores cannot be given as dashes, and the variable name must be specified in full. This syntax still is recognized, but is deprecated and is removed in MySQL 5.5.

4.2.9 Option Defaults, Options Expecting Values, and the = Sign

By convention, long forms of options that assign a value are written with an equals (=) sign, like this:

```
shell> mysql --host=tonfisk --user=jon
```

For options that require a value (that is, not having a default value), the equal sign is not required, and so the following is also valid:

```
shell> mysql --host tonfisk --user jon
```

In both cases, the `mysql` client attempts to connect to a MySQL server running on the host named "tonfisk" using an account with the user name "jon".

Due to this behavior, problems can occasionally arise when no value is provided for an option that expects one. Consider the following example, where a user connects to a MySQL server running on host `tonfisk` as user `jon`:

```
shell> mysql --host 85.224.35.45 --user jon
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 3
Server version: 5.1.73 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT CURRENT_USER();
+----------------+
| CURRENT_USER() |
+----------------+
| jon@%          |
+----------------+
1 row in set (0.00 sec)
```

Omitting the required value for one of these option yields an error, such as the one shown here:

```
shell> mysql --host 85.224.35.45 --user
mysql: option '--user' requires an argument
```

In this case, `mysql` was unable to find a value following the `--user` option because nothing came after it on the command line. However, if you omit the value for an option that is *not* the last option to be used, you obtain a different error that you may not be expecting:

```
shell> mysql --host --user jon
ERROR 2005 (HY000): Unknown MySQL server host '--user' (1)
```

Because `mysql` assumes that any string following `--host` on the command line is a host name, `--host --user` is interpreted as `--host=--user`, and the client attempts to connect to a MySQL server running on a host named "--user".

Options having default values always require an equal sign when assigning a value; failing to do so causes an error. For example, the MySQL server `--log-error` option has the default value *host_name*`.err`, where *host_name* is the name of the host on which MySQL is running. Assume that you are running MySQL on a computer whose host name is "tonfisk", and consider the following invocation of `mysqld_safe`:

```
shell> mysqld_safe &
[1] 11699
shell> 080112 12:53:40 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080112 12:53:40 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
shell>
```

After shutting down the server, restart it as follows:

```
shell> mysqld_safe --log-error &
[1] 11699
shell> 080112 12:53:40 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080112 12:53:40 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
```

```
shell>
```

The result is the same, since `--log-error` is not followed by anything else on the command line, and it supplies its own default value. (The `&` character tells the operating system to run MySQL in the background; it is ignored by MySQL itself.) Now suppose that you wish to log errors to a file named `my-errors.err`. You might try starting the server with `--log-error my-errors`, but this does not have the intended effect, as shown here:

```
shell> mysqld_safe --log-error my-errors &
[1] 31357
shell> 080111 22:53:31 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080111 22:53:32 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
080111 22:53:34 mysqld_safe mysqld from pid file /usr/local/mysql/var/tonfisk.pid ended

[1]+  Done                    ./mysqld_safe --log-error my-errors
```

The server attempted to start using `/usr/local/mysql/var/tonfisk.err` as the error log, but then shut down. Examining the last few lines of this file shows the reason:

```
shell> tail /usr/local/mysql/var/tonfisk.err
080111 22:53:32  InnoDB: Started; log sequence number 0 46409
/usr/local/mysql/libexec/mysqld: Too many arguments (first extra is 'my-errors').
Use --verbose --help to get a list of available options
080111 22:53:32 [ERROR] Aborting

080111 22:53:32  InnoDB: Starting shutdown...
080111 22:53:34  InnoDB: Shutdown completed; log sequence number 0 46409
080111 22:53:34 [Note] /usr/local/mysql/libexec/mysqld: Shutdown complete

080111 22:53:34 mysqld_safe mysqld from pid file /usr/local/mysql/var/tonfisk.pid ended
```

Because the `--log-error` option supplies a default value, you must use an equal sign to assign a different value to it, as shown here:

```
shell> mysqld_safe --log-error=my-errors &
[1] 31437
shell> 080111 22:54:15 mysqld_safe Logging to '/usr/local/mysql/var/my-errors.err'.
080111 22:54:15 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var

shell>
```

Now the server has been started successfully, and is logging errors to the file `/usr/local/mysql/var/my-errors.err`.

Similar issues can arise when specifying option values in option files. For example, consider a `my.cnf` file that contains the following:

```
[mysql]

host
user
```

When the `mysql` client reads this file, these entries are parsed as `--host --user` or `--host=--user`, with the result shown here:

```
shell> mysql
ERROR 2005 (HY000): Unknown MySQL server host '--user' (1)
```

However, in option files, an equal sign is not assumed. Suppose the `my.cnf` file is as shown here:

```
[mysql]

user jon
```

Trying to start `mysql` in this case causes a different error:

```
shell> mysql
mysql: unknown option '--user jon'
```

A similar error would occur if you were to write `host tonfisk` in the option file rather than `host=tonfisk`. Instead, you must use the equals sign:

```
[mysql]

user=jon
```

Now the login attempt succeeds:

```
shell> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 5
Server version: 5.1.73 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT USER();
+---------------+
| USER()        |
+---------------+
| jon@localhost |
+---------------+
1 row in set (0.00 sec)
```

This is not the same behavior as with the command line, where the equal sign is not required:

```
shell> mysql --user jon --host tonfisk
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 6
Server version: 5.1.73 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT USER();
+---------------+
| USER()        |
+---------------+
| jon@tonfisk   |
+---------------+
1 row in set (0.00 sec)
```

4.2.10 Setting Environment Variables

Environment variables can be set at the command prompt to affect the current invocation of your command processor, or set permanently to affect future invocations. To set a variable permanently, you can set it in a startup file or by using the interface provided by your system for this purpose. Consult the documentation for your command interpreter for specific details. Section 2.14, "Environment Variables", lists all environment variables that affect MySQL program operation.

To specify a value for an environment variable, use the syntax appropriate for your command processor. For example, on Windows or NetWare, you can set the USER variable to specify your MySQL account name. To do so, use this syntax:

```
SET USER=your_name
```

The syntax on Unix depends on your shell. Suppose that you want to specify the TCP/IP port number using the MYSQL_TCP_PORT variable. Typical syntax (such as for sh, ksh, bash, zsh, and so on) is as follows:

```
MYSQL_TCP_PORT=3306
export MYSQL_TCP_PORT
```

The first command sets the variable, and the export command exports the variable to the shell environment so that its value becomes accessible to MySQL and other processes.

For csh and tcsh, use setenv to make the shell variable available to the environment:

```
setenv MYSQL_TCP_PORT 3306
```

The commands to set environment variables can be executed at your command prompt to take effect immediately, but the settings persist only until you log out. To have the settings take effect each time you log in, use the interface provided by your system or place the appropriate command or commands in a startup file that your command interpreter reads each time it starts.

On Windows, you can set environment variables using the System Control Panel (under Advanced).

On Unix, typical shell startup files are .bashrc or .bash_profile for bash, or .tcshrc for tcsh.

Suppose that your MySQL programs are installed in /usr/local/mysql/bin and that you want to make it easy to invoke these programs. To do this, set the value of the PATH environment variable to include that directory. For example, if your shell is bash, add the following line to your .bashrc file:

```
PATH=${PATH}:/usr/local/mysql/bin
```

bash uses different startup files for login and nonlogin shells, so you might want to add the setting to .bashrc for login shells and to .bash_profile for nonlogin shells to make sure that PATH is set regardless.

If your shell is tcsh, add the following line to your .tcshrc file:

```
setenv PATH ${PATH}:/usr/local/mysql/bin
```

If the appropriate startup file does not exist in your home directory, create it with a text editor.

After modifying your PATH setting, open a new console window on Windows or log in again on Unix so that the setting goes into effect.

4.3 MySQL Server and Server-Startup Programs

This section describes mysqld, the MySQL server, and several programs that are used to start the server.

4.3.1 mysqld — The MySQL Server

`mysqld`, also known as MySQL Server, is the main program that does most of the work in a MySQL installation. MySQL Server manages access to the MySQL data directory that contains databases and tables. The data directory is also the default location for other information such as log files and status files.

When MySQL server starts, it listens for network connections from client programs and manages access to databases on behalf of those clients.

The `mysqld` program has many options that can be specified at startup. For a complete list of options, run this command:

```
shell> mysqld --verbose --help
```

MySQL Server also has a set of system variables that affect its operation as it runs. System variables can be set at server startup, and many of them can be changed at runtime to effect dynamic server reconfiguration. MySQL Server also has a set of status variables that provide information about its operation. You can monitor these status variables to access runtime performance characteristics.

For a full description of MySQL Server command options, system variables, and status variables, see Section 5.1, "The MySQL Server". For information about installing MySQL and setting up the initial configuration, see Chapter 2, *Installing and Upgrading MySQL*.

4.3.2 `mysqld_safe` — MySQL Server Startup Script

`mysqld_safe` is the recommended way to start a `mysqld` server on Unix and NetWare. `mysqld_safe` adds some safety features such as restarting the server when an error occurs and logging runtime information to an error log file. Descriptions of error logging and NetWare-specific behaviors are given later in this section.

> **Note**
>
> In MySQL 5.1.20 (only), the default error logging behavior with `mysqld_safe` is to write errors to `syslog` on systems that support the `logger` program. This differs from the default behavior of writing an error log file for other versions.
>
> **In 5.1.20, logging to `syslog` may fail to operate correctly in some cases; if so, use `--skip-syslog` to use the default log file or `--log-error=`*`file_name`* to specify a log file name explicitly.**

`mysqld_safe` tries to start an executable named `mysqld`. To override the default behavior and specify explicitly the name of the server you want to run, specify a `--mysqld` or `--mysqld-version` option to `mysqld_safe`. You can also use `--ledir` to indicate the directory where `mysqld_safe` should look for the server.

Many of the options to `mysqld_safe` are the same as the options to `mysqld`. See Section 5.1.3, "Server Command Options".

Options unknown to `mysqld_safe` are passed to `mysqld` if they are specified on the command line, but ignored if they are specified in the `[mysqld_safe]` group of an option file. See Section 4.2.6, "Using Option Files".

`mysqld_safe` reads all options from the `[mysqld]`, `[server]`, and `[mysqld_safe]` sections in option files. For example, if you specify a `[mysqld]` section like this, `mysqld_safe` will find and use the `--log-error` option:

```
[mysqld]
log-error=error.log
```

For backward compatibility, `mysqld_safe` also reads `[safe_mysqld]` sections, but to be current you should rename such sections to `[mysqld_safe]`.

`mysqld_safe` supports the options in the following list. It also reads option files and supports the options for processing them described at Section 4.2.7, "Command-Line Options that Affect Option-File Handling".

Table 4.3 `mysqld_safe` Options

Format	Description	Introduced
--autoclose	On NetWare, mysqld_safe provides a screen presence	
--basedir	Path to MySQL installation directory	
--core-file-size	Size of core file that mysqld should be able to create	
--datadir	Path to data directory	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--help	Display help message and exit	
--ledir	Path to directory where server is located	
--log-error	Write error log to named file	
--mysqld	Name of server program to start (in ledir directory)	
--mysqld-version	Suffix for server program name	
--nice	Use nice program to set server scheduling priority	
--no-defaults	Read no option files	
--open-files-limit	Number of files that mysqld should be able to open	
--pid-file	Path name of process ID file	
--port	Port number on which to listen for TCP/IP connections	
--skip-kill-mysqld	Do not try to kill stray mysqld processes	
--skip-syslog	Do not write error messages to syslog; use error log file	5.1.20
--socket	Socket file on which to listen for Unix socket connections	
--syslog	Write error messages to syslog	5.1.20
--syslog-tag	Tag suffix for messages written to syslog	5.1.21
--timezone	Set TZ time zone environment variable to named value	
--user	Run mysqld as user having name user_name or numeric user ID user_id	

- `--help`

  Display a help message and exit.

- `--autoclose`

  (NetWare only) On NetWare, `mysqld_safe` provides a screen presence. When you unload (shut down) the `mysqld_safe` NLM, the screen does not by default go away. Instead, it prompts for user input:

```
*<NLM has terminated; Press any key to close the screen>*
```

If you want NetWare to close the screen automatically instead, use the `--autoclose` option to `mysqld_safe`.

- `--basedir=dir_name`

The path to the MySQL installation directory.

- `--core-file-size=size`

The size of the core file that `mysqld` should be able to create. The option value is passed to `ulimit -c`.

- `--datadir=dir_name`

The path to the data directory.

- `--defaults-extra-file=file_name`

The name of an option file to be read in addition to the usual option files. This must be the first option on the command line if it is used. If the file does not exist or is otherwise inaccessible, the server will exit with an error.

- `--defaults-file=file_name`

The name of an option file to be read instead of the usual option files. This must be the first option on the command line if it is used.

- `--ledir=dir_name`

If `mysqld_safe` cannot find the server, use this option to indicate the path name to the directory where the server is located.

- `--log-error=file_name`

Write the error log to the given file. See Section 5.4.2, "The Error Log".

- `--mysqld=prog_name`

The name of the server program (in the `ledir` directory) that you want to start. This option is needed if you use the MySQL binary distribution but have the data directory outside of the binary distribution. If `mysqld_safe` cannot find the server, use the `--ledir` option to indicate the path name to the directory where the server is located.

- `--mysqld-version=suffix`

This option is similar to the `--mysqld` option, but you specify only the suffix for the server program name. The base name is assumed to be `mysqld`. For example, if you use `--mysqld-version=debug`, `mysqld_safe` starts the `mysqld-debug` program in the `ledir` directory. If the argument to `--mysqld-version` is empty, `mysqld_safe` uses `mysqld` in the `ledir` directory.

- `--nice=priority`

Use the `nice` program to set the server's scheduling priority to the given value.

- `--no-defaults`

Do not read any option files. This must be the first option on the command line if it is used.

- `--open-files-limit=count`

The number of files that `mysqld` should be able to open. The option value is passed to `ulimit -n`.

> **Note**
>
> You must start `mysqld_safe` as `root` for this to function properly.

- `--pid-file=file_name`

The path name of the process ID file.

- `--port=port_num`

The port number that the server should use when listening for TCP/IP connections. The port number must be 1024 or higher unless the server is started by the `root` system user.

- `--skip-kill-mysqld`

Do not try to kill stray `mysqld` processes at startup. This option works only on Linux.

- `--socket=path`

The Unix socket file that the server should use when listening for local connections.

- `--syslog`, `--skip-syslog`

`--syslog` causes error messages to be sent to `syslog` on systems that support the `logger` program. `--skip-syslog` suppresses the use of `syslog`; messages are written to an error log file. These options were added in MySQL 5.1.20.

When `syslog` is used, the `daemon.err` syslog facility/severity is used for all log messages.

- `--syslog-tag=tag`

For logging to `syslog`, messages from `mysqld_safe` and `mysqld` are written with identifiers of `mysqld_safe` and `mysqld`, respectively. To specify a suffix for the identifiers, use `--syslog-tag=tag`, which modifies the identifiers to be `mysqld_safe-tag` and `mysqld-tag`. This option was added in MySQL 5.1.21.

- `--timezone=timezone`

Set the `TZ` time zone environment variable to the given option value. Consult your operating system documentation for legal time zone specification formats.

- `--user={user_name|user_id}`

Run the `mysqld` server as the user having the name `user_name` or the numeric user ID `user_id`. ("User" in this context refers to a system login account, not a MySQL user listed in the grant tables.)

If you execute `mysqld_safe` with the `--defaults-file` or `--defaults-extra-file` option to name an option file, the option must be the first one given on the command line or the option file will not be used. For example, this command will not use the named option file:

```
mysql> mysqld_safe --port=port_num --defaults-file=file_name
```

Instead, use the following command:

```
mysql> mysqld_safe --defaults-file=file_name --port=port_num
```

The `mysqld_safe` script is written so that it normally can start a server that was installed from either a source or a binary distribution of MySQL, even though these types of distributions typically install the server in slightly different locations. (See Section 2.1.4, "Installation Layouts".) `mysqld_safe` expects one of the following conditions to be true:

- The server and databases can be found relative to the working directory (the directory from which `mysqld_safe` is invoked). For binary distributions, `mysqld_safe` looks under its working directory for `bin` and `data` directories. For source distributions, it looks for `libexec` and `var` directories. This condition should be met if you execute `mysqld_safe` from your MySQL installation directory (for example, `/usr/local/mysql` for a binary distribution).

- If the server and databases cannot be found relative to the working directory, `mysqld_safe` attempts to locate them by absolute path names. Typical locations are `/usr/local/libexec` and `/usr/local/var`. The actual locations are determined from the values configured into the distribution at the time it was built. They should be correct if MySQL is installed in the location specified at configuration time.

Because `mysqld_safe` tries to find the server and databases relative to its own working directory, you can install a binary distribution of MySQL anywhere, as long as you run `mysqld_safe` from the MySQL installation directory:

```
shell> cd mysql_installation_directory
shell> bin/mysqld_safe &
```

If `mysqld_safe` fails, even when invoked from the MySQL installation directory, specify the `--ledir` and `--datadir` options to indicate the directories in which the server and databases are located on your system.

When you use `mysqld_safe` to start `mysqld`, `mysqld_safe` arranges for error (and notice) messages from itself and from `mysqld` to go to the same destination.

As of MySQL 5.1.20, there are several `mysqld_safe` options for controlling the destination of these messages:

- `--log-error=file_name`: Write error messages to the named error file.

- `--syslog`: Write error messages to `syslog` on systems that support the `logger` program.

- `--skip-syslog`: Do not write error messages to `syslog`. Messages are written to the default error log file (`host_name.err` in the data directory), or to a named file if the `--log-error` option is given.

If none of these options is given, the default is `--skip-syslog`.

> **Note**
>
> In MySQL 5.1.20 *only*, the default is `--syslog`. This differs from logging behavior for other versions of MySQL, for which the default is to write messages to the default error log file.

If `--log-error` and `--syslog` are both given, a warning is issued and `--log-error` takes precedence.

When `mysqld_safe` writes a message, notices go to the logging destination (`syslog` or the error log file) and `stdout`. Errors go to the logging destination and `stderr`.

Before MySQL 5.1.20, error logging is controlled only with the `--log-error` option. If it is given, messages go to the named error file. Otherwise, messages go to the default error file.

Normally, you should not edit the `mysqld_safe` script. Instead, configure `mysqld_safe` by using command-line options or options in the `[mysqld_safe]` section of a `my.cnf` option file. In rare cases, it might be necessary to edit `mysqld_safe` to get it to start the server properly. However, if you do this, your modified version of `mysqld_safe` might be overwritten if you upgrade MySQL in the future, so you should make a copy of your edited version that you can reinstall.

On NetWare, `mysqld_safe` is a NetWare Loadable Module (NLM) that is ported from the original Unix shell script. It starts the server as follows:

1. Runs a number of system and option checks.

2. Runs a check on `MyISAM` tables.

3. Provides a screen presence for the MySQL server.

4. Starts `mysqld`, monitors it, and restarts it if it terminates in error.

5. Sends error messages from `mysqld` to the *`host_name.err`* file in the data directory.

6. Sends `mysqld_safe` screen output to the *`host_name.safe`* file in the data directory.

4.3.3 `mysql.server` — MySQL Server Startup Script

MySQL distributions on Unix include a script named `mysql.server`, which starts the server using `mysqld_safe`. It can be used on systems such as Linux and Solaris that use System V-style run directories to start and stop system services. It is also used by the OS X Startup Item for MySQL.

To start or stop the server manually using the `mysql.server` script, invoke it with `start` or `stop` arguments:

```
shell> mysql.server start
shell> mysql.server stop
```

Before `mysql.server` starts the server, it changes location to the MySQL installation directory, and then invokes `mysqld_safe`. To run the server as some specific user, add an appropriate `user` option to the `[mysqld]` group of the `/etc/my.cnf` option file, as shown later in this section. (It is possible that you must edit `mysql.server` if you've installed a binary distribution of MySQL in a nonstandard location. Modify it to change location into the proper directory before it runs `mysqld_safe`. If you do this, your modified version of `mysql.server` may be overwritten if you upgrade MySQL in the future, so you should make a copy of your edited version that you can reinstall.)

`mysql.server stop` stops the server by sending a signal to it. You can also stop the server manually by executing `mysqladmin shutdown`.

To start and stop MySQL automatically on your server, you must add start and stop commands to the appropriate places in your `/etc/rc*` files.

If you use the Linux server RPM package (`MySQL-server-`*`VERSION`*`.rpm`), or a native Linux package installation, the `mysql.server` script may be installed in the `/etc/init.d` directory with the name

`mysql`. See Section 2.5.1, "Installing MySQL on Linux Using RPM Packages", for more information on the Linux RPM packages.

Some vendors provide RPM packages that install a startup script under a different name such as `mysqld`.

If you install MySQL from a source distribution or using a binary distribution format that does not install `mysql.server` automatically, you can install it manually. The script can be found in the `support-files` directory under the MySQL installation directory or in a MySQL source tree. Copy it to the `/etc/init.d` directory with the name `mysql`, and then make it executable:

```
shell> cp mysql.server /etc/init.d/mysql
shell> chmod +x /etc/init.d/mysql
```

> **Note**
>
> Older Red Hat systems use the `/etc/rc.d/init.d` directory rather than `/etc/init.d`. Adjust the preceding commands accordingly. Alternatively, first create `/etc/init.d` as a symbolic link that points to `/etc/rc.d/init.d`:

```
shell> cd /etc
shell> ln -s rc.d/init.d .
```

After installing the script, the commands needed to activate it to run at system startup depend on your operating system. On Linux, you can use `chkconfig`:

```
shell> chkconfig --add mysql
```

On some Linux systems, the following command also seems to be necessary to fully enable the `mysql` script:

```
shell> chkconfig --level 345 mysql on
```

On FreeBSD, startup scripts generally should go in `/usr/local/etc/rc.d/`. The `rc(8)` manual page states that scripts in this directory are executed only if their base name matches the `*.sh` shell file name pattern. Any other files or directories present within the directory are silently ignored. In other words, on FreeBSD, you should install the `mysql.server` script as `/usr/local/etc/rc.d/mysql.server.sh` to enable automatic startup.

As an alternative to the preceding setup, some operating systems also use `/etc/rc.local` or `/etc/init.d/boot.local` to start additional services on startup. To start up MySQL using this method, append a command like the one following to the appropriate startup file:

```
/bin/sh -c 'cd /usr/local/mysql; ./bin/mysqld_safe --user=mysql &'
```

For other systems, consult your operating system documentation to see how to install startup scripts.

`mysql.server` reads options from the `[mysql.server]` and `[mysqld]` sections of option files. For backward compatibility, it also reads `[mysql_server]` sections, but to be current you should rename such sections to `[mysql.server]`.

You can add options for `mysql.server` in a global `/etc/my.cnf` file. A typical `/etc/my.cnf` file might look like this:

```
[mysqld]
```

```
datadir=/usr/local/mysql/var
socket=/var/tmp/mysql.sock
port=3306
user=mysql

[mysql.server]
basedir=/usr/local/mysql
```

The `mysql.server` script supports the following options. If specified, they *must* be placed in an option file, not on the command line. `mysql.server` supports only `start` and `stop` as command-line arguments.

Table 4.4 `mysql.server` Options

Format	Description	Introduced
--basedir	Path to MySQL installation directory	
--datadir	Path to MySQL data directory	
--pid-file	File in which server should write its process ID	
--service-startup-timeout	How long to wait for server startup	5.1.17
--use-manager	Use Instance Manager to start server	
--use-mysqld_safe	Use mysqld_safe to start server	
--user	Run server using this login user name	

- `--basedir=dir_name`

  The path to the MySQL installation directory.

- `--datadir=dir_name`

  The path to the MySQL data directory.

- `--pid-file=file_name`

  The path name of the file in which the server should write its process ID.

- `--service-startup-timeout=seconds`

  How long in seconds to wait for confirmation of server startup. If the server does not start within this time, `mysql.server` exits with an error. The default value is 900. A value of 0 means not to wait at all for startup. Negative values mean to wait forever (no timeout). This option was added in MySQL 5.1.17. Before that, a value of 900 is always used.

- `--use-mysqld_safe`

  Use `mysqld_safe` to start the server. This is the default.

- `--use-manager`

  Use Instance Manager to start the server.

- `--user=user_name`

  The login user name to use for running `mysqld`.

4.3.4 `mysqld_multi` — Manage Multiple MySQL Servers

`mysqld_multi` is designed to manage several `mysqld` processes that listen for connections on different Unix socket files and TCP/IP ports. It can start or stop servers, or report their current status. The MySQL Instance Manager is an alternative means of managing multiple servers (see Section 4.6.10, "`mysqlmanager` — The MySQL Instance Manager").

`mysqld_multi` searches for groups named `[mysqldN]` in `my.cnf` (or in the file named by the `--config-file` option). `N` can be any positive integer. This number is referred to in the following discussion as the option group number, or `GNR`. Group numbers distinguish option groups from one another and are used as arguments to `mysqld_multi` to specify which servers you want to start, stop, or obtain a status report for. Options listed in these groups are the same that you would use in the `[mysqld]` group used for starting `mysqld`. (See, for example, Section 2.12.5, "Starting and Stopping MySQL Automatically".) However, when using multiple servers, it is necessary that each one use its own value for options such as the Unix socket file and TCP/IP port number. For more information on which options must be unique per server in a multiple-server environment, see Section 5.5, "Running Multiple MySQL Instances on One Machine".

To invoke `mysqld_multi`, use the following syntax:

```
shell> mysqld_multi [options] {start|stop|report} [GNR[,GNR] ...]
```

`start`, `stop`, and `report` indicate which operation to perform. You can perform the designated operation for a single server or multiple servers, depending on the `GNR` list that follows the option name. If there is no list, `mysqld_multi` performs the operation for all servers in the option file.

Each `GNR` value represents an option group number or range of group numbers. The value should be the number at the end of the group name in the option file. For example, the `GNR` for a group named `[mysqld17]` is `17`. To specify a range of numbers, separate the first and last numbers by a dash. The `GNR` value `10-13` represents groups `[mysqld10]` through `[mysqld13]`. Multiple groups or group ranges can be specified on the command line, separated by commas. There must be no whitespace characters (spaces or tabs) in the `GNR` list; anything after a whitespace character is ignored.

This command starts a single server using option group `[mysqld17]`:

```
shell> mysqld_multi start 17
```

This command stops several servers, using option groups `[mysqld8]` and `[mysqld10]` through `[mysqld13]`:

```
shell> mysqld_multi stop 8,10-13
```

For an example of how you might set up an option file, use this command:

```
shell> mysqld_multi --example
```

As of MySQL 5.1.18, `mysqld_multi` searches for option files as follows:

- With `--no-defaults`, no option files are read.

- With `--defaults-file=file_name`, only the named file is read.

- Otherwise, option files in the standard list of locations are read, including any file named by the `--defaults-extra-file=file_name` option, if one is given. (If the option is given multiple times, the last value is used.)

Before MySQL 5.1.18, the preceding options are not recognized. Files in the standard locations are read, and any file named by the `--config-file=file_name` option, if one is given. A file named by `--config-file` is read only for `[mysqldN]` option groups, not the `[mysqld_multi]` group.

Option files read are searched for `[mysqld_multi]` and `[mysqldN]` option groups. The `[mysqld_multi]` group can be used for options to `mysqld_multi` itself. `[mysqldN]` groups can be used for options passed to specific `mysqld` instances.

As of MySQL 5.1.35, the `[mysqld]` or `[mysqld_safe]` groups can be used for common options read by all instances of `mysqld` or `mysqld_safe`. You can specify a `--defaults-file=file_name` option to use a different configuration file for that instance, in which case the `[mysqld]` or `[mysqld_safe]` groups from that file will be used for that instance. Before MySQL 5.1.35, some versions of `mysqld_multi` pass the `--no-defaults` options to instances, so these techniques are inapplicable.

`mysqld_multi` supports the following options.

- `--help`

  Display a help message and exit.

- `--config-file=file_name`

  As of MySQL 5.1.18, this option is deprecated. If given, it is treated the same way as `--defaults-extra-file`, described earlier. `--config-file` is removed in MySQL 5.5.

  Before MySQL 5.1.18, this option specifies the name of an extra option file. It affects where `mysqld_multi` looks for `[mysqldN]` option groups. Without this option, all options are read from the usual `my.cnf` file. The option does not affect where `mysqld_multi` reads its own options, which are always taken from the `[mysqld_multi]` group in the usual `my.cnf` file.

- `--example`

  Display a sample option file.

- `--log=file_name`

  Specify the name of the log file. If the file exists, log output is appended to it.

- `--mysqladmin=prog_name`

  The `mysqladmin` binary to be used to stop servers.

- `--mysqld=prog_name`

  The `mysqld` binary to be used. Note that you can specify `mysqld_safe` as the value for this option also. If you use `mysqld_safe` to start the server, you can include the `mysqld` or `ledir` options in the corresponding `[mysqldN]` option group. These options indicate the name of the server that `mysqld_safe` should start and the path name of the directory where the server is located. (See the descriptions for these options in Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".) Example:

```
[mysqld38]
mysqld = mysqld-debug
ledir  = /opt/local/mysql/libexec
```

- `--no-log`

  Print log information to `stdout` rather than to the log file. By default, output goes to the log file.

- `--password=password`

  The password of the MySQL account to use when invoking `mysqladmin`. Note that the password value is not optional for this option, unlike for other MySQL programs.

- `--silent`

  Silent mode; disable warnings.

- `--tcp-ip`

  Connect to each MySQL server through the TCP/IP port instead of the Unix socket file. (If a socket file is missing, the server might still be running, but accessible only through the TCP/IP port.) By default, connections are made using the Unix socket file. This option affects `stop` and `report` operations.

- `--user=user_name`

  The user name of the MySQL account to use when invoking `mysqladmin`.

- `--verbose`

  Be more verbose.

- `--version`

  Display version information and exit.

Some notes about `mysqld_multi`:

- **Most important**: Before using `mysqld_multi` be sure that you understand the meanings of the options that are passed to the `mysqld` servers and *why* you would want to have separate `mysqld` processes. Beware of the dangers of using multiple `mysqld` servers with the same data directory. Use separate data directories, unless you *know* what you are doing. Starting multiple servers with the same data directory does *not* give you extra performance in a threaded system. See Section 5.5, "Running Multiple MySQL Instances on One Machine".

-

  Important

  Make sure that the data directory for each server is fully accessible to the Unix account that the specific `mysqld` process is started as. *Do not* use the Unix `root` account for this, unless you *know* what you are doing. See Section 6.1.5, "How to Run MySQL as a Normal User".

- Make sure that the MySQL account used for stopping the `mysqld` servers (with the `mysqladmin` program) has the same user name and password for each server. Also, make sure that the account has the `SHUTDOWN` privilege. If the servers that you want to manage have different user names or passwords for the administrative accounts, you might want to create an account on each server that has the same user name and password. For example, you might set up a common `multi_admin` account by executing the following commands for each server:

```
shell> mysql -u root -S /tmp/mysql.sock -p
Enter password:
mysql> CREATE USER 'multi_admin'@'localhost' IDENTIFIED BY 'multipass';
mysql> GRANT SHUTDOWN ON *.* TO 'multi_admin'@'localhost';
```

  See Section 6.2, "The MySQL Access Privilege System". You have to do this for each `mysqld` server. Change the connection parameters appropriately when connecting to each one. Note that the host name

part of the account name must permit you to connect as `multi_admin` from the host where you want to run `mysqld_multi`.

- The Unix socket file and the TCP/IP port number must be different for every `mysqld`. (Alternatively, if the host has multiple network addresses, you can use `--bind-address` to cause different servers to listen to different interfaces.)

- The `--pid-file` option is very important if you are using `mysqld_safe` to start `mysqld` (for example, `--mysqld=mysqld_safe`) Every `mysqld` should have its own process ID file. The advantage of using `mysqld_safe` instead of `mysqld` is that `mysqld_safe` monitors its `mysqld` process and restarts it if the process terminates due to a signal sent using `kill -9` or for other reasons, such as a segmentation fault. Please note that the `mysqld_safe` script might require that you start it from a certain place. This means that you might have to change location to a certain directory before running `mysqld_multi`. If you have problems starting, please see the `mysqld_safe` script. Check especially the lines:

```
----------------------------------------------------------------
MY_PWD=`pwd`
# Check if we are starting this relative (for the binary release)
if test -d $MY_PWD/data/mysql -a \
   -f ./share/mysql/english/errmsg.sys -a \
   -x ./bin/mysqld
----------------------------------------------------------------
```

The test performed by these lines should be successful, or you might encounter problems. See Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script".

- You might want to use the `--user` option for `mysqld`, but to do this you need to run the `mysqld_multi` script as the Unix superuser (`root`). Having the option in the option file doesn't matter; you just get a warning if you are not the superuser and the `mysqld` processes are started under your own Unix account.

The following example shows how you might set up an option file for use with `mysqld_multi`. The order in which the `mysqld` programs are started or stopped depends on the order in which they appear in the option file. Group numbers need not form an unbroken sequence. The first and fifth `[mysqldN]` groups were intentionally omitted from the example to illustrate that you can have "gaps" in the option file. This gives you more flexibility.

```
# This is an example of a my.cnf file for mysqld_multi.
# Usually this file is located in home dir ~/.my.cnf or /etc/my.cnf

[mysqld_multi]
mysqld     = /usr/local/mysql/bin/mysqld_safe
mysqladmin = /usr/local/mysql/bin/mysqladmin
user       = multi_admin
password   = my_password

[mysqld2]
socket     = /tmp/mysql.sock2
port       = 3307
pid-file   = /usr/local/mysql/data2/hostname.pid2
datadir    = /usr/local/mysql/data2
language   = /usr/local/mysql/share/mysql/english
user       = unix_user1

[mysqld3]
mysqld     = /path/to/mysqld_safe
ledir      = /path/to/mysqld-binary/
mysqladmin = /path/to/mysqladmin
socket     = /tmp/mysql.sock3
port       = 3308
```

```
pid-file   = /usr/local/mysql/data3/hostname.pid3
datadir    = /usr/local/mysql/data3
language   = /usr/local/mysql/share/mysql/swedish
user       = unix_user2

[mysqld4]
socket     = /tmp/mysql.sock4
port       = 3309
pid-file   = /usr/local/mysql/data4/hostname.pid4
datadir    = /usr/local/mysql/data4
language   = /usr/local/mysql/share/mysql/estonia
user       = unix_user3

[mysqld6]
socket     = /tmp/mysql.sock6
port       = 3311
pid-file   = /usr/local/mysql/data6/hostname.pid6
datadir    = /usr/local/mysql/data6
language   = /usr/local/mysql/share/mysql/japanese
user       = unix_user4
```

See Section 4.2.6, "Using Option Files".

4.4 MySQL Installation-Related Programs

The programs in this section are used when installing or upgrading MySQL.

4.4.1 `comp_err` — Compile MySQL Error Message File

`comp_err` creates the `errmsg.sys` file that is used by `mysqld` to determine the error messages to display for different error codes. `comp_err` normally is run automatically when MySQL is built. It compiles the `errmsg.sys` file from the text file located at `sql/share/errmsg.txt` in MySQL source distributions.

`comp_err` also generates `mysqld_error.h`, `mysqld_ername.h`, and `sql_state.h` header files.

For more information about how error messages are defined, see the MySQL Internals Manual.

Invoke `comp_err` like this:

```
shell> comp_err [options]
```

`comp_err` supports the following options.

- `--help`, `-?`

  Display a help message and exit.

- `--charset=dir_name`, `-C dir_name`

  The character set directory. The default is `../sql/share/charsets`.

- `--debug=debug_options`, `-# debug_options`

  Write a debugging log. A typical `debug_options` string is `d:t:O,file_name`. The default is `d:t:O,/tmp/comp_err.trace`.

- `--debug-info`, `-T`

  Print some debugging information when the program exits.

- `--header_file=file_name`, `-H file_name`

  The name of the error header file. The default is `mysqld_error.h`.

- `--in_file=file_name`, `-F file_name`

  The name of the input file. The default is `../sql/share/errmsg.txt`.

- `--name_file=file_name`, `-N file_name`

  The name of the error name file. The default is `mysqld_ername.h`.

- `--out_dir=dir_name`, `-D dir_name`

  The name of the output base directory. The default is `../sql/share/`.

- `--out_file=file_name`, `-O file_name`

  The name of the output file. The default is `errmsg.sys`.

- `--statefile=file_name`, `-S file_name`

  The name for the SQLSTATE header file. The default is `sql_state.h`.

- `--version`, `-V`

  Display version information and exit.

4.4.2 `make_win_bin_dist` — Package MySQL Distribution as Zip Archive

This script is used on Windows after building a MySQL distribution from source to create executable programs. It packages the binaries and support files into a Zip archive that can be unpacked at the location where you want to install MySQL.

`make_win_bin_dist` is a shell script, so you must have Cygwin installed to use it.

This program's use is subject to change. Currently, you invoke it as follows from the root directory of your source distribution:

```
shell> make_win_bin_dist [options] package_basename [copy_def ...]
```

The `package_basename` argument provides the base name for the resulting Zip archive. This name will be the name of the directory that results from unpacking the archive.

Because you might want to include files of directories from other builds, you can instruct this script to copy them in for you, using `copy_def` arguments, which have the form `relative_dest_name=source_name`.

Example:

```
bin/mysqld-max.exe=../my-max-build/sql/release/mysqld.exe
```

If you specify a directory, the entire directory will be copied.

`make_win_bin_dist` supports the following options.

- `--debug`

Pack the debug binaries and produce an error if they were not built.

- `--embedded`

Pack the embedded server and produce an error if it was not built. The default is to pack it if it was built.

- `--exe-suffix=suffix`

Add a suffix to the base name of the `mysql` binary. For example, a suffix of `-abc` produces a binary named `mysqld-abc.exe`.

- `--no-debug`

Do not pack the debug binaries even if they were built.

- `--no-embedded`

Do not pack the embedded server even if it was built.

- `--only-debug`

Use this option when the target for this build was `Debug`, and you just want to replace the normal binaries with debug versions (that is, do not use separate `debug` directories).

4.4.3 `mysqlbug` — Generate Bug Report

This program enables you to generate a bug report and send it to Oracle Corporation. It is a shell script and runs on Unix.

The normal way to report bugs is to visit http://bugs.mysql.com/, which is the address for our bugs database. This database is public and can be browsed and searched by anyone. If you log in to the system, you can enter new reports. If you have no Web access, you can generate a bug report by using the `mysqlbug` script.

`mysqlbug` helps you generate a report by determining much of the following information automatically, but if something important is missing, please include it with your message. `mysqlbug` can be found in the `scripts` directory (source distribution) and in the `bin` directory under your MySQL installation directory (binary distribution).

Invoke `mysqlbug` without arguments:

```
shell> mysqlbug
```

The script will place you in an editor with a copy of the report to be sent. Edit the lines near the beginning that indicate the nature of the problem. Then write the file to save your changes, quit the editor, and `mysqlbug` will send the report by email.

4.4.4 `mysql_fix_privilege_tables` — Upgrade MySQL System Tables

Note

In MySQL 5.1.7, `mysql_fix_privilege_tables` was superseded by `mysql_upgrade`, which should be used instead. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

Some releases of MySQL introduce changes to the structure of the system tables in the `mysql` database to add new privileges or support new features. When you update to a new version of MySQL, update your system tables as well to make sure that their structure is up to date. Otherwise, there might be capabilities that you cannot take advantage of.

`mysql_fix_privilege_tables` is an older script that previously was used to upgrade the system tables in the `mysql` database after a MySQL upgrade.

Before running `mysql_fix_privilege_tables`, make a backup of your `mysql` database.

On Unix or Unix-like systems, update the system tables by running the `mysql_fix_privilege_tables` script:

```
shell> mysql_fix_privilege_tables
```

You must run this script while the server is running. It attempts to connect to the server running on the local host as `root`. If your `root` account requires a password, indicate the password on the command line like this:

```
shell> mysql_fix_privilege_tables --password=root_password
```

The `mysql_fix_privilege_tables` script performs any actions necessary to convert your system tables to the current format. You might see some `Duplicate column name` warnings as it runs; you can ignore them.

After running the script, stop the server and restart it so that any changes made to the system tables take effect.

On Windows systems, MySQL distributions include a `mysql_fix_privilege_tables.sql` SQL script that you can run using the `mysql` client. For example, if your MySQL installation is located at `C:\Program Files\MySQL\MySQL Server 5.1`, the commands look like this:

```
C:\> cd "C:\Program Files\MySQL\MySQL Server 5.1"
C:\> bin\mysql -u root -p mysql
mysql> SOURCE share/mysql_fix_privilege_tables.sql
```

Note

Prior to version 5.1.17, the `mysql_fix_privilege_tables.sql` script is found in the `scripts` directory.

The `mysql` command will prompt you for the `root` password; enter it when prompted.

If your installation is located in some other directory, adjust the path names appropriately.

As with the Unix procedure, you might see some `Duplicate column name` warnings as `mysql` processes the statements in the `mysql_fix_privilege_tables.sql` script; you can ignore them.

After running the script, stop the server and restart it.

4.4.5 `mysql_install_db` — Initialize MySQL Data Directory

`mysql_install_db` initializes the MySQL data directory and creates the system tables that it contains, if they do not exist. `mysql_install_db` is a shell script and is available only on Unix platforms.

To invoke `mysql_install_db`, use the following syntax:

```
shell> mysql_install_db [options]
```

Because the MySQL server, `mysqld`, must access the data directory when it runs later, you should either run `mysql_install_db` from the same system account that will be used for running `mysqld`, or run it as `root` and specify the `--user` option to indicate the user name that `mysqld` will run as. It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysql_install_db` does not use the correct locations for the installation directory or data directory. For example:

```
shell> bin/mysql_install_db --user=mysql \
        --basedir=/opt/mysql/mysql \
        --datadir=/opt/mysql/mysql/data
```

`mysql_install_db` needs to invoke `mysqld` with the `--bootstrap` and `--skip-grant-tables` options. If MySQL was configured with the `--disable-grant-options` option, `--bootstrap` and `--skip-grant-tables` will be disabled (see Section 2.11.4, "MySQL Source-Configuration Options"). To handle this, set the `MYSQLD_BOOTSTRAP` environment variable to the full path name of a server that has all options enabled. `mysql_install_db` will use that server.

> **Note**
>
> If you have set a custom `TMPDIR` environment variable when performing the installation, and the specified directory is not accessible, `mysql_install_db` may fail. If so, unset `TMPDIR` or set `TMPDIR` to point to the system temporary directory (usually `/tmp`).

`mysql_install_db` supports the following options, which can be specified on the command line or in the `[mysql_install_db]` group of an option file. (Options that are common to `mysqld` can also be specified in the `[mysqld]` group.) Other options are passed to `mysqld`. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files". `mysql_install_db` also supports the options for processing option files described at Section 4.2.7, "Command-Line Options that Affect Option-File Handling".

- `--help`

  Display a help message and exit.

- `--basedir=dir_name`

  The path to the MySQL installation directory.

- `--builddir=dir_name`

  For use with `--srcdir` and out-of-source builds. Set this to the location of the directory where the built files reside.

- `--cross-bootstrap`

  For internal use. This option is used for building system tables on one host intended for another.

- `--datadir=dir_name`

  The path to the MySQL data directory.

- `--defaults-extra-file=file_name`

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name.

- `--defaults-file=file_name`

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is interpreted relative to the current directory if given as a relative path name rather than a full path name.

- `--force`

Cause `mysql_install_db` to run even if DNS does not work. Grant table entries normally created using host names will use IP addresses instead.

- `--ldata=dir_name`

A synonym for `--datadir`.

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--rpm`

For internal use. This option is used during the MySQL installation process for install operations performed using RPM packages.

- `--skip-name-resolve`

Use IP addresses rather than host names when creating grant table entries. This option can be useful if your DNS does not work.

- `--srcdir=dir_name`

For internal use. This option specifies the directory under which `mysql_install_db` looks for support files such as the error message file and the file for populating the help tables. This option was added in MySQL 5.1.14.

- `--user=user_name`

The system (login) user name to use for running `mysqld`. Files and directories created by `mysqld` will be owned by this user. You must be the system `root` user to use this option. By default, `mysqld` runs using your current login name and files and directories that it creates will be owned by you.

- `--verbose`

Verbose mode. Print more information about what the program does.

- `--windows`

For internal use. This option is used for creating Windows distributions.

4.4.6 `mysql_secure_installation` — Improve MySQL Installation Security

This program enables you to improve the security of your MySQL installation in the following ways:

- You can set a password for `root` accounts.

- You can remove `root` accounts that are accessible from outside the local host.

- You can remove anonymous-user accounts.

- You can remove the `test` database (which by default can be accessed by all users, even anonymous users), and privileges that permit anyone to access databases with names that start with `test_`.

`mysql_secure_installation` helps you implement security recommendations similar to those described at Section 2.12.4, "Securing the Initial MySQL Accounts".

Invoke `mysql_secure_installation` without arguments:

```
shell> mysql_secure_installation
```

When executed, the script prompts you to determine which actions to perform.

4.4.7 `mysql_tzinfo_to_sql` — Load the Time Zone Tables

The `mysql_tzinfo_to_sql` program loads the time zone tables in the `mysql` database. It is used on systems that have a *zoneinfo* database (the set of files describing time zones). Examples of such systems are Linux, FreeBSD, Solaris, and OS X. One likely location for these files is the `/usr/share/zoneinfo` directory (`/usr/share/lib/zoneinfo` on Solaris). If your system does not have a zoneinfo database, you can use the downloadable package described in Section 10.6, "MySQL Server Time Zone Support".

`mysql_tzinfo_to_sql` can be invoked several ways:

```
shell> mysql_tzinfo_to_sql tz_dir
shell> mysql_tzinfo_to_sql tz_file tz_name
shell> mysql_tzinfo_to_sql --leap tz_file
```

For the first invocation syntax, pass the zoneinfo directory path name to `mysql_tzinfo_to_sql` and send the output into the `mysql` program. For example:

```
shell> mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql -u root mysql
```

`mysql_tzinfo_to_sql` reads your system's time zone files and generates SQL statements from them. `mysql` processes those statements to load the time zone tables.

The second syntax causes `mysql_tzinfo_to_sql` to load a single time zone file *tz_file* that corresponds to a time zone name *tz_name*:

```
shell> mysql_tzinfo_to_sql tz_file tz_name | mysql -u root mysql
```

If your time zone needs to account for leap seconds, invoke `mysql_tzinfo_to_sql` using the third syntax, which initializes the leap second information. *tz_file* is the name of your time zone file:

```
shell> mysql_tzinfo_to_sql --leap tz_file | mysql -u root mysql
```

After running `mysql_tzinfo_to_sql`, it is best to restart the server so that it does not continue to use any previously cached time zone data.

4.4.8 `mysql_upgrade` — Check and Upgrade MySQL Tables

`mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL Server. `mysql_upgrade` also upgrades the system tables so that you can take advantage of new privileges or capabilities that might have been added.

If `mysql_upgrade` finds that a table has a possible incompatibility, it performs a table check and, if problems are found, attempts a table repair. If the table cannot be repaired, see Section 2.13.4, "Rebuilding or Repairing Tables or Indexes" for manual table repair strategies.

You should execute `mysql_upgrade` each time you upgrade MySQL. It supersedes the older `mysql_fix_privilege_tables` script, which should no longer be used.

If you install MySQL from RPM packages on Linux, you must install the server and client RPMs. `mysql_upgrade` is included in the server RPM but requires the client RPM because the latter includes `mysqlcheck`. (See Section 2.5.1, "Installing MySQL on Linux Using RPM Packages".)

> **Note**
>
> On Windows Server 2008, Vista, and newer, you must run `mysql_upgrade` with administrator privileges. You can do this by running a Command Prompt as Administrator and running the command. Failure to do so may result in the upgrade failing to execute correctly.

> **Caution**
>
> You should always back up your current MySQL installation *before* performing an upgrade. See Section 7.2, "Database Backup Methods".
>
> Some upgrade incompatibilities may require special handling before you upgrade your MySQL installation and run `mysql_upgrade`. See Section 2.13.1, "Upgrading MySQL", for instructions on determining whether any such incompatibilities apply to your installation and how to handle them.

To use `mysql_upgrade`, make sure that the server is running. Then invoke it like this:

```
shell> mysql_upgrade [options]
```

After running `mysql_upgrade`, stop the server and restart it so that any changes made to the system tables take effect.

If you have multiple MySQL server instances running, invoke `mysql_upgrade` with connection parameters appropriate for connecting to the desired server. For example, with servers running on the local host on parts 3306 through 3308, upgrade each of them by connecting to the appropriate port:

```
shell> mysql_upgrade --protocol=tcp -P 3306 [other_options]
shell> mysql_upgrade --protocol=tcp -P 3307 [other_options]
shell> mysql_upgrade --protocol=tcp -P 3308 [other_options]
```

For local host connections on Unix, the `--protocol=tcp` option forces a connection using TCP/IP rather than the Unix socket file.

`mysql_upgrade` executes the following commands to check and repair tables and to upgrade the system tables:

```
mysqlcheck --no-defaults --all-databases --fix-db-names --fix-table-names
mysqlcheck --no-defaults --check-upgrade --all-databases --auto-repair
mysql < fix_priv_tables
```

Notes about the preceding commands:

- `mysql_upgrade` also adds `--write-binlog` or `--skip-write-binlog` to the `mysqlcheck` commands, depending on whether the `--write-binlog` option was specified on the `mysql_upgrade` command.

- Because `mysql_upgrade` invokes `mysqlcheck` with the `--all-databases` option, it processes all tables in all databases, which might take a long time to complete. Each table is locked and therefore unavailable to other sessions while it is being processed. Check and repair operations can be time-consuming, particularly for large tables.

- For details about what checks the `--check-upgrade` option entails, see the description of the FOR UPGRADE option of the CHECK TABLE statement (see Section 13.7.2.3, "CHECK TABLE Syntax").

- `fix_priv_tables` represents a script generated internally by `mysql_upgrade` that contains SQL statements to upgrade the tables in the `mysql` database.

- Prior to MySQL 5.1.31, `mysql_upgrade` does not run the second `mysqlcheck` command, which is necessary to re-encode database or table names that contain nonalphanumeric characters. (They still appear after the upgrade with the `#mysql50#` prefix described in Section 9.2.3, "Mapping of Identifiers to File Names".) If you have such database or table names, execute the second `mysqlcheck` command manually after executing `mysql_upgrade`.

All checked and repaired tables are marked with the current MySQL version number. This ensures that next time you run `mysql_upgrade` with the same version of the server, it can tell whether there is any need to check or repair the table again.

`mysql_upgrade` also saves the MySQL version number in a file named `mysql_upgrade_info` in the data directory. This is used to quickly check whether all tables have been checked for this release so that table-checking can be skipped. To ignore this file and perform the check regardless, use the `--force` option.

In MySQL 5.1.7, `mysql_upgrade` was added as a shell script and worked only for Unix systems. As of MySQL 5.1.10, `mysql_upgrade` is an executable binary and is available on all systems.

`mysql_upgrade` does not upgrade the contents of the help tables. For upgrade instructions, see Section 5.1.9, "Server-Side Help".

`mysql_upgrade` supports the following options, which can be specified on the command line or in the `[mysql_upgrade]` and `[client]` groups of an option file. Unrecognized options are passed to `mysqlcheck`. For information about option files, see Section 4.2.6, "Using Option Files".

- `--help`

  Display a short help message and exit.

- `--basedir=dir_name`

  The path to the MySQL installation directory. This option is accepted for backward compatibility but ignored.

- `--character-sets-dir=dir_name`

The directory where character sets are installed. See Section 10.5, "Character Set Configuration". This option was added in MySQL 5.1.13.

- `--compress`

Compress all information sent between the client and the server if both support compression. This option was added in MySQL 5.1.13.

- `--datadir=`*`dir_name`*

The path to the data directory. This option is accepted for backward compatibility but ignored.

- `--debug[=`*`debug_options`*`]`, `-# [`*`debug_options`*`]`

Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. The default is `d:t:O,/tmp/mysql_upgrade.trace`.

- `--debug-check`

Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`, `-T`

Print some debugging information when the program exits.

- `--default-character-set=`*`charset_name`*

Use *`charset_name`* as the default character set. See Section 10.5, "Character Set Configuration". This option was added in MySQL 5.1.13.

- `--defaults-extra-file=`*`file_name`*

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-file=`*`file_name`*

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-group-suffix=`*`str`*

Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysql_upgrade` normally reads the `[client]` and `[mysql_upgrade]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql_upgrade` also reads the `[client_other]` and `[mysql_upgrade_other]` groups.

- `--force`

Ignore the `mysql_upgrade_info` file and force execution even if `mysql_upgrade` has already been executed for the current version of MySQL.

- `--host=`*`host_name`*, `-h `*`host_name`*

Connect to the MySQL server on the given host. This option was added in MySQL 5.1.13.

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=`*`password`*`]`, `-p[`*`password`*`]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysql_upgrade` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections. This option was added in MySQL 5.1.13.

- `--port=`*`port_num`*, `-P` *`port_num`*

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--shared-memory-base-name=`*`name`*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections. This option was added in MySQL 5.1.13.

- `--socket=`*`path`*, `-S` *`path`*

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections". These options were added in MySQL 5.1.13.

- `--tmpdir=`*`dir_name`*, `-t` *`dir_name`*

  The path name of the directory to use for creating temporary files. This option was added in MySQL 5.1.25.

- `--user=`*`user_name`*, `-u` *`user_name`*

The MySQL user name to use when connecting to the server. The default user name is `root`.

* `--verbose`

  Verbose mode. Print more information about what the program does.

* `--write-binlog`

  Cause binary logging to be enabled while `mysql_upgrade` runs. This is the default behavior; to disable binary logging during the upgrade, use the inverse of this option (that is, start the program with `--skip-write-binlog`).

  This option was introduced in MySQL 5.1.40.

4.5 MySQL Client Programs

This section describes client programs that connect to the MySQL server.

4.5.1 `mysql` — The MySQL Command-Line Tool

`mysql` is a simple SQL shell with input line editing capabilities. It supports interactive and noninteractive use. When used interactively, query results are presented in an ASCII-table format. When used noninteractively (for example, as a filter), the result is presented in tab-separated format. The output format can be changed using command options.

If you have problems due to insufficient memory for large result sets, use the `--quick` option. This forces `mysql` to retrieve results from the server a row at a time rather than retrieving the entire result set and buffering it in memory before displaying it. This is done by returning the result set using the `mysql_use_result()` C API function in the client/server library rather than `mysql_store_result()`.

Using `mysql` is very easy. Invoke it from the prompt of your command interpreter as follows:

```
shell> mysql db_name
```

Or:

```
shell> mysql --user=user_name --password=your_password db_name
```

Then type an SQL statement, end it with "`;`", `\g`, or `\G` and press Enter.

As of MySQL 5.1.10, typing **Control+C** causes `mysql` to attempt to kill the current statement. If this cannot be done, or **Control+C** is typed again before the statement is killed, `mysql` exits. Previously, **Control+C** caused `mysql` to exit in all cases.

You can execute SQL statements in a script file (batch file) like this:

```
shell> mysql db_name < script.sql > output.tab
```

On Unix, the `mysql` client logs statements executed interactively to a history file. See Section 4.5.1.3, "mysql Logging".

4.5.1.1 mysql Options

`mysql` supports the following options, which can be specified on the command line or in the `[mysql]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.5 `mysql` Options

Format	Description	Introduced
--auto-rehash	Enable automatic rehashing	
--batch	Do not use history file	
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--character-sets-dir	Directory where character sets are installed	
--column-names	Write column names in results	
--column-type-info	Display result set metadata	5.1.14
--comments	Whether to retain or strip comments in statements sent to the server	5.1.23
--compress	Compress all information sent between client and server	
--connect_timeout	Number of seconds before connection timeout	
--database	The database to use	
--debug	Write debugging log; supported only if MySQL was built with debugging support	
--debug-check	Print debugging information when program exits	5.1.21
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--delimiter	Set the statement delimiter	
--execute	Execute the statement and quit	
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--html	Produce HTML output	
--ignore-spaces	Ignore spaces after function names	
--line-numbers	Write line numbers for errors	
--local-infile	Enable or disable for LOCAL capability for LOAD DATA INFILE	
--max_allowed_packet	Maximum packet length to send to or receive from server	
--max_join_size	The automatic limit for rows in a join when using --safe-updates	
--named-commands	Enable named mysql commands	
--net_buffer_length	Buffer size for TCP/IP and socket communication	

Format	Description	Introduced
--no-auto-rehash	Disable automatic rehashing	
--no-beep	Do not beep when errors occur	
--no-defaults	Read no option files	
--no-named-commands	Disable named mysql commands	
--no-pager	Deprecated form of --skip-pager	
--no-tee	Do not copy output to a file	
--one-database	Ignore statements except those for the default database named on the command line	
--pager	Use the given command for paging query output	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--port	TCP/IP port number to use for connection	
--print-defaults	Print default options	
--prompt	Set the prompt to the specified format	
--protocol	Connection protocol to use	
--quick	Do not cache each query result	
--raw	Write column values without escape conversion	
--reconnect	If the connection to the server is lost, automatically try to reconnect	
--i-am-a-dummy, --safe-updates	Allow only UPDATE and DELETE statements that specify key values	
--secure-auth	Do not send passwords to server in old (pre-4.1) format	
--select_limit	The automatic limit for SELECT statements when using --safe-updates	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--show-warnings	Show warnings after each statement if there are any	
--sigint-ignore	Ignore SIGINT signals (typically the result of typing Control +C)	
--silent	Silent mode	
--skip-auto-rehash	Disable automatic rehashing	
--skip-column-names	Do not write column names in results	
--skip-line-numbers	Skip line numbers for errors	
--skip-named-commands	Disable named mysql commands	
--skip-pager	Disable paging	
--skip-reconnect	Disable reconnecting	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	

Format	Description	Introduced
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11
--table	Display output in tabular format	
--tee	Append a copy of output to named file	
--unbuffered	Flush the buffer after each query	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	
--vertical	Print query output rows vertically (one line per column value)	
--wait	If the connection cannot be established, wait and retry instead of aborting	
--xml	Produce XML output	

- `--help`, `-?`

  Display a help message and exit.

- `--auto-rehash`

  Enable automatic rehashing. This option is on by default, which enables database, table, and column name completion. Use `--disable-auto-rehash` to disable rehashing. That causes `mysql` to start faster, but you must issue the `rehash` command or its `\#` shortcut if you want to use name completion.

  To complete a name, enter the first part and press Tab. If the name is unambiguous, `mysql` completes it. Otherwise, you can press Tab again to see the possible names that begin with what you have typed so far. Completion does not occur if there is no default database.

  > **Note**
  >
  > This feature requires a MySQL client that is compiled with the **readline** library. Typically, the **readline** library is not available on Windows.

- `--batch`, `-B`

  Print results using tab as the column separator, with each row on a new line. With this option, `mysql` does not use the history file.

  Batch mode results in nontabular output format and escaping of special characters. Escaping may be disabled by using raw mode; see the description for the `--raw` option.

- `--bind-address=ip_address`

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of the `mysql` client that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=`*`dir_name`*

The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--column-names`

Write column names in results.

- `--column-type-info`

Display result set metadata. This option was added in MySQL 5.1.14. (Before that, use `--debug-info`.)

- `--comments`, `-c`

Whether to preserve comments in statements sent to the server. The default is --skip-comments (discard comments), enable with --comments (preserve comments). This option was added in MySQL 5.1.23.

- `--compress`, `-C`

Compress all information sent between the client and the server if both support compression.

- `--database=`*`db_name`*, `-D` *`db_name`*

The database to use. This is useful primarily in an option file.

- `--debug[=`*`debug_options`*`]`, `-# [`*`debug_options`*`]`

Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. The default is `d:t:o,/tmp/mysql.trace`.

This option is available only if MySQL was built using `--with-debug`. MySQL release binaries are *not* built using this option.

- `--debug-check`

Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`, `-T`

Before MySQL 5.1.14, this option prints debugging information and memory and CPU usage statistics when the program exits, and also causes display of result set metadata during execution. As of MySQL 5.1.14, use `--column-type-info` to display result set metadata.

- `--default-character-set=`*`charset_name`*

Use *`charset_name`* as the default character set for the client and connection.

A common issue that can occur when the operating system uses `utf8` or another multibyte character set is that output from the `mysql` client is formatted incorrectly, due to the fact that the MySQL client uses the `latin1` character set by default. You can usually fix such issues by using this option to force the client to use the system character set instead.

See Section 10.5, "Character Set Configuration", for more information.

- `--defaults-extra-file=`*`file_name`*

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysql` normally reads the `[client]` and `[mysql]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql` also reads the `[client_other]` and `[mysql_other]` groups.

- `--delimiter=str`

Set the statement delimiter. The default is the semicolon character ("`;`").

- `--disable-named-commands`

Disable named commands. Use the `\*` form only, or use named commands only at the beginning of a line ending with a semicolon ("`;`"). `mysql` starts with this option *enabled* by default. However, even with this option, long-format commands still work from the first line. See Section 4.5.1.2, "mysql Commands".

- `--execute=statement`, `-e statement`

Execute the statement and quit. The default output format is like that produced with `--batch`. See Section 4.2.4, "Using Options on the Command Line", for some examples. With this option, `mysql` does not use the history file.

- `--force`, `-f`

Continue even if an SQL error occurs.

- `--host=host_name`, `-h host_name`

Connect to the MySQL server on the given host.

- `--html`, `-H`

Produce HTML output.

- `--ignore-spaces`, `-i`

Ignore spaces after function names. The effect of this is described in the discussion for the `IGNORE_SPACE` SQL mode (see Section 5.1.7, "Server SQL Modes").

- `--line-numbers`

Write line numbers for errors. Disable this with `--skip-line-numbers`.

- `--local-infile[={0|1}]`

Enable or disable `LOCAL` capability for `LOAD DATA INFILE`. With no value, the option enables `LOCAL`. The option may be given as `--local-infile=0` or `--local-infile=1` to explicitly disable or enable `LOCAL`. Enabling `LOCAL` has no effect if the server does not also support it.

- `--named-commands`, `-G`

Enable named `mysql` commands. Long-format commands are permitted, not just short-format commands. For example, `quit` and `\q` both are recognized. Use `--skip-named-commands` to disable named commands. See Section 4.5.1.2, "mysql Commands".

- `--no-auto-rehash`, `-A`

This has the same effect as `--skip-auto-rehash`. See the description for `--auto-rehash`.

- `--no-beep`, `-b`

Do not beep when errors occur.

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--no-named-commands`, `-g`

Deprecated, use `--disable-named-commands` instead. `--no-named-commands` is removed in MySQL 5.5.

- `--no-pager`

Deprecated form of `--skip-pager`. See the `--pager` option. `--no-pager` is removed in MySQL 5.5.

- `--no-tee`

Deprecated form of `--skip-tee`. See the `--tee` option. `--no-tee` is removed in MySQL 5.5.

- `--one-database`, `-o`

Ignore statements except those that occur while the default database is the one named on the command line. This option is rudimentary and should be used with care. Statement filtering is based only on `USE` statements.

Initially, `mysql` executes statements in the input because specifying a database *db_name* on the command line is equivalent to inserting `USE` *db_name* at the beginning of the input. Then, for each `USE` statement encountered, `mysql` accepts or rejects following statements depending on whether the database named is the one on the command line. The content of the statements is immaterial.

Suppose that `mysql` is invoked to process this set of statements:

```
DELETE FROM db2.t2;
USE db2;
DROP TABLE db1.t1;
CREATE TABLE db1.t1 (i INT);
USE db1;
INSERT INTO t1 (i) VALUES(1);
CREATE TABLE db2.t1 (j INT);
```

If the command line is `mysql --force --one-database db1`, `mysql` handles the input as follows:

- The `DELETE` statement is executed because the default database is `db1`, even though the statement names a table in a different database.

- The `DROP TABLE` and `CREATE TABLE` statements are not executed because the default database is not `db1`, even though the statements name a table in `db1`.

- The `INSERT` and `CREATE TABLE` statements are executed because the default database is `db1`, even though the `CREATE TABLE` statement names a table in a different database.

- `--pager[=command]`

  Use the given command for paging query output. If the command is omitted, the default pager is the value of your `PAGER` environment variable. Valid pagers are `less`, `more`, `cat [> filename]`, and so forth. This option works only on Unix and only in interactive mode. To disable paging, use `--skip-pager`. Section 4.5.1.2, "mysql Commands", discusses output paging further.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the `password` value following the `--password` or `-p` option on the command line, `mysql` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--prompt=format_str`

  Set the prompt to the specified format. The default is `mysql>`. The special sequences that the prompt can contain are described in Section 4.5.1.2, "mysql Commands".

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--quick`, `-q`

  Do not cache each query result, print each row as it is received. This may slow down the server if the output is suspended. With this option, `mysql` does not use the history file.

- `--raw`, `-r`

  For tabular output, the "boxing" around columns enables one column value to be distinguished from another. For nontabular output (such as is produced in batch mode or when the `--batch` or `--silent` option is given), special characters are escaped in the output so they can be identified easily. Newline, tab, `NUL`, and backslash are written as `\n`, `\t`, `\0`, and `\\`. The `--raw` option disables this character escaping.

The following example demonstrates tabular versus nontabular output and the use of raw mode to disable escaping:

```
% mysql
mysql> SELECT CHAR(92);
+----------+
| CHAR(92) |
+----------+
| \        |
+----------+

% mysql -s
mysql> SELECT CHAR(92);
CHAR(92)
\\

% mysql -s -r
mysql> SELECT CHAR(92);
CHAR(92)
\
```

- `--reconnect`

  If the connection to the server is lost, automatically try to reconnect. A single reconnect attempt is made each time the connection is lost. To suppress reconnection behavior, use `--skip-reconnect`.

- `--safe-updates`, `--i-am-a-dummy`, `-U`

  Permit only those `UPDATE` and `DELETE` statements that specify which rows to modify by using key values. If you have set this option in an option file, you can override it by using `--safe-updates` on the command line. See Section 4.5.1.6, "mysql Tips", for more information about this option.

- `--secure-auth`

  Do not send passwords to the server in old (pre-4.1) format. This prevents connections except for servers that use the newer password format.

- `--shared-memory-base-name=`*name*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--show-warnings`

  Cause warnings to be shown after each statement if there are any. This option applies to interactive and batch mode.

- `--sigint-ignore`

  Ignore `SIGINT` signals (typically the result of typing **Control+C**).

- `--silent`, `-s`

  Silent mode. Produce less output. This option can be given multiple times to produce less and less output.

This option results in nontabular output format and escaping of special characters. Escaping may be disabled by using raw mode; see the description for the `--raw` option.

- `--skip-column-names`, `-N`

Do not write column names in results.

- `--skip-line-numbers`, `-L`

Do not write line numbers for errors. Useful when you want to compare result files that include error messages.

- `--socket=`*`path`*, `-S` *`path`*

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--table`, `-t`

Display output in table format. This is the default for interactive use, but can be used to produce table output in batch mode.

- `--tee=`*`file_name`*

Append a copy of output to the given file. This option works only in interactive mode. Section 4.5.1.2, "mysql Commands", discusses tee files further.

- `--unbuffered`, `-n`

Flush the buffer after each query.

- `--user=`*`user_name`*, `-u` *`user_name`*

The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

Verbose mode. Produce more output about what the program does. This option can be given multiple times to produce more and more output. (For example, `-v -v -v` produces table output format even in batch mode.)

- `--version`, `-V`

Display version information and exit.

- `--vertical`, `-E`

Print query output rows vertically (one line per column value). Without this option, you can specify vertical output for individual statements by terminating them with `\G`.

- `--wait`, `-w`

If the connection cannot be established, wait and retry instead of aborting.

- `--xml`, `-X`

  Produce XML output.

  > **Note**
  >
  > Prior to MySQL 5.1.12, there was no differentiation in the output when using this option between columns containing the `NULL` value and columns containing the string literal `'NULL'`; both were represented as

  ```
  <field name="column_name">NULL</field>
  ```

  Beginning with MySQL 5.1.12, the output when `--xml` is used with `mysql` matches that of `mysqldump --xml`. See Section 4.5.4, "`mysqldump` — A Database Backup Program" for details.

  Beginning with MySQL 5.1.18, the XML output also uses an XML namespace, as shown here:

  ```
  shell> mysql --xml -uroot -e "SHOW VARIABLES LIKE 'version%'"
  <?xml version="1.0"?>

  <resultset statement="SHOW VARIABLES LIKE 'version%'" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instan
  <row>
  <field name="Variable_name">version</field>
  <field name="Value">5.0.40-debug</field>
  </row>

  <row>
  <field name="Variable_name">version_comment</field>
  <field name="Value">Source distribution</field>
  </row>

  <row>
  <field name="Variable_name">version_compile_machine</field>
  <field name="Value">i686</field>
  </row>

  <row>
  <field name="Variable_name">version_compile_os</field>
  <field name="Value">suse-linux-gnu</field>
  </row>
  </resultset>
  ```

  (See Bug #25946.)

You can also set the following variables by using `--var_name=value`. The `--set-variable` format is deprecated and is removed in MySQL 5.5.

- `connect_timeout`

  The number of seconds before connection timeout. (Default value is `0`.)

- `max_allowed_packet`

  The maximum size of the buffer for client/server communication. The default is 16MB, the maximum is 1GB.

- `max_join_size`

  The automatic limit for rows in a join when using `--safe-updates`. (Default value is 1,000,000.)

- `net_buffer_length`

  The buffer size for TCP/IP and socket communication. (Default value is 16KB.)

- `select_limit`

  The automatic limit for `SELECT` statements when using `--safe-updates`. (Default value is 1,000.)

4.5.1.2 mysql Commands

`mysql` sends each SQL statement that you issue to the server to be executed. There is also a set of commands that `mysql` itself interprets. For a list of these commands, type `help` or `\h` at the `mysql>` prompt:

```
mysql> help

List of all MySQL commands:
Note that all text commands must be first on line and end with ';'
?         (\?) Synonym for `help'.
clear     (\c) Clear command.
connect   (\r) Reconnect to the server. Optional arguments are db and host.
delimiter (\d) Set statement delimiter.
edit      (\e) Edit command with $EDITOR.
ego       (\G) Send command to mysql server, display result vertically.
exit      (\q) Exit mysql. Same as quit.
go        (\g) Send command to mysql server.
help      (\h) Display this help.
nopager   (\n) Disable pager, print to stdout.
notee     (\t) Don't write into outfile.
pager     (\P) Set PAGER [to_pager]. Print the query results via PAGER.
print     (\p) Print current command.
prompt    (\R) Change your mysql prompt.
quit      (\q) Quit mysql.
rehash    (\#) Rebuild completion hash.
source    (\.) Execute an SQL script file. Takes a file name as an argument.
status    (\s) Get status information from the server.
system    (\!) Execute a system shell command.
tee       (\T) Set outfile [to_outfile]. Append everything into given
               outfile.
use       (\u) Use another database. Takes database name as argument.
charset   (\C) Switch to another charset. Might be needed for processing
               binlog with multi-byte charsets.
warnings  (\W) Show warnings after every statement.
nowarning (\w) Don't show warnings after every statement.

For server side help, type 'help contents'
```

Each command has both a long and short form. The long form is not case sensitive; the short form is. The long form can be followed by an optional semicolon terminator, but the short form should not.

The use of short-form commands within multiple-line `/* ... */` comments is not supported.

- `help [arg]`, `\h [arg]`, `\? [arg]`, `? [arg]`

  Display a help message listing the available `mysql` commands.

  If you provide an argument to the `help` command, `mysql` uses it as a search string to access server-side help from the contents of the MySQL Reference Manual. For more information, see Section 4.5.1.4, "mysql Server-Side Help".

- `charset charset_name`, `\C charset_name`

Change the default character set and issue a `SET NAMES` statement. This enables the character set to remain synchronized on the client and server if `mysql` is run with auto-reconnect enabled (which is not recommended), because the specified character set is used for reconnects. This command was added in MySQL 5.1.7.

- `clear`, `\c`

  Clear the current input. Use this if you change your mind about executing the statement that you are entering.

- `connect [`*`db_name host_name`*`]]`, `\r [`*`db_name host_name`*`]]`

  Reconnect to the server. The optional database name and host name arguments may be given to specify the default database or the host where the server is running. If omitted, the current values are used.

- `delimiter` *`str`*, `\d` *`str`*

  Change the string that `mysql` interprets as the separator between SQL statements. The default is the semicolon character ("`;`").

  The delimiter string can be specified as an unquoted or quoted argument on the `delimiter` command line. Quoting can be done with either single quote (`'`), double quote (`"`), or backtick (`` ` ``) characters. To include a quote within a quoted string, either quote the string with a different quote character or escape the quote with a backslash ("`\`") character. Backslash should be avoided outside of quoted strings because it is the escape character for MySQL. For an unquoted argument, the delimiter is read up to the first space or end of line. For a quoted argument, the delimiter is read up to the matching quote on the line.

  `mysql` interprets instances of the delimiter string as a statement delimiter anywhere it occurs, except within quoted strings. Be careful about defining a delimiter that might occur within other words. For example, if you define the delimiter as `X`, you will be unable to use the word `INDEX` in statements. `mysql` interprets this as `INDE` followed by the delimiter `X`.

  When the delimiter recognized by `mysql` is set to something other than the default of "`;`", instances of that character are sent to the server without interpretation. However, the server itself still interprets "`;`" as a statement delimiter and processes statements accordingly. This behavior on the server side comes into play for multiple-statement execution (see Section 21.8.16, "C API Support for Multiple Statement Execution"), and for parsing the body of stored procedures and functions, triggers, and events (see Section 19.1, "Defining Stored Programs").

- `edit`, `\e`

  Edit the current input statement. `mysql` checks the values of the `EDITOR` and `VISUAL` environment variables to determine which editor to use. The default editor is `vi` if neither variable is set.

  The `edit` command works only in Unix.

- `ego`, `\G`

  Send the current statement to the server to be executed and display the result using vertical format.

- `exit`, `\q`

  Exit `mysql`.

- `go`, `\g`

Send the current statement to the server to be executed.

- `nopager`, `\n`

  Disable output paging. See the description for `pager`.

  The `nopager` command works only in Unix.

- `notee`, `\t`

  Disable output copying to the tee file. See the description for `tee`.

- `nowarning`, `\w`

  Disable display of warnings after each statement.

- `pager [command]`, `\P [command]`

  Enable output paging. By using the `--pager` option when you invoke `mysql`, it is possible to browse or search query results in interactive mode with Unix programs such as `less`, `more`, or any other similar program. If you specify no value for the option, `mysql` checks the value of the `PAGER` environment variable and sets the pager to that. Pager functionality works only in interactive mode.

  Output paging can be enabled interactively with the `pager` command and disabled with `nopager`. The command takes an optional argument; if given, the paging program is set to that. With no argument, the pager is set to the pager that was set on the command line, or `stdout` if no pager was specified.

  Output paging works only in Unix because it uses the `popen()` function, which does not exist on Windows. For Windows, the `tee` option can be used instead to save query output, although it is not as convenient as `pager` for browsing output in some situations.

- `print`, `\p`

  Print the current input statement without executing it.

- `prompt [str]`, `\R [str]`

  Reconfigure the `mysql` prompt to the given string. The special character sequences that can be used in the prompt are described later in this section.

  If you specify the `prompt` command with no argument, `mysql` resets the prompt to the default of `mysql>`.

- `quit`, `\q`

  Exit `mysql`.

- `rehash`, `\#`

  Rebuild the completion hash that enables database, table, and column name completion while you are entering statements. (See the description for the `--auto-rehash` option.)

- `source file_name`, `\. file_name`

  Read the named file and executes the statements contained therein. On Windows, you can specify path name separators as `/` or `\\`.

- `status`, `\s`

Provide status information about the connection and the server you are using. If you are running in `--safe-updates` mode, `status` also prints the values for the `mysql` variables that affect your queries.

- `system command`, `\! command`

Execute the given command using your default command interpreter.

The `system` command works only in Unix.

- `tee [file_name]`, `\T [file_name]`

By using the `--tee` option when you invoke `mysql`, you can log statements and their output. All the data displayed on the screen is appended into a given file. This can be very useful for debugging purposes also. `mysql` flushes results to the file after each statement, just before it prints its next prompt. Tee functionality works only in interactive mode.

You can enable this feature interactively with the `tee` command. Without a parameter, the previous file is used. The `tee` file can be disabled with the `notee` command. Executing `tee` again re-enables logging.

- `use db_name`, `\u db_name`

Use `db_name` as the default database.

- `warnings`, `\W`

Enable display of warnings after each statement (if there are any).

Here are a few tips about the `pager` command:

- You can use it to write to a file and the results go only to the file:

```
mysql> pager cat > /tmp/log.txt
```

You can also pass any options for the program that you want to use as your pager:

```
mysql> pager less -n -i -S
```

- In the preceding example, note the `-S` option. You may find it very useful for browsing wide query results. Sometimes a very wide result set is difficult to read on the screen. The `-S` option to `less` can make the result set much more readable because you can scroll it horizontally using the left-arrow and right-arrow keys. You can also use `-S` interactively within `less` to switch the horizontal-browse mode on and off. For more information, read the `less` manual page:

```
shell> man less
```

- The `-F` and `-X` options may be used with `less` to cause it to exit if output fits on one screen, which is convenient when no scrolling is necessary:

```
mysql> pager less -n -i -S -F -X
```

- You can specify very complex pager commands for handling query output:

```
mysql> pager cat | tee /dr1/tmp/res.txt \
          | tee /dr2/tmp/res2.txt | less -n -i -S
```

In this example, the command would send query results to two files in two different directories on two different file systems mounted on `/dr1` and `/dr2`, yet still display the results onscreen using `less`.

You can also combine the `tee` and `pager` functions. Have a `tee` file enabled and `pager` set to `less`, and you are able to browse the results using the `less` program and still have everything appended into a file the same time. The difference between the Unix `tee` used with the `pager` command and the `mysql` built-in `tee` command is that the built-in `tee` works even if you do not have the Unix `tee` available. The built-in `tee` also logs everything that is printed on the screen, whereas the Unix `tee` used with `pager` does not log quite that much. Additionally, `tee` file logging can be turned on and off interactively from within `mysql`. This is useful when you want to log some queries to a file, but not others.

The `prompt` command reconfigures the default `mysql>` prompt. The string for defining the prompt can contain the following special sequences.

Option	Description
`\c`	A counter that increments for each statement you issue
`\D`	The full current date
`\d`	The default database
`\h`	The server host
`\l`	The current delimiter (new in 5.1.12)
`\m`	Minutes of the current time
`\n`	A newline character
`\O`	The current month in three-letter format (Jan, Feb, …)
`\o`	The current month in numeric format
`\P`	am/pm
`\p`	The current TCP/IP port or socket file
`\R`	The current time, in 24-hour military time (0–23)
`\r`	The current time, standard 12-hour time (1–12)
`\S`	Semicolon
`\s`	Seconds of the current time
`\t`	A tab character
`\U`	Your full *user_name@host_name* account name
`\u`	Your user name
`\v`	The server version
`\w`	The current day of the week in three-letter format (Mon, Tue, …)
`\Y`	The current year, four digits
`\y`	The current year, two digits
`\_`	A space
`\`	A space (a space follows the backslash)
`\'`	Single quote
`\"`	Double quote
`\\`	A literal "\" backslash character
`\x`	x, for any "x" not listed above

You can set the prompt in several ways:

- *Use an environment variable.* You can set the MYSQL_PS1 environment variable to a prompt string. For example:

```
shell> export MYSQL_PS1="(\u@\h) [\d]> "
```

- *Use a command-line option.* You can set the --prompt option on the command line to mysql. For example:

```
shell> mysql --prompt="(\u@\h) [\d]> "
(user@host) [database]>
```

- *Use an option file.* You can set the prompt option in the [mysql] group of any MySQL option file, such as /etc/my.cnf or the .my.cnf file in your home directory. For example:

```
[mysql]
prompt=(\\u@\\h) [\\d]>\\_
```

In this example, note that the backslashes are doubled. If you set the prompt using the prompt option in an option file, it is advisable to double the backslashes when using the special prompt options. There is some overlap in the set of permissible prompt options and the set of special escape sequences that are recognized in option files. (The rules for escape sequences in option files are listed in Section 4.2.6, "Using Option Files".) The overlap may cause you problems if you use single backslashes. For example, \s is interpreted as a space rather than as the current seconds value. The following example shows how to define a prompt within an option file to include the current time in HH:MM:SS> format:

```
[mysql]
prompt="\\r:\\m:\\s> "
```

- *Set the prompt interactively.* You can change your prompt interactively by using the prompt (or \R) command. For example:

```
mysql> prompt (\u@\h) [\d]>\_
PROMPT set to '(\u@\h) [\d]>\_'
(user@host) [database]>
(user@host) [database]> prompt
Returning to default PROMPT of mysql>
mysql>
```

4.5.1.3 mysql Logging

On Unix, the mysql client logs statements executed interactively to a history file. By default, this file is named .mysql_history in your home directory. To specify a different file, set the value of the MYSQL_HISTFILE environment variable.

How Logging Occurs

Statement logging occurs as follows:

- Statements are logged only when executed interactively. Statements are noninteractive, for example, when read from a file or a pipe. It is also possible to suppress statement logging by using the --batch or --execute option.

- mysql logs each nonempty statement line individually.

- If a statement spans multiple lines (not including the terminating delimiter), `mysql` concatenates the lines to form the complete statement, maps newlines to spaces, and logs the result, plus a delimiter.

Consequently, an input statement that spans multiple lines can be logged twice. Consider this input:

```
mysql> SELECT
    -> 'Today is'
    -> ,
    -> CURDATE()
    -> ;
```

In this case, `mysql` logs the "SELECT", "'Today is'", ",", "CURDATE()", and ";" lines as it reads them. It also logs the complete statement, after mapping `SELECT\n'Today is'\n,\nCURDATE()` to `SELECT 'Today is' , CURDATE()`, plus a delimiter. Thus, these lines appear in logged output:

```
SELECT
'Today is'
,
CURDATE()
;
SELECT 'Today is' , CURDATE();
```

Controlling the History File

The `.mysql_history` file should be protected with a restrictive access mode because sensitive information might be written to it, such as the text of SQL statements that contain passwords. See Section 6.1.2.1, "End-User Guidelines for Password Security".

If you do not want to maintain a history file, first remove `.mysql_history` if it exists. Then use either of the following techniques to prevent it from being created again:

- Set the `MYSQL_HISTFILE` environment variable to `/dev/null`. To cause this setting to take effect each time you log in, put it in one of your shell's startup files.

- Create `.mysql_history` as a symbolic link to `/dev/null`; this need be done only once:

```
shell> ln -s /dev/null $HOME/.mysql_history
```

4.5.1.4 mysql Server-Side Help

```
mysql> help search_string
```

If you provide an argument to the `help` command, `mysql` uses it as a search string to access server-side help from the contents of the MySQL Reference Manual. The proper operation of this command requires that the help tables in the `mysql` database be initialized with help topic information (see Section 5.1.9, "Server-Side Help").

If there is no match for the search string, the search fails:

```
mysql> help me

Nothing found
Please try to run 'help contents' for a list of all accessible topics
```

Use `help contents` to see a list of the help categories:

```
mysql> help contents
```

```
You asked for help about help category: "Contents"
For more information, type 'help <item>', where <item> is one of the
following categories:
   Account Management
   Administration
   Data Definition
   Data Manipulation
   Data Types
   Functions
   Functions and Modifiers for Use with GROUP BY
   Geographic Features
   Language Structure
   Plugins
   Storage Engines
   Stored Routines
   Table Maintenance
   Transactions
   Triggers
```

If the search string matches multiple items, `mysql` shows a list of matching topics:

```
mysql> help logs
Many help items for your request exist.
To make a more specific request, please type 'help <item>',
where <item> is one of the following topics:
   SHOW
   SHOW BINARY LOGS
   SHOW ENGINE
   SHOW LOGS
```

Use a topic as the search string to see the help entry for that topic:

```
mysql> help show binary logs
Name: 'SHOW BINARY LOGS'
Description:
Syntax:
SHOW BINARY LOGS
SHOW MASTER LOGS

Lists the binary log files on the server. This statement is used as
part of the procedure described in [purge-binary-logs], that shows how
to determine which logs can be purged.

mysql> SHOW BINARY LOGS;
+---------------+-----------+
| Log_name      | File_size |
+---------------+-----------+
| binlog.000015 |    724935 |
| binlog.000016 |    733481 |
+---------------+-----------+
```

The search string can contain the wildcard characters "`%`" and "`_`". These have the same meaning as for pattern-matching operations performed with the LIKE operator. For example, HELP rep% returns a list of topics that begin with rep:

```
mysql> HELP rep%
Many help items for your request exist.
To make a more specific request, please type 'help <item>',
where <item> is one of the following
topics:
   REPAIR TABLE
   REPEAT FUNCTION
   REPEAT LOOP
   REPLACE
```

```
    REPLACE FUNCTION
```

4.5.1.5 Executing SQL Statements from a Text File

The `mysql` client typically is used interactively, like this:

```
shell> mysql db_name
```

However, it is also possible to put your SQL statements in a file and then tell `mysql` to read its input from that file. To do so, create a text file `text_file` that contains the statements you wish to execute. Then invoke `mysql` as shown here:

```
shell> mysql db_name < text_file
```

If you place a `USE db_name` statement as the first statement in the file, it is unnecessary to specify the database name on the command line:

```
shell> mysql < text_file
```

If you are already running `mysql`, you can execute an SQL script file using the `source` command or `\.` command:

```
mysql> source file_name
mysql> \. file_name
```

Sometimes you may want your script to display progress information to the user. For this you can insert statements like this:

```
SELECT '<info_to_display>' AS ' ';
```

The statement shown outputs `<info_to_display>`.

You can also invoke `mysql` with the `--verbose` option, which causes each statement to be displayed before the result that it produces.

As of MySQL 5.1.23, `mysql` ignores Unicode byte order mark (BOM) characters at the beginning of input files. Previously, it read them and sent them to the server, resulting in a syntax error. Presence of a BOM does not cause `mysql` to change its default character set. To do that, invoke `mysql` with an option such as `--default-character-set=utf8`.

For more information about batch mode, see Section 3.5, "Using mysql in Batch Mode".

4.5.1.6 mysql Tips

This section describes some techniques that can help you use `mysql` more effectively.

Input-Line Editing

`mysql` supports input-line editing, which enables you to modify the current input line in place or recall previous input lines. For example, the **left-arrow** and **right-arrow** keys move horizontally within the current input line, and the **up-arrow** and **down-arrow** keys move up and down through the set of previously entered lines. **Backspace** deletes the character before the cursor and typing new characters enters them at the cursor position. To enter the line, press **Enter**.

On Windows, the editing key sequences are the same as supported for command editing in console windows. On Unix, the key sequences depend on the input library used to build `mysql` (for example, the `libedit` or `readline` library).

Documentation for the `libedit` and `readline` libraries is available online. To change the set of key sequences permitted by a given input library, define key bindings in the library startup file. This is a file in your home directory: `.editrc` for `libedit` and `.inputrc` for `readline`.

For example, in `libedit`, **Control+W** deletes everything before the current cursor position and **Control +U** deletes the entire line. In `readline`, **Control+W** deletes the word before the cursor and **Control +U** deletes everything before the current cursor position. If `mysql` was built using `libedit`, a user who prefers the `readline` behavior for these two keys can put the following lines in the `.editrc` file (creating the file if necessary):

```
bind "^W" ed-delete-prev-word
bind "^U" vi-kill-line-prev
```

To see the current set of key bindings, temporarily put a line that says only `bind` at the end of `.editrc`. `mysql` will show the bindings when it starts.

Displaying Query Results Vertically

Some query results are much more readable when displayed vertically, instead of in the usual horizontal table format. Queries can be displayed vertically by terminating the query with \G instead of a semicolon. For example, longer text values that include newlines often are much easier to read with vertical output:

```
mysql> SELECT * FROM mails WHERE LENGTH(txt) < 300 LIMIT 300,1\G
*************************** 1. row ***************************
  msg_nro: 3068
     date: 2000-03-01 23:29:50
time_zone: +0200
mail_from: Monty
    reply: monty@no.spam.com
  mail_to: "Thimble Smith" <tim@no.spam.com>
      sbj: UTF-8
      txt: >>>>> "Thimble" == Thimble Smith writes:

Thimble> Hi.  I think this is a good idea.  Is anyone familiar
Thimble> with UTF-8 or Unicode? Otherwise, I'll put this on my
Thimble> TODO list and see what happens.

Yes, please do that.

Regards,
Monty
     file: inbox-jani-1
     hash: 190402944
1 row in set (0.09 sec)
```

Using the --safe-updates Option

For beginners, a useful startup option is `--safe-updates` (or `--i-am-a-dummy`, which has the same effect). It is helpful for cases when you might have issued a `DELETE FROM` `tbl_name` statement but forgotten the `WHERE` clause. Normally, such a statement deletes all rows from the table. With `--safe-updates`, you can delete rows only by specifying the key values that identify them. This helps prevent accidents.

When you use the `--safe-updates` option, `mysql` issues the following statement when it connects to the MySQL server:

```
SET sql_safe_updates=1, sql_select_limit=1000, sql_max_join_size=1000000;
```

See Section 5.1.4, "Server System Variables".

The `SET` statement has the following effects:

- You are not permitted to execute an `UPDATE` or `DELETE` statement unless you specify a key constraint in the `WHERE` clause or provide a `LIMIT` clause (or both). For example:

```
UPDATE tbl_name SET not_key_column=val WHERE key_column=val;

UPDATE tbl_name SET not_key_column=val LIMIT 1;
```

- The server limits all large `SELECT` results to 1,000 rows unless the statement includes a `LIMIT` clause.

- The server aborts multiple-table `SELECT` statements that probably need to examine more than 1,000,000 row combinations.

To specify limits different from 1,000 and 1,000,000, you can override the defaults by using the `--select_limit` and `--max_join_size` options:

```
shell> mysql --safe-updates --select_limit=500 --max_join_size=10000
```

Disabling mysql Auto-Reconnect

If the `mysql` client loses its connection to the server while sending a statement, it immediately and automatically tries to reconnect once to the server and send the statement again. However, even if `mysql` succeeds in reconnecting, your first connection has ended and all your previous session objects and settings are lost: temporary tables, the autocommit mode, and user-defined and session variables. Also, any current transaction rolls back. This behavior may be dangerous for you, as in the following example where the server was shut down and restarted between the first and second statements without you knowing it:

```
mysql> SET @a=1;
Query OK, 0 rows affected (0.05 sec)

mysql> INSERT INTO t VALUES(@a);
ERROR 2006: MySQL server has gone away
No connection. Trying to reconnect...
Connection id:    1
Current database: test

Query OK, 1 row affected (1.30 sec)

mysql> SELECT * FROM t;
+------+
| a    |
+------+
| NULL |
+------+
1 row in set (0.05 sec)
```

The `@a` user variable has been lost with the connection, and after the reconnection it is undefined. If it is important to have `mysql` terminate with an error if the connection has been lost, you can start the `mysql` client with the `--skip-reconnect` option.

For more information about auto-reconnect and its effect on state information when a reconnection occurs, see Section 21.8.15, "Controlling Automatic Reconnection Behavior".

4.5.2 `mysqladmin` — Client for Administering a MySQL Server

`mysqladmin` is a client for performing administrative operations. You can use it to check the server's configuration and current status, to create and drop databases, and more.

Invoke `mysqladmin` like this:

```
shell> mysqladmin [options] command [command-arg] [command [command-arg]] ...
```

`mysqladmin` supports the following commands. Some of the commands take an argument following the command name.

- `create db_name`

  Create a new database named `db_name`.

- `debug`

  Tell the server to write debug information to the error log. Format and content of this information is subject to change.

  Beginning with MySQL 5.1.12, this includes information about the Event Scheduler. See Section 19.4.5, "Event Scheduler Status".

- `drop db_name`

  Delete the database named `db_name` and all its tables.

- `extended-status`

  Display the server status variables and their values.

- `flush-hosts`

  Flush all information in the host cache.

- `flush-logs`

  Flush all logs.

- `flush-privileges`

  Reload the grant tables (same as `reload`).

- `flush-status`

  Clear status variables.

- `flush-tables`

  Flush all tables.

- `flush-threads`

  Flush the thread cache.

- `kill id,id,...`

  Kill server threads. If multiple thread ID values are given, there must be no spaces in the list.

- `old-password new_password`

  This is like the `password` command but stores the password using the old (pre-4.1) password-hashing format. (See Section 6.1.2.4, "Password Hashing in MySQL".)

- password *new_password*

  Set a new password. This changes the password to *new_password* for the account that you use with `mysqladmin` for connecting to the server. Thus, the next time you invoke `mysqladmin` (or any other client program) using the same account, you will need to specify the new password.

  If the *new_password* value contains spaces or other characters that are special to your command interpreter, you need to enclose it within quotation marks. On Windows, be sure to use double quotation marks rather than single quotation marks; single quotation marks are not stripped from the password, but rather are interpreted as part of the password. For example:

  ```
  shell> mysqladmin password "my new password"
  ```

  > **Caution**
  >
  > Do not use this command used if the server was started with the `--skip-grant-tables` option. No password change will be applied. This is true even if you precede the `password` command with `flush-privileges` on the same command line to re-enable the grant tables because the flush operation occurs after you connect. However, you can use `mysqladmin flush-privileges` to re-enable the grant table and then use a separate `mysqladmin password` command to change the password.

- ping

  Check whether the server is available. The return status from `mysqladmin` is 0 if the server is running, 1 if it is not. This is 0 even in case of an error such as `Access denied`, because this means that the server is running but refused the connection, which is different from the server not running.

- processlist

  Show a list of active server threads. This is like the output of the `SHOW PROCESSLIST` statement. If the `--verbose` option is given, the output is like that of `SHOW FULL PROCESSLIST`. (See Section 13.7.5.31, "SHOW PROCESSLIST Syntax".)

- reload

  Reload the grant tables.

- refresh

  Flush all tables and close and open log files.

- shutdown

  Stop the server.

- start-slave

  Start replication on a slave server.

- status

  Display a short server status message.

- stop-slave

  Stop replication on a slave server.

- `variables`

  Display the server system variables and their values.

- `version`

  Display version information from the server.

All commands can be shortened to any unique prefix. For example:

```
shell> mysqladmin proc stat
+----+-------+-----------+----+---------+------+-------+------------------+
| Id | User  | Host      | db | Command | Time | State | Info             |
+----+-------+-----------+----+---------+------+-------+------------------+
| 51 | monty | localhost |    | Query   | 0    |       | show processlist |
+----+-------+-----------+----+---------+------+-------+------------------+
Uptime: 1473624  Threads: 1  Questions: 39487
Slow queries: 0  Opens: 541  Flush tables: 1
Open tables: 19  Queries per second avg: 0.0268
```

The `mysqladmin status` command result displays the following values:

- `Uptime`

  The number of seconds the MySQL server has been running.

- `Threads`

  The number of active threads (clients).

- `Questions`

  The number of questions (queries) from clients since the server was started.

- `Slow queries`

  The number of queries that have taken more than `long_query_time` seconds. See Section 5.4.5, "The Slow Query Log".

- `Opens`

  The number of tables the server has opened.

- `Flush tables`

  The number of `flush-*`, `refresh`, and `reload` commands the server has executed.

- `Open tables`

  The number of tables that currently are open.

- `Memory in use`

  The amount of memory allocated directly by `mysqld`. This value is displayed only when MySQL has been compiled with `--with-debug=full`.

- `Maximum memory used`

  The maximum amount of memory allocated directly by `mysqld`. This value is displayed only when MySQL has been compiled with `--with-debug=full`.

If you execute `mysqladmin shutdown` when connecting to a local server using a Unix socket file, `mysqladmin` waits until the server's process ID file has been removed, to ensure that the server has stopped properly.

`mysqladmin` supports the following options, which can be specified on the command line or in the `[mysqladmin]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.6 `mysqladmin` Options

Format	Description	Introduced
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--compress	Compress all information sent between client and server	
--connect_timeout	Number of seconds before connection timeout	
--count	Number of iterations to make for repeated command execution	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	5.1.21
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.14
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--no-beep	Do not beep when errors occur	5.1.17
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--port	TCP/IP port number to use for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--relative	Show the difference between the current and previous values when used with the --sleep option	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--shutdown_timeout	The maximum number of seconds to wait for server shutdown	
--silent	Silent mode	
--sleep	Execute commands repeatedly, sleeping for delay seconds in between	
--socket	For connections to localhost, the Unix socket file to use	

Format	Description	Introduced
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	
--vertical	Print query output rows vertically (one line per column value)	
--wait	If the connection cannot be established, wait and retry instead of aborting	

- `--help`, `-?`

  Display a help message and exit.

- `--bind-address=`*`ip_address`*

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of `mysqladmin` that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=`*`dir_name`*

  The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--count=`*`N`*, `-c` *`N`*

  The number of iterations to make for repeated command execution if the `--sleep` option is given.

- `--debug[=`*`debug_options`*`]`, `-# [`*`debug_options`*`]`

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. The default is `d:t:o,/tmp/mysqladmin.trace`.

- `--debug-check`

  Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`

Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.14.

- `--default-character-set=`*`charset_name`*

  Use *`charset_name`* as the default character set. See Section 10.5, "Character Set Configuration".

- `--defaults-extra-file=`*`file_name`*

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-file=`*`file_name`*

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-group-suffix=`*`str`*

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqladmin` normally reads the `[client]` and `[mysqladmin]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqladmin` also reads the `[client_other]` and `[mysqladmin_other]` groups.

- `--force`, `-f`

  Do not ask for confirmation for the `drop `*`db_name`* command. With multiple commands, continue even if an error occurs.

- `--host=`*`host_name`*, `-h `*`host_name`*

  Connect to the MySQL server on the given host.

- `--no-beep`, `-b`

  Suppress the warning beep that is emitted by default for errors such as a failure to connect to the server. This option was added in MySQL 5.1.17.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=`*`password`*`]`, `-p[`*`password`*`]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqladmin` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=`*port_num*, `-P` *port_num*

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--relative`, `-r`

  Show the difference between the current and previous values when used with the `--sleep` option. This option works only with the `extended-status` command.

- `--shared-memory-base-name=`*name*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--silent`, `-s`

  Exit silently if a connection to the server cannot be established.

- `--sleep=`*delay*, `-i` *delay*

  Execute commands repeatedly, sleeping for *delay* seconds in between. The `--count` option determines the number of iterations. If `--count` is not given, `mysqladmin` executes commands indefinitely until interrupted.

- `--socket=`*path*, `-S` *path*

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--user=`*user_name*, `-u` *user_name*

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

- `--vertical`, `-E`

Print output vertically. This is similar to `--relative`, but prints output vertically.

- `--wait[=`*count*`]`, `-w[`*count*`]`

  If the connection cannot be established, wait and retry instead of aborting. If a *count* value is given, it indicates the number of times to retry. The default is one time.

You can also set the following variables by using `--`*var_name*`=`*value* The `--set-variable` format is deprecated and is removed in MySQL 5.5.

- `connect_timeout`

  The maximum number of seconds before connection timeout. The default value is 43200 (12 hours).

- `shutdown_timeout`

  The maximum number of seconds to wait for server shutdown. The default value is 3600 (1 hour).

4.5.3 `mysqlcheck` — A Table Maintenance Program

The `mysqlcheck` client performs table maintenance: It checks, repairs, optimizes, or analyzes tables.

Each table is locked and therefore unavailable to other sessions while it is being processed, although for check operations, the table is locked with a `READ` lock only (see Section 13.3.5, "LOCK TABLES and UNLOCK TABLES Syntax", for more information about `READ` and `WRITE` locks). Table maintenance operations can be time-consuming, particularly for large tables. If you use the `--databases` or `--all-databases` option to process all tables in one or more databases, an invocation of `mysqlcheck` might take a long time. (This is also true for `mysql_upgrade` because that program invokes `mysqlcheck` to check all tables and repair them if necessary.)

`mysqlcheck` is similar in function to `myisamchk`, but works differently. The main operational difference is that `mysqlcheck` must be used when the `mysqld` server is running, whereas `myisamchk` should be used when it is not. The benefit of using `mysqlcheck` is that you do not have to stop the server to perform table maintenance.

`mysqlcheck` uses the SQL statements `CHECK TABLE`, `REPAIR TABLE`, `ANALYZE TABLE`, and `OPTIMIZE TABLE` in a convenient way for the user. It determines which statements to use for the operation you want to perform, and then sends the statements to the server to be executed. For details about which storage engines each statement works with, see the descriptions for those statements in Section 13.7.2, "Table Maintenance Statements".

The `MyISAM` storage engine supports all four maintenance operations, so `mysqlcheck` can be used to perform any of them on `MyISAM` tables. Other storage engines do not necessarily support all operations. In such cases, an error message is displayed. For example, if `test.t` is a `MEMORY` table, an attempt to check it produces this result:

```
shell> mysqlcheck test t
test.t
note     : The storage engine for the table doesn't support check
```

If `mysqlcheck` is unable to repair a table, see Section 2.13.4, "Rebuilding or Repairing Tables or Indexes" for manual table repair strategies. This will be the case, for example, for `InnoDB` tables, which can be checked with `CHECK TABLE`, but not repaired with `REPAIR TABLE`.

The use of `mysqlcheck` with partitioned tables is not supported before MySQL 5.1.27.

Caution

It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors.

There are three general ways to invoke `mysqlcheck`:

```
shell> mysqlcheck [options] db_name [tbl_name ...]
shell> mysqlcheck [options] --databases db_name ...
shell> mysqlcheck [options] --all-databases
```

If you do not name any tables following `db_name` or if you use the `--databases` or `--all-databases` option, entire databases are checked.

`mysqlcheck` has a special feature compared to other client programs. The default behavior of checking tables (`--check`) can be changed by renaming the binary. If you want to have a tool that repairs tables by default, you should just make a copy of `mysqlcheck` named `mysqlrepair`, or make a symbolic link to `mysqlcheck` named `mysqlrepair`. If you invoke `mysqlrepair`, it repairs tables.

The names shown in the following table can be used to change `mysqlcheck` default behavior.

Command	Meaning
mysqlrepair	The default option is `--repair`
mysqlanalyze	The default option is `--analyze`
mysqloptimize	The default option is `--optimize`

`mysqlcheck` supports the following options, which can be specified on the command line or in the `[mysqlcheck]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.7 `mysqlcheck` Options

Format	Description	Introduced
--all-databases	Check all tables in all databases	
--all-in-1	Execute a single statement for each database that names all the tables from that database	
--analyze	Analyze the tables	
--auto-repair	If a checked table is corrupted, automatically fix it	
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--character-sets-dir	Directory where character sets are installed	
--check	Check the tables for errors	
--check-only-changed	Check only tables that have changed since the last check	
--check-upgrade	Invoke CHECK TABLE with the FOR UPGRADE option	5.1.7
--compress	Compress all information sent between client and server	
--databases	Interpret all arguments as database names	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	5.1.21

Format	Description	Introduced
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.14
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--extended	Check and repair tables	
--fast	Check only tables that have not been closed properly	
--fix-db-names	Convert database names to 5.1 format	5.1.7
--fix-table-names	Convert table names to 5.1 format	5.1.7
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--medium-check	Do a check that is faster than an --extended operation	
--no-defaults	Read no option files	
--optimize	Optimize the tables	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--port	TCP/IP port number to use for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--quick	The fastest method of checking	
--repair	Perform a repair that can fix almost anything except unique keys that are not unique	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--silent	Silent mode	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11
--tables	Overrides the --databases or -B option	
--use-frm	For repair operations on MyISAM tables	

Format	Description	Introduced
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	
--write-binlog	Log ANALYZE, OPTIMIZE, REPAIR statements to binary log. --skip-write-binlog adds NO_WRITE_TO_BINLOG to these statements.	5.1.18

- `--help`, `-?`

  Display a help message and exit.

- `--all-databases`, `-A`

  Check all tables in all databases. This is the same as using the `--databases` option and naming all the databases on the command line.

- `--all-in-1`, `-1`

  Instead of issuing a statement for each table, execute a single statement for each database that names all the tables from that database to be processed.

- `--analyze`, `-a`

  Analyze the tables.

- `--auto-repair`

  If a checked table is corrupted, automatically fix it. Any necessary repairs are done after all tables have been checked.

- `--bind-address=`*`ip_address`*

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of `mysqlcheck` that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=`*`dir_name`*

  The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--check`, `-c`

  Check the tables for errors. This is the default operation.

- `--check-only-changed`, `-C`

  Check only tables that have changed since the last check or that have not been closed properly.

- `--check-upgrade`, `-g`

  Invoke `CHECK TABLE` with the `FOR UPGRADE` option to check tables for incompatibilities with the current version of the server. This option automatically enables the `--fix-db-names` and `--fix-table-names` options. `--check-upgrade` was added in MySQL 5.1.7.

- `--compress`

  Compress all information sent between the client and the server if both support compression.

- `--databases`, `-B`

  Process all tables in the named databases. Normally, `mysqlcheck` treats the first name argument on the command line as a database name and any following names as table names. With this option, it treats all name arguments as database names.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o`.

- `--debug-check`

  Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.14.

- `--default-character-set=charset_name`

  Use `charset_name` as the default character set. See Section 10.5, "Character Set Configuration".

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqlcheck` normally reads the `[client]` and `[mysqlcheck]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlcheck` also reads the `[client_other]` and `[mysqlcheck_other]` groups.

- `--extended`, `-e`

  If you are using this option to check tables, it ensures that they are 100% consistent but takes a long time.

  If you are using this option to repair tables, it runs an extended repair that may not only take a long time to execute, but may produce a lot of garbage rows also!

- `--fast`, `-F`

  Check only tables that have not been closed properly.

- `--fix-db-names`

Convert database names to 5.1 format. Only database names that contain special characters are affected. This option was added in MySQL 5.1.7.

- `--fix-table-names`

Convert table names to 5.1 format. Only table names that contain special characters are affected. This option was added in MySQL 5.1.7. As of MySQL 5.1.23, this option also applies to views.

- `--force`, `-f`

Continue even if an SQL error occurs.

- `--host=`*`host_name`*, `-h` *`host_name`*

Connect to the MySQL server on the given host.

- `--medium-check`, `-m`

Do a check that is faster than an `--extended` operation. This finds only 99.99% of all errors, which should be good enough in most cases.

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--optimize`, `-o`

Optimize the tables.

- `--password[=`*`password`*`]`, `-p[`*`password`*`]`

The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlcheck` prompts for one.

Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=`*`port_num`*, `-P` *`port_num`*

The TCP/IP port number to use for the connection.

- `--print-defaults`

Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--quick`, `-q`

  If you are using this option to check tables, it prevents the check from scanning the rows to check for incorrect links. This is the fastest check method.

  If you are using this option to repair tables, it tries to repair only the index tree. This is the fastest repair method.

- `--repair`, `-r`

  Perform a repair that can fix almost anything except unique keys that are not unique.

- `--shared-memory-base-name=`*name*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--silent`, `-s`

  Silent mode. Print only error messages.

- `--socket=`*path*, `-S` *path*

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--tables`

  Override the `--databases` or `-B` option. All name arguments following the option are regarded as table names.

- `--use-frm`

  For repair operations on `MyISAM` tables, get the table structure from the `.frm` file so that the table can be repaired even if the `.MYI` header is corrupted.

- `--user=`*user_name*, `-u` *user_name*

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print information about the various stages of program operation.

- `--version`, `-V`

  Display version information and exit.

- `--write-binlog`

  This option is enabled by default, so that `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements generated by `mysqlcheck` are written to the binary log. Use `--skip-write-binlog` to cause `NO_WRITE_TO_BINLOG` to be added to the statements so that they are not logged. Use the `--`

`skip-write-binlog` when these statements should not be sent to replication slaves or run when using the binary logs for recovery from backup. This option was added in MySQL 5.1.18.

4.5.4 `mysqldump` — A Database Backup Program

- Invocation Syntax

- Option Syntax - Alphabetical Summary

The `mysqldump` client is a backup program originally written by Igor Romanenko. It can be used to dump a database or a collection of databases for backup or transfer to another SQL server (not necessarily a MySQL server). The dump typically contains SQL statements to create the table, populate it, or both. However, `mysqldump` can also be used to generate files in CSV, other delimited text, or XML format.

`mysqldump` requires at least the `SELECT` privilege for dumped tables, `SHOW VIEW` for dumped views, `TRIGGER` for dumped triggers, and `LOCK TABLES` if the `--single-transaction` option is not used. Certain options might require other privileges as noted in the option descriptions.

To reload a dump file, you must have the privileges required to execute the statements that it contains, such as the appropriate `CREATE` privileges for objects created by those statements.

`mysqldump` output can include `ALTER DATABASE` statements that change the database collation. These may be used when dumping stored programs to preserve their character encodings. To reload a dump file containing such statements, the `ALTER` privilege for the affected database is required.

If you are performing a backup on the server and your tables all are `MyISAM` tables, you can also use `mysqlhotcopy` for this purpose.

Invocation Syntax

There are in general three ways to use `mysqldump`—in order to dump a set of one or more tables, a set of one or more complete databases, or an entire MySQL server—as shown here:

```
shell> mysqldump [options] db_name [tbl_name ...]
shell> mysqldump [options] --databases db_name ...
shell> mysqldump [options] --all-databases
```

To dump entire databases, do not name any tables following *db_name*, or use the `--databases` or `--all-databases` option.

`mysqldump` does not dump the `INFORMATION_SCHEMA` database by default. As of MySQL 5.1.38, `mysqldump` dumps `INFORMATION_SCHEMA` if you name it explicitly on the command line, although you must also use the `--skip-lock-tables` option. Before 5.1.38, `mysqldump` silently ignores `INFORMATION_SCHEMA` even if you name it explicitly on the command line.

Before MySQL 5.1.64, `mysqldump` does not dump the `general_log` or `slow_query_log` tables for dumps of the `mysql` database. As of 5.1.64, the dump includes statements to recreate those tables so that they are not missing after reloading the dump file. Log table contents are not dumped.

In MySQL Cluster NDB 7.1.7 and later, the `ndbinfo` information database is ignored and not dumped by `mysqldump`.

To see a list of the options your version of `mysqldump` supports, execute `mysqldump --help`.

Some `mysqldump` options are shorthand for groups of other options:

- Use of `--opt` is the same as specifying `--add-drop-table`, `--add-locks`, `--create-options`, `--disable-keys`, `--extended-insert`, `--lock-tables`, `--quick`, and `--set-charset`. All of the options that `--opt` stands for also are on by default because `--opt` is on by default.

- Use of `--compact` is the same as specifying `--skip-add-drop-table`, `--skip-add-locks`, `--skip-comments`, `--skip-disable-keys`, and `--skip-set-charset` options.

To reverse the effect of a group option, uses its `--skip-xxx` form (`--skip-opt` or `--skip-compact`). It is also possible to select only part of the effect of a group option by following it with options that enable or disable specific features. Here are some examples:

- To select the effect of `--opt` except for some features, use the `--skip` option for each feature. To disable extended inserts and memory buffering, use `--opt --skip-extended-insert --skip-quick`. (Actually, `--skip-extended-insert --skip-quick` is sufficient because `--opt` is on by default.)

- To reverse `--opt` for all features except index disabling and table locking, use `--skip-opt --disable-keys --lock-tables`.

When you selectively enable or disable the effect of a group option, order is important because options are processed first to last. For example, `--disable-keys --lock-tables --skip-opt` would not have the intended effect; it is the same as `--skip-opt` by itself.

`mysqldump` can retrieve and dump table contents row by row, or it can retrieve the entire content from a table and buffer it in memory before dumping it. Buffering in memory can be a problem if you are dumping large tables. To dump tables row by row, use the `--quick` option (or `--opt`, which enables `--quick`). The `--opt` option (and hence `--quick`) is enabled by default, so to enable memory buffering, use `--skip-quick`.

If you are using a recent version of `mysqldump` to generate a dump to be reloaded into a very old MySQL server, you should not use the `--opt` or `--extended-insert` option. Use `--skip-opt` instead.

> **Note**
>
> `mysqldump` from MySQL 5.1.21 cannot be used to create dumps from MySQL server 5.1.20 and older. This issue is fixed in MySQL 5.1.22. (Bug #30123)

Option Syntax - Alphabetical Summary

`mysqldump` supports the following options, which can be specified on the command line or in the `[mysqldump]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.8 `mysqldump` Options

Format	Description	Introduced
--add-drop-database	Add DROP DATABASE statement before each CREATE DATABASE statement	
--add-drop-table	Add DROP TABLE statement before each CREATE TABLE statement	
--add-drop-trigger	Add DROP TRIGGER statement before each CREATE TRIGGER statement	5.1.47-ndb-7.1.8
--add-locks	Surround each table dump with LOCK TABLES and UNLOCK TABLES statements	
--all-databases	Dump all tables in all databases	
--all-tablespaces	Adds to a table dump all SQL statements needed to create any tablespaces used by an NDB Cluster table	5.1.6
--allow-keywords	Allow creation of column names that are keywords	

Format	Description	Introduced
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--character-sets-dir	Directory where character sets are installed	
--comments	Add comments to dump file	
--compact	Produce more compact output	
--compatible	Produce output that is more compatible with other database systems or with older MySQL servers	
--complete-insert	Use complete INSERT statements that include column names	
--compress	Compress all information sent between client and server	
--create-options	Include all MySQL-specific table options in CREATE TABLE statements	
--databases	Interpret all name arguments as database names	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	5.1.21
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.14
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--delayed-insert	Write INSERT DELAYED statements rather than INSERT statements	
--delete-master-logs	On a master replication server, delete the binary logs after performing the dump operation	
--disable-keys	For each table, surround INSERT statements with statements to disable and enable keys	
--dump-date	Include dump date as "Dump completed on" comment if --comments is given	5.1.23
--events	Dump events from dumped databases	5.1.8
--extended-insert	Use multiple-row INSERT syntax	
--fields-enclosed-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-escaped-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-optionally-enclosed-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE	

Format	Description	Introduced
--fields-terminated-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE	
--first-slave	Deprecated; use --lock-all-tables instead	
--flush-logs	Flush MySQL server log files before starting dump	
--flush-privileges	Emit a FLUSH PRIVILEGES statement after dumping mysql database	
--force	Continue even if an SQL error occurs during a table dump	
--help	Display help message and exit	
--hex-blob	Dump binary columns using hexadecimal notation	
--host	Host to connect to (IP address or hostname)	
--ignore-table	Do not dump given table	
--insert-ignore	Write INSERT IGNORE rather than INSERT statements	
--lines-terminated-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE	
--lock-all-tables	Lock all tables across all databases	
--lock-tables	Lock all tables before dumping them	
--log-error	Append warnings and errors to named file	5.1.18
--master-data	Write the binary log file name and position to the output	
--max_allowed_packet	Maximum packet length to send to or receive from server	
--net_buffer_length	Buffer size for TCP/IP and socket communication	
--no-autocommit	Enclose the INSERT statements for each dumped table within SET autocommit = 0 and COMMIT statements	
--no-create-db	Do not write CREATE DATABASE statements	
--no-create-info	Do not write CREATE TABLE statements that re-create each dumped table	
--no-data	Do not dump table contents	
--no-defaults	Read no option files	
--no-set-names	Same as --skip-set-charset	
--no-tablespaces	Do not write any CREATE LOGFILE GROUP or CREATE TABLESPACE statements in output	5.1.14
--opt	Shorthand for --add-drop-table --add-locks --create-options --disable-keys --extended-insert --lock-tables --quick --set-charset.	
--order-by-primary	Dump each table's rows sorted by its primary key, or by its first unique index	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--port	TCP/IP port number to use for connection	
--print-defaults	Print default options	

Format	Description	Introduced
--protocol	Connection protocol to use	
--quick	Retrieve rows for a table from the server a row at a time	
--quote-names	Quote identifiers within backtick characters	
--replace	Write REPLACE statements rather than INSERT statements	5.1.3
--result-file	Direct output to a given file	
--routines	Dump stored routines (procedures and functions) from dumped databases	5.1.2
--set-charset	Add SET NAMES default_character_set to output	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--single-transaction	Issue a BEGIN SQL statement before dumping data from server	
--skip-add-drop-table	Do not add a DROP TABLE statement before each CREATE TABLE statement	
--skip-add-locks	Do not add locks	
--skip-comments	Do not add comments to dump file	
--skip-compact	Do not produce more compact output	
--skip-disable-keys	Do not disable keys	
--skip-extended-insert	Turn off extended-insert	
--skip-opt	Turn off options set by --opt	
--skip-quick	Do not retrieve rows for a table from the server a row at a time	
--skip-quote-names	Do not quote identifiers	
--skip-set-charset	Do not write SET NAMES statement	
--skip-triggers	Do not dump triggers	
--skip-tz-utc	Turn off tz-utc	5.1.2
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11
--tab	Produce tab-separated data files	
--tables	Override --databases or -B option	
--triggers	Dump triggers for each dumped table	

Format	Description	Introduced
--tz-utc	Add SET TIME_ZONE='+00:00' to dump file	5.1.2
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	
--where	Dump only rows selected by given WHERE condition	
--xml	Produce XML output	

- `--help`, `-?`

  Display a help message and exit.

- `--add-drop-database`

  Write a `DROP DATABASE` statement before each `CREATE DATABASE` statement. This option is typically used in conjunction with the `--all-databases` or `--databases` option because no `CREATE DATABASE` statements are written unless one of those options is specified.

- `--add-drop-table`

  Write a `DROP TABLE` statement before each `CREATE TABLE` statement.

- `--add-drop-trigger`

  Write a `DROP TRIGGER` statement before each `CREATE TRIGGER` statement.

  > **Note**
  >
  > This option is supported only by `mysqldump` as supplied with MySQL Cluster NDB 6.3.38, MySQL Cluster NDB 7.0.19, MySQL Cluster NDB 7.1.8, and later MySQL Cluster releases. It is not available when using MySQL 5.1.

- `--add-locks`

  Surround each table dump with `LOCK TABLES` and `UNLOCK TABLES` statements. This results in faster inserts when the dump file is reloaded. See Section 8.2.2.1, "Speed of INSERT Statements".

- `--all-databases`, `-A`

  Dump all tables in all databases. This is the same as using the `--databases` option and naming all the databases on the command line.

- `--all-tablespaces`, `-Y`

  Adds to a table dump all SQL statements needed to create any tablespaces used by an `NDBCLUSTER` table. This information is not otherwise included in the output from `mysqldump`. This option is currently relevant only to MySQL Cluster tables.

  This option was added in MySQL 5.1.6.

- `--allow-keywords`

  Permit creation of column names that are keywords. This works by prefixing each column name with the table name.

- `--bind-address=ip_address`

On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of `mysqldump` that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=`*`dir_name`*

The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--comments`, `-i`

Write additional information in the dump file such as program version, server version, and host. This option is enabled by default. To suppress this additional information, use `--skip-comments`.

- `--compact`

Produce more compact output. This option enables the `--skip-add-drop-table`, `--skip-add-locks`, `--skip-comments`, `--skip-disable-keys`, and `--skip-set-charset` options.

> **Note**
>
> Prior to MySQL 5.1.21, this option did not create valid SQL if the database dump contained views. The recreation of views requires the creation and removal of temporary tables and this option suppressed the removal of those temporary tables. As a workaround, use `--compact` with the `--add-drop-table` option and then manually adjust the dump file.

- `--compatible=`*`name`*

Produce output that is more compatible with other database systems or with older MySQL servers. The value of *`name`* can be `ansi`, `mysql323`, `mysql40`, `postgresql`, `oracle`, `mssql`, `db2`, `maxdb`, `no_key_options`, `no_table_options`, or `no_field_options`. To use several values, separate them by commas. These values have the same meaning as the corresponding options for setting the server SQL mode. See Section 5.1.7, "Server SQL Modes".

This option does not guarantee compatibility with other servers. It only enables those SQL mode values that are currently available for making dump output more compatible. For example, `--compatible=oracle` does not map data types to Oracle types or use Oracle comment syntax.

This option requires a server version of 4.1.0 or higher. With older servers, it does nothing.

- `--complete-insert`, `-c`

Use complete `INSERT` statements that include column names.

- `--compress`, `-C`

Compress all information sent between the client and the server if both support compression.

- `--create-options`

Include all MySQL-specific table options in the `CREATE TABLE` statements.

- `--databases`, `-B`

Dump several databases. Normally, `mysqldump` treats the first name argument on the command line as a database name and following names as table names. With this option, it treats all name arguments as

database names. `CREATE DATABASE` and `USE` statements are included in the output before each new database.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default value is `d:t:o,/tmp/mysqldump.trace`.

- `--debug-check`

  Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.14.

- `--default-character-set=charset_name`

  Use `charset_name` as the default character set. See Section 10.5, "Character Set Configuration". If no character set is specified, `mysqldump` uses `utf8`.

  Prior to MySQL 5.1.38, this option has no effect for output data files produced by using the `--tab` option. See the description for that option.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqldump` normally reads the `[client]` and `[mysqldump]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqldump` also reads the `[client_other]` and `[mysqldump_other]` groups.

- `--delayed-insert`

  Write `INSERT DELAYED` statements rather than `INSERT` statements.

- `--delete-master-logs`

  On a master replication server, delete the binary logs by sending a `PURGE BINARY LOGS` statement to the server after performing the dump operation. This option automatically enables `--master-data`.

- `--disable-keys`, `-K`

  For each table, surround the `INSERT` statements with `/*!40000 ALTER TABLE tbl_name DISABLE KEYS */;` and `/*!40000 ALTER TABLE tbl_name ENABLE KEYS */;` statements. This makes loading the dump file faster because the indexes are created after all rows are inserted. This option is effective only for nonunique indexes of `MyISAM` tables. It has no effect for other tables.

- `--dump-date`

If the `--comments` option is given, `mysqldump` produces a comment at the end of the dump of the following form:

```
-- Dump completed on DATE
```

However, the date causes dump files taken at different times to appear to be different, even if the data are otherwise identical. `--dump-date` and `--skip-dump-date` control whether the date is added to the comment. The default is `--dump-date` (include the date in the comment). `--skip-dump-date` suppresses date printing. This option was added in MySQL 5.1.23.

- `--events`, `-E`

Include Event Scheduler events for the dumped databases in the output. This option requires the `EVENT` privileges for those databases. This option was added in MySQL 5.1.8.

- `--extended-insert`, `-e`

Write `INSERT` statements using multiple-row syntax that includes several `VALUES` lists. This results in a smaller dump file and speeds up inserts when the file is reloaded.

- `--fields-terminated-by=...`, `--fields-enclosed-by=...`, `--fields-optionally-enclosed-by=...`, `--fields-escaped-by=...`

These options are used with the `--tab` option and have the same meaning as the corresponding `FIELDS` clauses for `LOAD DATA INFILE`. See Section 13.2.6, "LOAD DATA INFILE Syntax".

- `--first-slave`

Deprecated. Use `--lock-all-tables` instead. `--first-slave` is removed in MySQL 5.5.

- `--flush-logs`, `-F`

Flush the MySQL server log files before starting the dump. This option requires the `RELOAD` privilege. If you use this option in combination with the `--all-databases` option, the logs are flushed *for each database dumped*. The exception is when using `--lock-all-tables` or `--master-data`: In this case, the logs are flushed only once, corresponding to the moment that all tables are locked. If you want your dump and the log flush to happen at exactly the same moment, you should use `--flush-logs` together with either `--lock-all-tables` or `--master-data`.

- `--flush-privileges`

Add a `FLUSH PRIVILEGES` statement to the dump output after dumping the `mysql` database. This option should be used any time the dump contains the `mysql` database and any other database that depends on the data in the `mysql` database for proper restoration. This option was added in MySQL 5.1.12.

- `--force`, `-f`

Continue even if an SQL error occurs during a table dump.

One use for this option is to cause `mysqldump` to continue executing even when it encounters a view that has become invalid because the definition refers to a table that has been dropped. Without `--force`, `mysqldump` exits with an error message. With `--force`, `mysqldump` prints the error message, but it also writes an SQL comment containing the view definition to the dump output and continues executing.

- `--host=host_name`, `-h host_name`

  Dump data from the MySQL server on the given host. The default host is `localhost`.

- `--hex-blob`

  Dump binary columns using hexadecimal notation (for example, `'abc'` becomes `0x616263`). The affected data types are `BINARY`, `VARBINARY`, the `BLOB` types, and `BIT`.

- `--ignore-table=db_name.tbl_name`

  Do not dump the given table, which must be specified using both the database and table names. To ignore multiple tables, use this option multiple times. This option also can be used to ignore views.

- `--insert-ignore`

  Write `INSERT IGNORE` statements rather than `INSERT` statements.

- `--lines-terminated-by=...`

  This option is used with the `--tab` option and has the same meaning as the corresponding `LINES` clause for `LOAD DATA INFILE`. See Section 13.2.6, "LOAD DATA INFILE Syntax".

- `--lock-all-tables`, `-x`

  Lock all tables across all databases. This is achieved by acquiring a global read lock for the duration of the whole dump. This option automatically turns off `--single-transaction` and `--lock-tables`.

- `--lock-tables`, `-l`

  For each dumped database, lock all tables to be dumped before dumping them. The tables are locked with `READ LOCAL` to permit concurrent inserts in the case of `MyISAM` tables. For transactional tables such as `InnoDB`, `--single-transaction` is a much better option than `--lock-tables` because it does not need to lock the tables at all.

  Because `--lock-tables` locks tables for each database separately, this option does not guarantee that the tables in the dump file are logically consistent between databases. Tables in different databases may be dumped in completely different states.

- `--log-error=file_name`

  Log warnings and errors by appending them to the named file. The default is to do no logging. This option was added in MySQL 5.1.18.

- `--master-data[=value]`

  Use this option to dump a master replication server to produce a dump file that can be used to set up another server as a slave of the master. It causes the dump output to include a `CHANGE MASTER TO` statement that indicates the binary log coordinates (file name and position) of the dumped server. These are the master server coordinates from which the slave should start replicating after you load the dump file into the slave.

  If the option value is 2, the `CHANGE MASTER TO` statement is written as an SQL comment, and thus is informative only; it has no effect when the dump file is reloaded. If the option value is 1, the statement is not written as a comment and takes effect when the dump file is reloaded. If no option value is specified, the default value is 1.

  This option requires the `RELOAD` privilege and the binary log must be enabled.

The `--master-data` option automatically turns off `--lock-tables`. It also turns on `--lock-all-tables`, unless `--single-transaction` also is specified, in which case, a global read lock is acquired only for a short time at the beginning of the dump (see the description for `--single-transaction`). In all cases, any action on logs happens at the exact moment of the dump.

It is also possible to set up a slave by dumping an existing slave of the master. To do this, use the following procedure on the existing slave:

1. Stop the slave's SQL thread and get its current status:

   ```
   mysql> STOP SLAVE SQL_THREAD;
   mysql> SHOW SLAVE STATUS;
   ```

2. From the output of the `SHOW SLAVE STATUS` statement, the binary log coordinates of the master server from which the new slave should start replicating are the values of the `Relay_Master_Log_File` and `Exec_Master_Log_Pos` fields. Denote those values as `file_name` and `file_pos`.

3. Dump the slave server:

   ```
   shell> mysqldump --master-data=2 --all-databases > dumpfile
   ```

   Using `--master-data=2` works only if binary logging has been enabled on the slave. Otherwise, `mysqldump` fails with the error `Binlogging on server not active`. In this case you must handle any locking issues in another manner, using one or more of `--add-locks`, `--lock-tables`, `--lock-all-tables`, or `--single-transaction`, as required by your application and environment.

4. Restart the slave:

   ```
   mysql> START SLAVE;
   ```

5. On the new slave, load the dump file:

   ```
   shell> mysql < dumpfile
   ```

6. On the new slave, set the replication coordinates to those of the master server obtained earlier:

   ```
   mysql> CHANGE MASTER TO
       -> MASTER_LOG_FILE = 'file_name', MASTER_LOG_POS = file_pos;
   ```

   The `CHANGE MASTER TO` statement might also need other parameters, such as `MASTER_HOST` to point the slave to the correct master server host. Add any such parameters as necessary.

- `--no-autocommit`

Enclose the `INSERT` statements for each dumped table within `SET autocommit = 0` and `COMMIT` statements.

- `--no-create-db`, `-n`

Suppress the `CREATE DATABASE` statements that are otherwise included in the output if the `--databases` or `--all-databases` option is given.

- `--no-create-info`, `-t`

  Do not write `CREATE TABLE` statements that create each dumped table.

  > **Note**
  >
  > This option does *not* exclude statements creating log file groups or tablespaces from `mysqldump` output; in MySQL 5.1.14 and later, you can use the `--no-tablespaces` option for this purpose.

- `--no-data`, `-d`

  Do not write any table row information (that is, do not dump table contents). This is useful if you want to dump only the `CREATE TABLE` statement for the table (for example, to create an empty copy of the table by loading the dump file).

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--no-set-names`, `-N`

  This has the same effect as `--skip-set-charset`.

- `--no-tablespaces`, `-y`

  This option suppresses all `CREATE LOGFILE GROUP` and `CREATE TABLESPACE` statements in the output of `mysqldump`.

  This option was added in MySQL 5.1.14.

- `--opt`

  This option is shorthand. It is the same as specifying `--add-drop-table --add-locks --create-options --disable-keys --extended-insert --lock-tables --quick --set-charset`. It should give you a fast dump operation and produce a dump file that can be reloaded into a MySQL server quickly.

  The `--opt` option is enabled by default. Use `--skip-opt` to disable it. See the discussion at the beginning of this section for information about selectively enabling or disabling a subset of the options affected by `--opt`.

- `--order-by-primary`

  Dump each table's rows sorted by its primary key, or by its first unique index, if such an index exists. This is useful when dumping a `MyISAM` table to be loaded into an `InnoDB` table, but will make the dump operation take considerably longer.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the `password` value following the `--password` or `-p` option on the command line, `mysqldump` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--quick`, `-q`

  This option is useful for dumping large tables. It forces `mysqldump` to retrieve rows for a table from the server a row at a time rather than retrieving the entire row set and buffering it in memory before writing it out.

- `--quote-names`, `-Q`

  Quote identifiers (such as database, table, and column names) within "`` ` ``" characters. If the `ANSI_QUOTES` SQL mode is enabled, identifiers are quoted within """ characters. This option is enabled by default. It can be disabled with `--skip-quote-names`, but this option should be given after any option such as `--compatible` that may enable `--quote-names`.

- `--replace`

  Write `REPLACE` statements rather than `INSERT` statements. This option was added in MySQL 5.1.3.

- `--result-file=file_name`, `-r file_name`

  Direct output to the named file. The result file is created and its previous contents overwritten, even if an error occurs while generating the dump.

  This option should be used on Windows to prevent newline "`\n`" characters from being converted to "`\r\n`" carriage return/newline sequences.

- `--routines`, `-R`

  Include stored routines (procedures and functions) for the dumped databases in the output. This option requires the `SELECT` privilege for the `mysql.proc` table.

  The output generated by using `--routines` contains `CREATE PROCEDURE` and `CREATE FUNCTION` statements to create the routines. However, these statements do not include attributes such as the routine creation and modification timestamps, so when the routines are reloaded, they are created with timestamps equal to the reload time.

  If you require routines to be created with their original timestamp attributes, do not use `--routines`. Instead, dump and reload the contents of the `mysql.proc` table directly, using a MySQL account that has appropriate privileges for the `mysql` database.

This option was added in MySQL 5.1.2. Before that, stored routines are not dumped. Routine `DEFINER` values are not dumped until MySQL 5.1.8. This means that before 5.1.8, when routines are reloaded, they will be created with the definer set to the reloading user. If you require routines to be re-created with their original definer, dump and load the contents of the `mysql.proc` table directly as described earlier.

Prior to MySQL 5.1.62, this option had no effect when used together with the `--xml` option. (Bug #11760384, Bug #52792)

- `--set-charset`

Write `SET NAMES` *default_character_set* to the output. This option is enabled by default. To suppress the `SET NAMES` statement, use `--skip-set-charset`.

- `--shared-memory-base-name=`*name*

On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--single-transaction`

This option sets the transaction isolation mode to `REPEATABLE READ` and sends a `START TRANSACTION` SQL statement to the server before dumping data. It is useful only with transactional tables such as `InnoDB`, because then it dumps the consistent state of the database at the time when `START TRANSACTION` was issued without blocking any applications.

When using this option, you should keep in mind that only `InnoDB` tables are dumped in a consistent state. For example, any `MyISAM` or `MEMORY` tables dumped while using this option may still change state.

While a `--single-transaction` dump is in process, to ensure a valid dump file (correct table contents and binary log coordinates), no other connection should use the following statements: `ALTER TABLE`, `CREATE TABLE`, `DROP TABLE`, `RENAME TABLE`, `TRUNCATE TABLE`. A consistent read is not isolated from those statements, so use of them on a table to be dumped can cause the `SELECT` that is performed by `mysqldump` to retrieve the table contents to obtain incorrect contents or fail.

The `--single-transaction` option and the `--lock-tables` option are mutually exclusive because `LOCK TABLES` causes any pending transactions to be committed implicitly.

This option is not supported for MySQL Cluster tables; the results cannot be guaranteed to be consistent due to the fact that the `NDBCLUSTER` storage engine supports only the `READ_COMMITTED` transaction isolation level. You should always use `NDB` backup and restore instead.

To dump large tables, combine the `--single-transaction` option with the `--quick` option.

- `--skip-comments`

See the description for the `--comments` option.

- `--skip-opt`

See the description for the `--opt` option.

- `--socket=`*path*, `-S` *path*

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--tab=`*dir_name*, `-T` *dir_name*

Produce tab-separated text-format data files. For each dumped table, `mysqldump` creates a *tbl_name*`.sql` file that contains the `CREATE TABLE` statement that creates the table, and the server writes a *tbl_name*`.txt` file that contains its data. The option value is the directory in which to write the files.

> **Note**
>
> This option should be used only when `mysqldump` is run on the same machine as the `mysqld` server. Because the server creates files `*.txt` file in the directory that you specify, the directory must be writable by the server and the MySQL account that you use must have the `FILE` privilege. Because `mysqldump` creates `*.sql` in the same directory, it must be writable by your system login account.

By default, the `.txt` data files are formatted using tab characters between column values and a newline at the end of each line. The format can be specified explicitly using the `--fields-`*xxx* and `--lines-terminated-by` options.

As of MySQL 5.1.38, column values are converted to the character set specified by the `--default-character-set` option. Prior to 5.1.38 or if no such option is present, values are dumped using the `binary` character set. In effect, there is no character set conversion. If a table contains columns in several character sets, the output data file will as well and you may not be able to reload the file correctly.

- `--tables`

Override the `--databases` or `-B` option. `mysqldump` regards all name arguments following the option as table names.

- `--triggers`

Include triggers for each dumped table in the output. This option is enabled by default; disable it with `--skip-triggers`.

To be able to dump a table's triggers, you must have the `TRIGGER` privilege for the table.

- `--tz-utc`

This option enables `TIMESTAMP` columns to be dumped and reloaded between servers in different time zones. `mysqldump` sets its connection time zone to UTC and adds `SET TIME_ZONE='+00:00'` to the dump file. Without this option, `TIMESTAMP` columns are dumped and reloaded in the time zones local to the source and destination servers, which can cause the values to change if the servers are in different time zones. `--tz-utc` also protects against changes due to daylight saving time. `--tz-utc` is enabled by default. To disable it, use `--skip-tz-utc`. This option was added in MySQL 5.1.2.

- `--user=`*user_name*, `-u` *user_name*

The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

- `--where='`*`where_condition`*`'`, `-w '`*`where_condition`*`'`

  Dump only rows selected by the given `WHERE` condition. Quotes around the condition are mandatory if it contains spaces or other characters that are special to your command interpreter.

  Examples:

  ```
  --where="user='jimf'"
  -w"userid>1"
  -w"userid<1"
  ```

- `--xml`, `-X`

  Write dump output as well-formed XML.

  `NULL`, `'NULL'`, and Empty Values: For a column named *`column_name`*, the `NULL` value, an empty string, and the string value `'NULL'` are distinguished from one another in the output generated by this option as follows.

Value:	XML Representation:
`NULL` (*unknown value*)	`<field name="`*`column_name`*`" xsi:nil="true" />`
`''` (*empty string*)	`<field name="`*`column_name`*`"></field>`
`'NULL'` (*string value*)	`<field name="`*`column_name`*`">NULL</field>`

  Beginning with MySQL 5.1.12, the output from the `mysql` client when run using the `--xml` option also follows the preceding rules. (See Section 4.5.1.1, "mysql Options".)

  Beginning with MySQL 5.1.18, XML output from `mysqldump` includes the XML namespace, as shown here:

  ```
  shell> mysqldump --xml -u root world City
  <?xml version="1.0"?>
  <mysqldump xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <database name="world">
  <table_structure name="City">
  <field Field="ID" Type="int(11)" Null="NO" Key="PRI" Extra="auto_increment" />
  <field Field="Name" Type="char(35)" Null="NO" Key="" Default="" Extra="" />
  <field Field="CountryCode" Type="char(3)" Null="NO" Key="" Default="" Extra="" />
  <field Field="District" Type="char(20)" Null="NO" Key="" Default="" Extra="" />
  <field Field="Population" Type="int(11)" Null="NO" Key="" Default="0" Extra="" />
  <key Table="City" Non_unique="0" Key_name="PRIMARY" Seq_in_index="1" Column_name="ID"
  Collation="A" Cardinality="4079" Null="" Index_type="BTREE" Comment="" />
  <options Name="City" Engine="MyISAM" Version="10" Row_format="Fixed" Rows="4079"
  Avg_row_length="67" Data_length="273293" Max_data_length="18858823439613951"
  Index_length="43008" Data_free="0" Auto_increment="4080"
  Create_time="2007-03-31 01:47:01" Update_time="2007-03-31 01:47:02"
  Collation="latin1_swedish_ci" Create_options="" Comment="" />
  </table_structure>
  ```

```
<table_data name="City">
<row>
<field name="ID">1</field>
<field name="Name">Kabul</field>
<field name="CountryCode">AFG</field>
<field name="District">Kabol</field>
<field name="Population">1780000</field>
</row>

...

<row>
<field name="ID">4079</field>
<field name="Name">Rafah</field>
<field name="CountryCode">PSE</field>
<field name="District">Rafah</field>
<field name="Population">92020</field>
</row>
</table_data>
</database>
</mysqldump>
```

Prior to MySQL 5.1.62, this option prevented the `--routines` option from working correctly—that is, no stored routines, triggers, or events could be dumped in XML format. (Bug #11760384, Bug #52792)

You can also set the following variables by using `--var_name=value` syntax:

- `max_allowed_packet`

  The maximum size of the buffer for client/server communication. The default is 24MB, the maximum is 1GB.

- `net_buffer_length`

  The initial size of the buffer for client/server communication. When creating multiple-row `INSERT` statements (as with the `--extended-insert` or `--opt` option), `mysqldump` creates rows up to `net_buffer_length` bytes long. If you increase this variable, ensure that the MySQL server `net_buffer_length` system variable has a value at least this large.

A common use of `mysqldump` is for making a backup of an entire database:

```
shell> mysqldump db_name > backup-file.sql
```

You can load the dump file back into the server like this:

```
shell> mysql db_name < backup-file.sql
```

Or like this:

```
shell> mysql -e "source /path-to-backup/backup-file.sql" db_name
```

`mysqldump` is also very useful for populating databases by copying data from one MySQL server to another:

```
shell> mysqldump --opt db_name | mysql --host=remote_host -C db_name
```

It is possible to dump several databases with one command:

```
shell> mysqldump --databases db_name1 [db_name2 ...] > my_databases.sql
```

To dump all databases, use the `--all-databases` option:

```
shell> mysqldump --all-databases > all_databases.sql
```

For `InnoDB` tables, `mysqldump` provides a way of making an online backup:

```
shell> mysqldump --all-databases --master-data --single-transaction > all_databases.sql
```

This backup acquires a global read lock on all tables (using `FLUSH TABLES WITH READ LOCK`) at the beginning of the dump. As soon as this lock has been acquired, the binary log coordinates are read and the lock is released. If long updating statements are running when the `FLUSH` statement is issued, the MySQL server may get stalled until those statements finish. After that, the dump becomes lock free and does not disturb reads and writes on the tables. If the update statements that the MySQL server receives are short (in terms of execution time), the initial lock period should not be noticeable, even with many updates.

For point-in-time recovery (also known as "roll-forward," when you need to restore an old backup and replay the changes that happened since that backup), it is often useful to rotate the binary log (see Section 5.4.4, "The Binary Log") or at least know the binary log coordinates to which the dump corresponds:

```
shell> mysqldump --all-databases --master-data=2 > all_databases.sql
```

Or:

```
shell> mysqldump --all-databases --flush-logs --master-data=2
            > all_databases.sql
```

The `--master-data` and `--single-transaction` options can be used simultaneously, which provides a convenient way to make an online backup suitable for use prior to point-in-time recovery if tables are stored using the `InnoDB` storage engine.

For more information on making backups, see Section 7.2, "Database Backup Methods", and Section 7.3, "Example Backup and Recovery Strategy".

If you encounter problems backing up views, please read the section that covers restrictions on views which describes a workaround for backing up views when this fails due to insufficient privileges. See Section C.4, "Restrictions on Views".

4.5.5 `mysqlimport` — A Data Import Program

The `mysqlimport` client provides a command-line interface to the `LOAD DATA INFILE` SQL statement. Most options to `mysqlimport` correspond directly to clauses of `LOAD DATA INFILE` syntax. See Section 13.2.6, "LOAD DATA INFILE Syntax".

Invoke `mysqlimport` like this:

```
shell> mysqlimport [options] db_name textfile1 [textfile2 ...]
```

For each text file named on the command line, `mysqlimport` strips any extension from the file name and uses the result to determine the name of the table into which to import the file's contents. For example, files named `patient.txt`, `patient.text`, and `patient` all would be imported into a table named `patient`.

`mysqlimport` supports the following options, which can be specified on the command line or in the `[mysqlimport]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.9 `mysqlimport` Options

Format	Description	Introduced
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--columns	This option takes a comma-separated list of column names as its value	
--compress	Compress all information sent between client and server	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	5.1.21
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.14
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--delete	Empty the table before importing the text file	
--fields-enclosed-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-escaped-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-optionally-enclosed-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-terminated-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--ignore	See the description for the --replace option	
--ignore-lines	Ignore the first N lines of the data file	
--lines-terminated-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--local	Read input files locally from the client host	
--lock-tables	Lock all tables for writing before processing any text files	
--low-priority	Use LOW_PRIORITY when loading the table.	
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--port	TCP/IP port number to use for connection	

Format	Description	Introduced
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--replace	The --replace and --ignore options control handling of input rows that duplicate existing rows on unique key values	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--silent	Produce output only when errors occur	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11
--use-threads	Number of threads for parallel file-loading	5.1.7
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	

- `--help`, `-?`

  Display a help message and exit.

  The output generated by using `--events` contains `CREATE EVENT` statements to create the events. However, these statements do not include attributes such as the event creation and modification timestamps, so when the events are reloaded, they are created with timestamps equal to the reload time.

  If you require events to be created with their original timestamp attributes, do not use `--events`. Instead, dump and reload the contents of the `mysql.event` table directly, using a MySQL account that has appropriate privileges for the `mysql` database.

- `--bind-address=`*`ip_address`*

  On a computer having multiple network interfaces, this option can be used to select which interface is employed when connecting to the MySQL server.

  This option is supported only in the version of `mysqlimport` that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=`*`dir_name`*

  The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--columns=`*`column_list`*, `-c` *`column_list`*

This option takes a comma-separated list of column names as its value. The order of the column names indicates how to match data file columns with table columns.

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o`.

- `--debug-check`

  Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.14.

- `--default-character-set=charset_name`

  Use `charset_name` as the default character set. See Section 10.5, "Character Set Configuration".

  Some options, such as `--opt`, automatically enable `--lock-tables`. If you want to override this, use `--skip-lock-tables` at the end of the option list.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqlimport` normally reads the `[client]` and `[mysqlimport]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlimport` also reads the `[client_other]` and `[mysqlimport_other]` groups.

- `--delete`, `-D`

  Empty the table before importing the text file.

- `--fields-terminated-by=...`, `--fields-enclosed-by=...`, `--fields-optionally-enclosed-by=...`, `--fields-escaped-by=...`

  These options have the same meaning as the corresponding clauses for `LOAD DATA INFILE`. See Section 13.2.6, "LOAD DATA INFILE Syntax".

- `--force`, `-f`

  Ignore errors. For example, if a table for a text file does not exist, continue processing any remaining files. Without `--force`, `mysqlimport` exits if a table does not exist.

- `--host=`*`host_name`*, `-h` *`host_name`*

  Import data to the MySQL server on the given host. The default host is `localhost`.

- `--ignore`, `-i`

  See the description for the `--replace` option.

- `--ignore-lines=`*`N`*

  Ignore the first *`N`* lines of the data file.

- `--lines-terminated-by=...`

  This option has the same meaning as the corresponding clause for `LOAD DATA INFILE`. For example, to import Windows files that have lines terminated with carriage return/linefeed pairs, use `--lines-terminated-by="\r\n"`. (You might have to double the backslashes, depending on the escaping conventions of your command interpreter.) See Section 13.2.6, "LOAD DATA INFILE Syntax".

- `--local`, `-L`

  Read input files locally from the client host.

- `--lock-tables`, `-l`

  Lock *all* tables for writing before processing any text files. This ensures that all tables are synchronized on the server.

- `--low-priority`

  Use `LOW_PRIORITY` when loading the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=`*`password`*`]`, `-p[`*`password`*`]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlimport` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=`*`port_num`*, `-P` *`port_num`*

  The TCP/IP port number to use for the connection.

- `--print-defaults`

Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--replace`, `-r`

  The `--replace` and `--ignore` options control handling of input rows that duplicate existing rows on unique key values. If you specify `--replace`, new rows replace existing rows that have the same unique key value. If you specify `--ignore`, input rows that duplicate an existing row on a unique key value are skipped. If you do not specify either option, an error occurs when a duplicate key value is found, and the rest of the text file is ignored.

- `--shared-memory-base-name=`*name*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--silent`, `-s`

  Silent mode. Produce output only when errors occur.

- `--socket=`*path*, `-S` *path*

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--user=`*user_name*, `-u` *user_name*

  The MySQL user name to use when connecting to the server.

- `--use-threads=`*N*

  Load files in parallel using *N* threads. This option was added in MySQL 5.1.7.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

Here is a sample session that demonstrates use of `mysqlimport`:

```
shell> mysql -e 'CREATE TABLE imptest(id INT, n VARCHAR(30))' test
shell> ed
a
```

```
100      Max Sydow
101      Count Dracula
.
w imptest.txt
32
q
shell> od -c imptest.txt
0000000   1   0   0  \t   M   a   x       S   y   d   o   w  \n   1   0
0000020   1  \t   C   o   u   n   t       D   r   a   c   u   l   a  \n
0000040
shell> mysqlimport --local test imptest.txt
test.imptest: Records: 2  Deleted: 0  Skipped: 0  Warnings: 0
shell> mysql -e 'SELECT * FROM imptest' test
+------+--------------+
| id   | n            |
+------+--------------+
|  100 | Max Sydow    |
|  101 | Count Dracula |
+------+--------------+
```

4.5.6 `mysqlshow` — Display Database, Table, and Column Information

The `mysqlshow` client can be used to quickly see which databases exist, their tables, or a table's columns or indexes.

`mysqlshow` provides a command-line interface to several SQL `SHOW` statements. See Section 13.7.5, "SHOW Syntax". The same information can be obtained by using those statements directly. For example, you can issue them from the `mysql` client program.

Invoke `mysqlshow` like this:

```
shell> mysqlshow [options] [db_name [tbl_name [col_name]]]
```

- If no database is given, a list of database names is shown.

- If no table is given, all matching tables in the database are shown.

- If no column is given, all matching columns and column types in the table are shown.

The output displays only the names of those databases, tables, or columns for which you have some privileges.

If the last argument contains shell or SQL wildcard characters ("`*`", "`?`", "`%`", or "`_`"), only those names that are matched by the wildcard are shown. If a database name contains any underscores, those should be escaped with a backslash (some Unix shells require two) to get a list of the proper tables or columns. "`*`" and "`?`" characters are converted into SQL "`%`" and "`_`" wildcard characters. This might cause some confusion when you try to display the columns for a table with a "`_`" in the name, because in this case, `mysqlshow` shows you only the table names that match the pattern. This is easily fixed by adding an extra "`%`" last on the command line as a separate argument.

`mysqlshow` supports the following options, which can be specified on the command line or in the `[mysqlshow]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.10 `mysqlshow` Options

Format	Description	Introduced
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--compress	Compress all information sent between client and server	

Format	Description	Introduced
--count	Show the number of rows per table	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	5.1.21
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.14
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--keys	Show table indexes	
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--port	TCP/IP port number to use for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--show-table-type	Show a column indicating the table type	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11
--status	Display extra information about each table	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	

- `--help`, `-?`

  Display a help message and exit.

- `--bind-address=ip_address`

On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of `mysqlshow` that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=dir_name`

  The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--count`

  Show the number of rows per table. This can be slow for non-`MyISAM` tables.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o`.

- `--debug-check`

  Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.14.

- `--default-character-set=charset_name`

  Use `charset_name` as the default character set. See Section 10.5, "Character Set Configuration".

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqlshow` normally reads the `[client]` and `[mysqlshow]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlshow` also reads the `[client_other]` and `[mysqlshow_other]` groups.

- `--host=host_name`, `-h host_name`

  Connect to the MySQL server on the given host.

- `--keys`, `-k`

  Show table indexes.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *password* value following the `--password` or `-p` option on the command line, `mysqlshow` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--show-table-type`, `-t`

  Show a column indicating the table type, as in `SHOW FULL TABLES`. The type is `BASE TABLE` or `VIEW`.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--status`, `-i`

  Display extra information about each table.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- `--version`, `-V`

  Display version information and exit.

4.5.7 `mysqlslap` — Load Emulation Client

`mysqlslap` is a diagnostic program designed to emulate client load for a MySQL server and to report the timing of each stage. It works as if multiple clients are accessing the server. `mysqlslap` is available as of MySQL 5.1.4.

Invoke `mysqlslap` like this:

```
shell> mysqlslap [options]
```

Some options such as `--create` or `--query` enable you to specify a string containing an SQL statement or a file containing statements. If you specify a file, by default it must contain one statement per line. (That is, the implicit statement delimiter is the newline character.) Use the `--delimiter` option to specify a different delimiter, which enables you to specify statements that span multiple lines or place multiple statements on a single line. You cannot include comments in a file; `mysqlslap` does not understand them.

`mysqlslap` runs in three stages:

1. Create schema, table, and optionally any stored programs or data to use for the test. This stage uses a single client connection.

2. Run the load test. This stage can use many client connections.

3. Clean up (disconnect, drop table if specified). This stage uses a single client connection.

Examples:

Supply your own create and query SQL statements, with 50 clients querying and 200 selects for each (enter the command on a single line):

```
mysqlslap --delimiter=";"
  --create="CREATE TABLE a (b int);INSERT INTO a VALUES (23)"
  --query="SELECT * FROM a" --concurrency=50 --iterations=200
```

Let `mysqlslap` build the query SQL statement with a table of two `INT` columns and three `VARCHAR` columns. Use five clients querying 20 times each. Do not create the table or insert the data (that is, use the previous test's schema and data):

```
mysqlslap --concurrency=5 --iterations=20
  --number-int-cols=2 --number-char-cols=3
  --auto-generate-sql
```

Tell the program to load the create, insert, and query SQL statements from the specified files, where the `create.sql` file has multiple table creation statements delimited by `';'` and multiple insert

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statements delimited by `';'`. The `--query` file will have multiple queries delimited by `';'`. Run all the load statements, then run all the queries in the query file with five clients (five times each):

```
mysqlslap --concurrency=5
  --iterations=5 --query=query.sql --create=create.sql
  --delimiter=";"
```

`mysqlslap` supports the following options, which can be specified on the command line or in the `[mysqlslap]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.11 `mysqlslap` Options

Format	Description	Introduced	Removed
--auto-generate-sql	Generate SQL statements automatically when they are not supplied in files or using command options		
--auto-generate-sql-add-autoincrement	Add AUTO_INCREMENT column to automatically generated tables	5.1.18	
--auto-generate-sql-execute-number	Specify how many queries to generate automatically	5.1.18	
--auto-generate-sql-guid-primary	Add a GUID-based primary key to automatically generated tables	5.1.18	
--auto-generate-sql-load-type	Specify the test load type	5.1.16	
--auto-generate-sql-secondary-indexes	Specify how many secondary indexes to add to automatically generated tables	5.1.18	
--auto-generate-sql-unique-query-number	How many different queries to generate for automatic tests.	5.1.18	
--auto-generate-sql-unique-write-number	How many different queries to generate for --auto-generate-sql-write-number	5.1.18	
--auto-generate-sql-write-number	How many row inserts to perform on each thread	5.1.16	
--commit	How many statements to execute before committing.	5.1.21	
--compress	Compress all information sent between client and server		
--concurrency	Number of clients to simulate when issuing the SELECT statement		
--create	File or string containing the statement to use for creating the table		
--create-schema	Schema in which to run the tests	5.1.5	
--csv	Generate output in comma-separated values format		
--debug	Write debugging log		
--debug-check	Print debugging information when program exits	5.1.21	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.21	
--defaults-extra-file	Read named option file in addition to usual option files		

Format	Description	Introduced	Removed
--defaults-file	Read only named option file		
--defaults-group-suffix	Option group suffix value		
--delimiter	Delimiter to use in SQL statements		
--detach	Detach (close and reopen) each connection after each N statements	5.1.21	
--engine	Storage engine to use for creating the table		
--help	Display help message and exit		
--host	Connect to MySQL server on given host		
--iterations	Number of times to run the tests		
--lock-directory	Directory to use for storing locks	5.1.5	5.1.18
--no-defaults	Read no option files		
--no-drop	Do not drop any schema created during the test run	5.1.57	
--number-char-cols	Number of VARCHAR columns to use if --auto-generate-sql is specified		
--number-int-cols	Number of INT columns to use if --auto-generate-sql is specified		
--number-of-queries	Limit each client to approximately this number of queries	5.1.5	
--only-print	Do not connect to databases. mysqlslap only prints what it would have done	5.1.5	
--password	Password to use when connecting to server		
--pipe	On Windows, connect to server using named pipe		
--port	TCP/IP port number to use for connection		
--post-query	File or string containing the statement to execute after the tests have completed	5.1.18	
--post-system	String to execute using system() after the tests have completed	5.1.21	
--pre-query	File or string containing the statement to execute before running the tests	5.1.18	
--pre-system	String to execute using system() before running the tests	5.1.21	
--preserve-schema	Preserve the schema from the mysqlslap run	5.1.5	5.1.23
--print-defaults	Print default options		
--protocol	Connection protocol to use		
--query	File or string containing the SELECT statement to use for retrieving data		
--shared-memory-base-name	The name of shared memory to use for shared-memory connections		
--silent	Silent mode		
--slave	Follow master locks for other mysqlslap clients	5.1.5	5.1.18

Format	Description	Introduced	Removed
--socket	For connections to localhost, the Unix socket file to use		
--ssl	Enable secure connection		
--ssl-ca	Path of file that contains list of trusted SSL CAs		
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format		
--ssl-cert	Path of file that contains X509 certificate in PEM format		
--ssl-cipher	List of permitted ciphers to use for connection encryption		
--ssl-key	Path of file that contains X509 key in PEM format	5.1.11	
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server		
--use-threads	On Unix, the default is to use fork() calls	5.1.6	5.1.18
--user	MySQL user name to use when connecting to server		
--verbose	Verbose mode		
--version	Display version information and exit		

- `--help`, `-?`

  Display a help message and exit.

- `--auto-generate-sql`, `-a`

  Generate SQL statements automatically when they are not supplied in files or using command options.

- `--auto-generate-sql-add-autoincrement`

  Add an `AUTO_INCREMENT` column to automatically generated tables. This option was added in MySQL 5.1.18.

- `--auto-generate-sql-execute-number=N`

  Specify how many queries to generate automatically. This option was added in MySQL 5.1.18.

- `--auto-generate-sql-guid-primary`

  Add a GUID-based primary key to automatically generated tables. This option was added in MySQL 5.1.18.

- `--auto-generate-sql-load-type=type`

  Specify the test load type. The permissible values are `read` (scan tables), `write` (insert into tables), `key` (read primary keys), `update` (update primary keys), or `mixed` (half inserts, half scanning selects). The default is `mixed`. This option was added in MySQL 5.1.16.

- `--auto-generate-sql-secondary-indexes=N`

  Specify how many secondary indexes to add to automatically generated tables. By default, none are added. This option was added in MySQL 5.1.18.

- `--auto-generate-sql-unique-query-number=N`

  How many different queries to generate for automatic tests. For example, if you run a `key` test that performs 1000 selects, you can use this option with a value of 1000 to run 1000 unique queries, or with a value of 50 to perform 50 different selects. The default is 10. This option was added in MySQL 5.1.18.

- `--auto-generate-sql-unique-write-number=N`

  How many different queries to generate for `--auto-generate-sql-write-number`. The default is 10. This option was added in MySQL 5.1.18.

- `--auto-generate-sql-write-number=N`

  How many row inserts to perform on each thread. The default is 100. This option was added in MySQL 5.1.16.

- `--commit=N`

  How many statements to execute before committing. The default is 0 (no commits are done). This option was added in MySQL 5.1.21.

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--concurrency=N`, `-c N`

  The number of clients to simulate when issuing the `SELECT` statement.

- `--create=value`

  The file or string containing the statement to use for creating the table.

- `--create-schema=value`

  The schema in which to run the tests. This option was added in MySQL 5.1.5.

  > **Note**
  >
  > If the `--auto-generate-sql` option is also given, `mysqlslap` drops the schema at the end of the test run. To avoid this, use the `--no-drop` option as well.

- `--csv[=file_name]`

  Generate output in comma-separated values format. The output goes to the named file, or to the standard output if no file is given. This option was added in MySQL 5.1.5.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o,/tmp/mysqlslap.trace`.

- `--debug-check`

  Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`, `-T`

Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.21.

- `--defaults-extra-file=`*`file_name`*

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-file=`*`file_name`*

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-group-suffix=`*`str`*

Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqlslap` normally reads the `[client]` and `[mysqlslap]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlslap` also reads the `[client_other]` and `[mysqlslap_other]` groups.

- `--delimiter=`*`str`*, `-F` *`str`*

The delimiter to use in SQL statements supplied in files or using command options.

- `--detach=`*`N`*

Detach (close and reopen) each connection after each *`N`* statements. The default is 0 (connections are not detached). This option was added in MySQL 5.1.21.

- `--engine=`*`engine_name`*, `-e` *`engine_name`*

The storage engine to use for creating tables.

- `--host=`*`host_name`*, `-h` *`host_name`*

Connect to the MySQL server on the given host.

- `--iterations=`*`N`*, `-i` *`N`*

The number of times to run the tests.

- `--lock-directory=`*`dir_name`*

The directory to use for storing locks. This option was added in MySQL 5.1.5 and removed in 5.1.18.

- `--no-drop`

Prevent `mysqlslap` from dropping any schema it creates during the test run. This option was added in MySQL 5.1.57.

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--number-char-cols=`*`N`*, `-x` *`N`*

The number of `VARCHAR` columns to use if `--auto-generate-sql` is specified.

- `--number-int-cols=`*N*, `-y` *N*

  The number of `INT` columns to use if `--auto-generate-sql` is specified.

- `--number-of-queries=`*N*

  Limit each client to approximately this many queries. Query counting takes into account the statement delimiter. For example, if you invoke `mysqlslap` as follows, the `;` delimiter is recognized so that each instance of the query string counts as two queries. As a result, 5 rows (not 10) are inserted.

  ```
  shell> mysqlslap --delimiter=";" --number-of-queries=10
           --query="use test;insert into t values(null)"
  ```

  This option was added in MySQL 5.1.5.

- `--only-print`

  Do not connect to databases. `mysqlslap` only prints what it would have done. This option was added in MySQL 5.1.5.

- `--password[=`*password*`]`, `-p[`*password*`]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *password* value following the `--password` or `-p` option on the command line, `mysqlslap` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--port=`*port_num*, `-P` *port_num*

  The TCP/IP port number to use for the connection.

- `--post-query=`*value*

  The file or string containing the statement to execute after the tests have completed. This execution is not counted for timing purposes. This option was added in MySQL 5.1.18.

- `--post-system=`*str*

  The string to execute using `system()` after the tests have completed. This execution is not counted for timing purposes. This option was added in MySQL 5.1.21.

- `--pre-query=`*value*

  The file or string containing the statement to execute before running the tests. This execution is not counted for timing purposes. This option was added in MySQL 5.1.18.

- `--pre-system=`*str*

  The string to execute using `system()` before running the tests. This execution is not counted for timing purposes. This option was added in MySQL 5.1.21.

- `--preserve-schema`

  Preserve the schema from the `mysqlslap` run. The `--auto-generate-sql` and `--create` options disable this option. This option was added in MySQL 5.1.5 and removed in MySQL 5.1.23.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--query=value`, `-q value`

  The file or string containing the `SELECT` statement to use for retrieving data.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. This option applies only if the server supports shared-memory connections.

- `--silent`, `-s`

  Silent mode. No output.

- `--slave`

  Follow master locks for other `mysqlslap` clients. Use this option if you are trying to synchronize around one master server with `--lock-directory` plus NFS. This option was added in MySQL 5.1.5 and removed in 5.1.18.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--use-threads`

  On Unix, the default is to use `fork()` calls and this option causes `pthread` calls to be used instead. (On Windows, the default is to use `pthread` calls and the option has no effect.) This option was added in MySQL 5.1.6 and removed in 5.1.18.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- `--version`, `-V`

  Display version information and exit.

4.6 MySQL Administrative and Utility Programs

This section describes administrative programs and programs that perform miscellaneous utility operations.

4.6.1 `innochecksum` — Offline InnoDB File Checksum Utility

`innochecksum` prints checksums for `InnoDB` files. This tool reads an `InnoDB` tablespace file, calculates the checksum for each page, compares the calculated checksum to the stored checksum, and reports mismatches, which indicate damaged pages. It was originally developed to speed up verifying the integrity of tablespace files after power outages but can also be used after file copies. Because checksum mismatches will cause `InnoDB` to deliberately shut down a running server, it can be preferable to use this tool rather than waiting for a server in production usage to encounter the damaged pages.

`innochecksum` cannot be used on tablespace files that the server already has open. For such files, you should use `CHECK TABLE` to check tables within the tablespace.

If checksum mismatches are found, you would normally restore the tablespace from backup or start the server and attempt to use `mysqldump` to make a backup of the tables within the tablespace.

Invoke `innochecksum` like this:

```
shell> innochecksum [options] file_name
```

`innochecksum` supports the following options. For options that refer to page numbers, the numbers are zero-based.

- `-c`

  Print a count of the number of pages in the file.

- `-d`

  Debug mode; prints checksums for each page.

- `-e` *num*

  End at this page number.

- `-p` *num*

  Check only this page number.

- `-s` *num*

  Start at this page number.

- `-v`

  Verbose mode; print a progress indicator every five seconds.

4.6.2 `myisam_ftdump` — Display Full-Text Index information

myisam_ftdump displays information about FULLTEXT indexes in MyISAM tables. It reads the MyISAM index file directly, so it must be run on the server host where the table is located. Before using myisam_ftdump, be sure to issue a FLUSH TABLES statement first if the server is running.

myisam_ftdump scans and dumps the entire index, which is not particularly fast. On the other hand, the distribution of words changes infrequently, so it need not be run often.

Invoke myisam_ftdump like this:

```
shell> myisam_ftdump [options] tbl_name index_num
```

The tbl_name argument should be the name of a MyISAM table. You can also specify a table by naming its index file (the file with the .MYI suffix). If you do not invoke myisam_ftdump in the directory where the table files are located, the table or index file name must be preceded by the path name to the table's database directory. Index numbers begin with 0.

Example: Suppose that the test database contains a table named mytexttable that has the following definition:

```
CREATE TABLE mytexttable
(
  id    INT NOT NULL,
  txt   TEXT NOT NULL,
  PRIMARY KEY (id),
  FULLTEXT (txt)
) ENGINE=MyISAM;
```

The index on id is index 0 and the FULLTEXT index on txt is index 1. If your working directory is the test database directory, invoke myisam_ftdump as follows:

```
shell> myisam_ftdump mytexttable 1
```

If the path name to the test database directory is /usr/local/mysql/data/test, you can also specify the table name argument using that path name. This is useful if you do not invoke myisam_ftdump in the database directory:

```
shell> myisam_ftdump /usr/local/mysql/data/test/mytexttable 1
```

You can use myisam_ftdump to generate a list of index entries in order of frequency of occurrence like this:

```
shell> myisam_ftdump -c mytexttable 1 | sort -r
```

myisam_ftdump supports the following options:

- --help, -h -?

  Display a help message and exit.

- --count, -c

  Calculate per-word statistics (counts and global weights).

- --dump, -d

Dump the index, including data offsets and word weights.

- `--length`, `-l`

  Report the length distribution.

- `--stats`, `-s`

  Report global index statistics. This is the default operation if no other operation is specified.

- `--verbose`, `-v`

  Verbose mode. Print more output about what the program does.

4.6.3 `myisamchk` — MyISAM Table-Maintenance Utility

The `myisamchk` utility gets information about your database tables or checks, repairs, or optimizes them. `myisamchk` works with `MyISAM` tables (tables that have `.MYD` and `.MYI` files for storing data and indexes).

You can also use the `CHECK TABLE` and `REPAIR TABLE` statements to check and repair `MyISAM` tables. See Section 13.7.2.3, "CHECK TABLE Syntax", and Section 13.7.2.6, "REPAIR TABLE Syntax".

The use of `myisamchk` with partitioned tables is not supported.

> **Caution**
>
> It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors.

Invoke `myisamchk` like this:

```
shell> myisamchk [options] tbl_name ...
```

The `options` specify what you want `myisamchk` to do. They are described in the following sections. You can also get a list of options by invoking `myisamchk --help`.

With no options, `myisamchk` simply checks your table as the default operation. To get more information or to tell `myisamchk` to take corrective action, specify options as described in the following discussion.

`tbl_name` is the database table you want to check or repair. If you run `myisamchk` somewhere other than in the database directory, you must specify the path to the database directory, because `myisamchk` has no idea where the database is located. In fact, `myisamchk` does not actually care whether the files you are working on are located in a database directory. You can copy the files that correspond to a database table into some other location and perform recovery operations on them there.

You can name several tables on the `myisamchk` command line if you wish. You can also specify a table by naming its index file (the file with the `.MYI` suffix). This enables you to specify all tables in a directory by using the pattern `*.MYI`. For example, if you are in a database directory, you can check all the `MyISAM` tables in that directory like this:

```
shell> myisamchk *.MYI
```

If you are not in the database directory, you can check all the tables there by specifying the path to the directory:

```
shell> myisamchk /path/to/database_dir/*.MYI
```

You can even check all tables in all databases by specifying a wildcard with the path to the MySQL data directory:

```
shell> myisamchk /path/to/datadir/*/*.MYI
```

The recommended way to quickly check all `MyISAM` tables is:

```
shell> myisamchk --silent --fast /path/to/datadir/*/*.MYI
```

If you want to check all `MyISAM` tables and repair any that are corrupted, you can use the following command:

```
shell> myisamchk --silent --force --fast --update-state \
          --key_buffer_size=64M --myisam_sort_buffer_size=64M \
          --read_buffer_size=1M --write_buffer_size=1M \
          /path/to/datadir/*/*.MYI
```

This command assumes that you have more than 64MB free. For more information about memory allocation with `myisamchk`, see Section 4.6.3.6, "myisamchk Memory Usage".

For additional information about using `myisamchk`, see Section 7.6, "MyISAM Table Maintenance and Crash Recovery".

> **Important**
>
> *You must ensure that no other program is using the tables while you are running* `myisamchk`. The most effective means of doing so is to shut down the MySQL server while running `myisamchk`, or to lock all tables that `myisamchk` is being used on.
>
> Otherwise, when you run `myisamchk`, it may display the following error message:
>
> ```
> warning: clients are using or haven't closed the table properly
> ```
>
> This means that you are trying to check a table that has been updated by another program (such as the `mysqld` server) that hasn't yet closed the file or that has died without closing the file properly, which can sometimes lead to the corruption of one or more `MyISAM` tables.
>
> If `mysqld` is running, you must force it to flush any table modifications that are still buffered in memory by using `FLUSH TABLES`. You should then ensure that no one is using the tables while you are running `myisamchk`
>
> However, the easiest way to avoid this problem is to use `CHECK TABLE` instead of `myisamchk` to check tables. See Section 13.7.2.3, "CHECK TABLE Syntax".

`myisamchk` supports the following options, which can be specified on the command line or in the `[myisamchk]` group of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.12 `myisamchk` Options

Format	Description	Introduced	Deprecated
--analyze	Analyze the distribution of key values		
--backup	Make a backup of the .MYD file as file_name-time.BAK		
--block-search	Find the record that a block at the given offset belongs to		
--check	Check the table for errors		
--check-only-changed	Check only tables that have changed since the last check		
--correct-checksum	Correct the checksum information for the table		
--data-file-length	Maximum length of the data file (when re-creating data file when it is full)		
--debug	Write debugging log		
--decode_bits	Decode_bits		
--defaults-extra-file	Read named option file in addition to usual option files		
--defaults-file	Read only named option file		
--defaults-group-suffix	Option group suffix value		
--description	Print some descriptive information about the table		
--extend-check	Do very thorough table check or repair that tries to recover every possible row from the data file		
--fast	Check only tables that haven't been closed properly		
--force	Do a repair operation automatically if myisamchk finds any errors in the table		
--force	Overwrite old temporary files. For use with the -r or -o option		
--ft_max_word_len	Maximum word length for FULLTEXT indexes		
--ft_min_word_len	Minimum word length for FULLTEXT indexes		
--ft_stopword_file	Use stopwords from this file instead of built-in list		
--HELP	Display help message and exit		
--help	Display help message and exit		
--information	Print informational statistics about the table that is checked		
--key_buffer_size	Size of buffer used for index blocks for MyISAM tables		
--keys-used	A bit-value that indicates which indexes to update		
--max-record-length	Skip rows larger than the given length if myisamchk cannot allocate memory to hold them		
--medium-check	Do a check that is faster than an --extend-check operation		
--myisam_block_size	Block size to be used for MyISAM index pages		

Format	Description	Introduced	Deprecated
--myisam_sort_buffer_size	The buffer that is allocated when sorting the index when doing a REPAIR or when creating indexes with CREATE INDEX or ALTER TABLE	5.1.67	
--no-defaults	Read no option files		
--parallel-recover	Uses the same technique as -r and -n, but creates all the keys in parallel, using different threads (beta)		
--print-defaults	Print default options		
--quick	Achieve a faster repair by not modifying the data file.		
--read_buffer_size	Each thread that does a sequential scan allocates a buffer of this size for each table it scans		
--read-only	Do not mark the table as checked		
--recover	Do a repair that can fix almost any problem except unique keys that aren't unique		
--safe-recover	Do a repair using an old recovery method that reads through all rows in order and updates all index trees based on the rows found		
--set-auto-increment	Force AUTO_INCREMENT numbering for new records to start at the given value		
--set-collation	Specify the collation to use for sorting table indexes		
--silent	Silent mode		
--sort_buffer_size	The buffer that is allocated when sorting the index when doing a REPAIR or when creating indexes with CREATE INDEX or ALTER TABLE		5.1.67
--sort-index	Sort the index tree blocks in high-low order		
--sort_key_blocks	sort_key_blocks		
--sort-records	Sort records according to a particular index		
--sort-recover	Force myisamchk to use sorting to resolve the keys even if the temporary files would be very large		
--stats_method	Specifies how MyISAM index statistics collection code should treat NULLs		
--tmpdir	Path of the directory to be used for storing temporary files		
--unpack	Unpack a table that was packed with myisampack		
--update-state	Store information in the .MYI file to indicate when the table was checked and whether the table crashed		
--verbose	Verbose mode		
--version	Display version information and exit		
--write_buffer_size	Write buffer size		

4.6.3.1 myisamchk General Options

The options described in this section can be used for any type of table maintenance operation performed by `myisamchk`. The sections following this one describe options that pertain only to specific operations, such as table checking or repairing.

- `--help`, `-?`

  Display a help message and exit. Options are grouped by type of operation.

- `--HELP`, `-H`

  Display a help message and exit. Options are presented in a single list.

- `--debug=`*`debug_options`*, `-# `*`debug_options`*

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. The default is `d:t:o,/tmp/myisamchk.trace`.

- `--defaults-extra-file=`*`file_name`*

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-file=`*`file_name`*

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-group-suffix=`*`str`*

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `myisamchk` normally reads the `[myisamchk]` group. If the `--defaults-group-suffix=_other` option is given, `myisamchk` also reads the `[myisamchk_other]` group.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--silent`, `-s`

  Silent mode. Write output only when errors occur. You can use `-s` twice (`-ss`) to make `myisamchk` very silent.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does. This can be used with `-d` and `-e`. Use `-v` multiple times (`-vv`, `-vvv`) for even more output.

- `--version`, `-V`

  Display version information and exit.

- `--wait`, `-w`

  Instead of terminating with an error if the table is locked, wait until the table is unlocked before continuing. If you are running `mysqld` with external locking disabled, the table can be locked only by another `myisamchk` command.

You can also set the following variables by using `--`*`var_name`*`=`*`value`* syntax:

Variable	Default Value
`decode_bits`	9
`ft_max_word_len`	version-dependent
`ft_min_word_len`	4
`ft_stopword_file`	built-in list
`key_buffer_size`	523264
`myisam_block_size`	1024
`myisam_sort_key_blocks`	16
`read_buffer_size`	262136
`sort_buffer_size`	2097144
`sort_key_blocks`	16
`stats_method`	nulls_unequal
`write_buffer_size`	262136

The possible `myisamchk` variables and their default values can be examined with `myisamchk --help`:

`sort_buffer_size` is used when the keys are repaired by sorting keys, which is the normal case when you use `--recover`. As of MySQL 5.1.67, `myisam_sort_buffer_size` is available as an alternative name to `sort_buffer_size`. `myisam_sort_buffer_size` is preferable to `sort_buffer_size` because its name corresponds to the `myisam_sort_buffer_size` server system variable that has a similar meaning. `sort_buffer_size` should be considered deprecated.

`key_buffer_size` is used when you are checking the table with `--extend-check` or when the keys are repaired by inserting keys row by row into the table (like when doing normal inserts). Repairing through the key buffer is used in the following cases:

• You use `--safe-recover`.

• The temporary files needed to sort the keys would be more than twice as big as when creating the key file directly. This is often the case when you have large key values for `CHAR`, `VARCHAR`, or `TEXT` columns, because the sort operation needs to store the complete key values as it proceeds. If you have lots of temporary space and you can force `myisamchk` to repair by sorting, you can use the `--sort-recover` option.

Repairing through the key buffer takes much less disk space than using sorting, but is also much slower.

If you want a faster repair, set the `key_buffer_size` and `myisam_sort_buffer_size` variables to about 25% of your available memory. You can set both variables to large values, because only one of them is used at a time.

`myisam_block_size` is the size used for index blocks.

`stats_method` influences how `NULL` values are treated for index statistics collection when the `--analyze` option is given. It acts like the `myisam_stats_method` system variable. For more information, see the description of `myisam_stats_method` in Section 5.1.4, "Server System Variables", and Section 8.3.7, "InnoDB and MyISAM Index Statistics Collection".

`ft_min_word_len` and `ft_max_word_len` indicate the minimum and maximum word length for `FULLTEXT` indexes. `ft_stopword_file` names the stopword file. These need to be set under the following circumstances.

If you use `myisamchk` to perform an operation that modifies table indexes (such as repair or analyze), the `FULLTEXT` indexes are rebuilt using the default full-text parameter values for minimum and maximum word length and the stopword file unless you specify otherwise. This can result in queries failing.

The problem occurs because these parameters are known only by the server. They are not stored in `MyISAM` index files. To avoid the problem if you have modified the minimum or maximum word length or the stopword file in the server, specify the same `ft_min_word_len`, `ft_max_word_len`, and `ft_stopword_file` values to `myisamchk` that you use for `mysqld`. For example, if you have set the minimum word length to 3, you can repair a table with `myisamchk` like this:

```
shell> myisamchk --recover --ft_min_word_len=3 tbl_name.MYI
```

To ensure that `myisamchk` and the server use the same values for full-text parameters, you can place each one in both the `[mysqld]` and `[myisamchk]` sections of an option file:

```
[mysqld]
ft_min_word_len=3

[myisamchk]
ft_min_word_len=3
```

An alternative to using `myisamchk` is to use the `REPAIR TABLE`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, or `ALTER TABLE`. These statements are performed by the server, which knows the proper full-text parameter values to use.

4.6.3.2 myisamchk Check Options

`myisamchk` supports the following options for table checking operations:

- `--check`, `-c`

  Check the table for errors. This is the default operation if you specify no option that selects an operation type explicitly.

- `--check-only-changed`, `-C`

  Check only tables that have changed since the last check.

- `--extend-check`, `-e`

  Check the table very thoroughly. This is quite slow if the table has many indexes. This option should only be used in extreme cases. Normally, `myisamchk` or `myisamchk --medium-check` should be able to determine whether there are any errors in the table.

  If you are using `--extend-check` and have plenty of memory, setting the `key_buffer_size` variable to a large value helps the repair operation run faster.

  See also the description of this option under table repair options.

  For a description of the output format, see Section 4.6.3.5, "Obtaining Table Information with myisamchk".

- `--fast`, `-F`

  Check only tables that haven't been closed properly.

- `--force`, `-f`

Do a repair operation automatically if `myisamchk` finds any errors in the table. The repair type is the same as that specified with the `--recover` or `-r` option.

- `--information`, `-i`

Print informational statistics about the table that is checked.

- `--medium-check`, `-m`

Do a check that is faster than an `--extend-check` operation. This finds only 99.99% of all errors, which should be good enough in most cases.

- `--read-only`, `-T`

Do not mark the table as checked. This is useful if you use `myisamchk` to check a table that is in use by some other application that does not use locking, such as `mysqld` when run with external locking disabled.

- `--update-state`, `-U`

Store information in the `.MYI` file to indicate when the table was checked and whether the table crashed. This should be used to get full benefit of the `--check-only-changed` option, but you shouldn't use this option if the `mysqld` server is using the table and you are running it with external locking disabled.

4.6.3.3 myisamchk Repair Options

`myisamchk` supports the following options for table repair operations (operations performed when an option such as `--recover` or `--safe-recover` is given):

- `--backup`, `-B`

Make a backup of the `.MYD` file as `file_name-time.BAK`

- `--character-sets-dir=`*dir_name*

The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--correct-checksum`

Correct the checksum information for the table.

- `--data-file-length=`*len*, `-D` *len*

The maximum length of the data file (when re-creating data file when it is "full").

- `--extend-check`, `-e`

Do a repair that tries to recover every possible row from the data file. Normally, this also finds a lot of garbage rows. Do not use this option unless you are desperate.

See also the description of this option under table checking options.

For a description of the output format, see Section 4.6.3.5, "Obtaining Table Information with myisamchk".

- `--force`, `-f`

Overwrite old intermediate files (files with names like `tbl_name.TMD`) instead of aborting.

- `--keys-used=val`, `-k val`

  For `myisamchk`, the option value is a bit-value that indicates which indexes to update. Each binary bit of the option value corresponds to a table index, where the first index is bit 0. An option value of 0 disables updates to all indexes, which can be used to get faster inserts. Deactivated indexes can be reactivated by using `myisamchk -r`.

- `--no-symlinks`, `-l`

  Do not follow symbolic links. Normally `myisamchk` repairs the table that a symlink points to. This option does not exist as of MySQL 4.0 because versions from 4.0 on do not remove symlinks during repair operations.

- `--max-record-length=len`

  Skip rows larger than the given length if `myisamchk` cannot allocate memory to hold them.

- `--parallel-recover`, `-p`

  Use the same technique as `-r` and `-n`, but create all the keys in parallel, using different threads. *This is beta-quality code. Use at your own risk!*

- `--quick`, `-q`

  Achieve a faster repair by modifying only the index file, not the data file. You can specify this option twice to force `myisamchk` to modify the original data file in case of duplicate keys.

- `--recover`, `-r`

  Do a repair that can fix almost any problem except unique keys that are not unique (which is an extremely unlikely error with `MyISAM` tables). If you want to recover a table, this is the option to try first. You should try `--safe-recover` only if `myisamchk` reports that the table cannot be recovered using `--recover`. (In the unlikely case that `--recover` fails, the data file remains intact.)

  If you have lots of memory, you should increase the value of `myisam_sort_buffer_size`.

- `--safe-recover`, `-o`

  Do a repair using an old recovery method that reads through all rows in order and updates all index trees based on the rows found. This is an order of magnitude slower than `--recover`, but can handle a couple of very unlikely cases that `--recover` cannot. This recovery method also uses much less disk space than `--recover`. Normally, you should repair first using `--recover`, and then with `--safe-recover` only if `--recover` fails.

  If you have lots of memory, you should increase the value of `key_buffer_size`.

- `--set-collation=name`

  Specify the collation to use for sorting table indexes. The character set name is implied by the first part of the collation name.

- `--sort-recover`, `-n`

  Force `myisamchk` to use sorting to resolve the keys even if the temporary files would be very large.

- `--tmpdir=dir_name`, `-t dir_name`

  The path of the directory to be used for storing temporary files. If this is not set, `myisamchk` uses the value of the `TMPDIR` environment variable. `--tmpdir` can be set to a list of directory paths that are

used successively in round-robin fashion for creating temporary files. The separator character between directory names is the colon ("`:`") on Unix and the semicolon ("`;`") on Windows, NetWare, and OS/2.

- `--unpack`, `-u`

Unpack a table that was packed with `myisampack`.

4.6.3.4 Other myisamchk Options

`myisamchk` supports the following options for actions other than table checks and repairs:

- `--analyze`, `-a`

Analyze the distribution of key values. This improves join performance by enabling the join optimizer to better choose the order in which to join the tables and which indexes it should use. To obtain information about the key distribution, use a `myisamchk --description --verbose` *`tbl_name`* command or the `SHOW INDEX FROM` *`tbl_name`* statement.

- `--block-search=`*`offset`*, `-b` *`offset`*

Find the record that a block at the given offset belongs to.

- `--description`, `-d`

Print some descriptive information about the table. Specifying the `--verbose` option once or twice produces additional information. See Section 4.6.3.5, "Obtaining Table Information with myisamchk".

- `--set-auto-increment[=`*`value`*`]`, `-A[`*`value`*`]`

Force `AUTO_INCREMENT` numbering for new records to start at the given value (or higher, if there are existing records with `AUTO_INCREMENT` values this large). If *`value`* is not specified, `AUTO_INCREMENT` numbers for new records begin with the largest value currently in the table, plus one.

- `--sort-index`, `-S`

Sort the index tree blocks in high-low order. This optimizes seeks and makes table scans that use indexes faster.

- `--sort-records=`*`N`*, `-R` *`N`*

Sort records according to a particular index. This makes your data much more localized and may speed up range-based `SELECT` and `ORDER BY` operations that use this index. (The first time you use this option to sort a table, it may be very slow.) To determine a table's index numbers, use `SHOW INDEX`, which displays a table's indexes in the same order that `myisamchk` sees them. Indexes are numbered beginning with 1.

If keys are not packed (`PACK_KEYS=0`), they have the same length, so when `myisamchk` sorts and moves records, it just overwrites record offsets in the index. If keys are packed (`PACK_KEYS=1`), `myisamchk` must unpack key blocks first, then re-create indexes and pack the key blocks again. (In this case, re-creating indexes is faster than updating offsets for each index.)

4.6.3.5 Obtaining Table Information with myisamchk

To obtain a description of a `MyISAM` table or statistics about it, use the commands shown here. The output from these commands is explained later in this section.

- `myisamchk -d` *`tbl_name`*

Runs `myisamchk` in "describe mode" to produce a description of your table. If you start the MySQL server with external locking disabled, `myisamchk` may report an error for a table that is updated while it runs. However, because `myisamchk` does not change the table in describe mode, there is no risk of destroying data.

- `myisamchk -dv tbl_name`

  Adding `-v` runs `myisamchk` in verbose mode so that it produces more information about the table. Adding `-v` a second time produces even more information.

- `myisamchk -eis tbl_name`

  Shows only the most important information from a table. This operation is slow because it must read the entire table.

- `myisamchk -eiv tbl_name`

  This is like `-eis`, but tells you what is being done.

The `tbl_name` argument can be either the name of a `MyISAM` table or the name of its index file, as described in Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility". Multiple `tbl_name` arguments can be given.

Suppose that a table named `person` has the following structure. (The `MAX_ROWS` table option is included so that in the example output from `myisamchk` shown later, some values are smaller and fit the output format more easily.)

```
CREATE TABLE person
(
  id         INT NOT NULL AUTO_INCREMENT,
  last_name  VARCHAR(20) NOT NULL,
  first_name VARCHAR(20) NOT NULL,
  birth      DATE,
  death      DATE,
  PRIMARY KEY (id),
  INDEX (last_name, first_name),
  INDEX (birth)
) MAX_ROWS = 1000000;
```

Suppose also that the table has these data and index file sizes:

```
-rw-rw----  1 mysql  mysql  9347072 Aug 19 11:47 person.MYD
-rw-rw----  1 mysql  mysql  6066176 Aug 19 11:47 person.MYI
```

Example of `myisamchk -dvv` output:

```
MyISAM file:          person
Record format:        Packed
Character set:        latin1_swedish_ci (8)
File-version:         1
Creation time:        2009-08-19 16:47:41
Recover time:         2009-08-19 16:47:56
Status:               checked,analyzed,optimized keys
Auto increment key:             1  Last value:                306688
Data records:              306688  Deleted blocks:                 0
Datafile parts:            306688  Deleted data:                   0
Datafile pointer (bytes):       4  Keyfile pointer (bytes):        3
```

```
Datafile length:            9347072  Keyfile length:            6066176
Max datafile length:     4294967294  Max keyfile length:    17179868159
Recordlength:                    54

table description:
Key Start Len Index    Type                  Rec/key          Root  Blocksize
1    2     4   unique   long                        1         99328       1024
2    6    20   multip.  varchar prefix            512       3563520       1024
     27   20            varchar                   512
3    48    3   multip.  uint24 NULL            306688       6065152       1024


Field Start Length Nullpos Nullbit Type
1     1     1
2     2     4                       no zeros
3     6    21                       varchar
4    27    21                       varchar
5    48     3     1       1         no zeros
6    51     3     1       2         no zeros
```

Explanations for the types of information `myisamchk` produces are given here. "Keyfile" refers to the index file. "Record" and "row" are synonymous, as are "field" and "column."

The initial part of the table description contains these values:

- `MyISAM file`

  Name of the `MyISAM` (index) file.

- `Record format`

  The format used to store table rows. The preceding examples use `Fixed length`. Other possible values are `Compressed` and `Packed`. (`Packed` corresponds to what `SHOW TABLE STATUS` reports as `Dynamic`.)

- `Chararacter set`

  The table default character set.

- `File-version`

  Version of `MyISAM` format. Always 1.

- `Creation time`

  When the data file was created.

- `Recover time`

  When the index/data file was last reconstructed.

- `Status`

  Table status flags. Possible values are `crashed`, `open`, `changed`, `analyzed`, `optimized keys`, and `sorted index pages`.

- `Auto increment key`, `Last value`

  The key number associated the table's `AUTO_INCREMENT` column, and the most recently generated value for this column. These fields do not appear if there is no such column.

- `Data records`

The number of rows in the table.

- `Deleted blocks`

  How many deleted blocks still have reserved space. You can optimize your table to minimize this space. See Section 7.6.4, "MyISAM Table Optimization".

- `Datafile parts`

  For dynamic-row format, this indicates how many data blocks there are. For an optimized table without fragmented rows, this is the same as `Data records`.

- `Deleted data`

  How many bytes of unreclaimed deleted data there are. You can optimize your table to minimize this space. See Section 7.6.4, "MyISAM Table Optimization".

- `Datafile pointer`

  The size of the data file pointer, in bytes. It is usually 2, 3, 4, or 5 bytes. Most tables manage with 2 bytes, but this cannot be controlled from MySQL yet. For fixed tables, this is a row address. For dynamic tables, this is a byte address.

- `Keyfile pointer`

  The size of the index file pointer, in bytes. It is usually 1, 2, or 3 bytes. Most tables manage with 2 bytes, but this is calculated automatically by MySQL. It is always a block address.

- `Max datafile length`

  How long the table data file can become, in bytes.

- `Max keyfile length`

  How long the table index file can become, in bytes.

- `Recordlength`

  How much space each row takes, in bytes.

The `table description` part of the output includes a list of all keys in the table. For each key, `myisamchk` displays some low-level information:

- `Key`

  This key's number. This value is shown only for the first column of the key. If this value is missing, the line corresponds to the second or later column of a multiple-column key. For the table shown in the example, there are two `table description` lines for the second index. This indicates that it is a multiple-part index with two parts.

- `Start`

  Where in the row this portion of the index starts.

- `Len`

  How long this portion of the index is. For packed numbers, this should always be the full length of the column. For strings, it may be shorter than the full length of the indexed column, because you can index

a prefix of a string column. The total length of a multiple-part key is the sum of the `Len` values for all key parts.

- `Index`

  Whether a key value can exist multiple times in the index. Possible values are `unique` or `multip.` (multiple).

- `Type`

  What data type this portion of the index has. This is a `MyISAM` data type with the possible values `packed`, `stripped`, or `empty`.

- `Root`

  Address of the root index block.

- `Blocksize`

  The size of each index block. By default this is 1024, but the value may be changed at compile time when MySQL is built from source.

- `Rec/key`

  This is a statistical value used by the optimizer. It tells how many rows there are per value for this index. A unique index always has a value of 1. This may be updated after a table is loaded (or greatly changed) with `myisamchk -a`. If this is not updated at all, a default value of 30 is given.

The last part of the output provides information about each column:

- `Field`

  The column number.

- `Start`

  The byte position of the column within table rows.

- `Length`

  The length of the column in bytes.

- `Nullpos`, `Nullbit`

  For columns that can be `NULL`, `MyISAM` stores `NULL` values as a flag in a byte. Depending on how many nullable columns there are, there can be one or more bytes used for this purpose. The `Nullpos` and `Nullbit` values, if nonempty, indicate which byte and bit contains that flag indicating whether the column is `NULL`.

  The position and number of bytes used to store `NULL` flags is shown in the line for field 1. This is why there are six `Field` lines for the `person` table even though it has only five columns.

- `Type`

  The data type. The value may contain any of the following descriptors:

  - `constant`

    All rows have the same value.

- `no endspace`

  Do not store endspace.

- `no endspace, not_always`

  Do not store endspace and do not do endspace compression for all values.

- `no endspace, no empty`

  Do not store endspace. Do not store empty values.

- `table-lookup`

  The column was converted to an `ENUM`.

- `zerofill(N)`

  The most significant N bytes in the value are always 0 and are not stored.

- `no zeros`

  Do not store zeros.

- `always zero`

  Zero values are stored using one bit.

- `Huff tree`

  The number of the Huffman tree associated with the column.

- `Bits`

  The number of bits used in the Huffman tree.

The `Huff tree` and `Bits` fields are displayed if the table has been compressed with `myisampack`. See Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables", for an example of this information.

Example of `myisamchk -eiv` output:

```
Checking MyISAM file: person
Data records:  306688   Deleted blocks:        0
- check file-size
- check record delete-chain
No recordlinks
- check key delete-chain
block_size 1024:
- check index reference
- check data record references index: 1
Key:  1:  Keyblocks used: 98%  Packed:    0%  Max levels:  3
- check data record references index: 2
Key:  2:  Keyblocks used: 99%  Packed:   97%  Max levels:  3
- check data record references index: 3
Key:  3:  Keyblocks used: 98%  Packed:  -14%  Max levels:  3
Total:    Keyblocks used: 98%  Packed:   89%

- check records and index references
```

```
*** LOTS OF ROW NUMBERS DELETED ***

Records:             306688  M.recordlength:        25  Packed:             83%
Recordspace used:       97% Empty space:           2% Blocks/Record:   1.00
Record blocks:       306688  Delete blocks:         0
Record data:        7934464  Deleted data:          0
Lost space:          256512  Linkdata:        1156096

User time 43.08, System time 1.68
Maximum resident set size 0, Integral resident set size 0
Non-physical pagefaults 0, Physical pagefaults 0, Swaps 0
Blocks in 0 out 7, Messages in 0 out 0, Signals 0
Voluntary context switches 0, Involuntary context switches 0
Maximum memory usage: 1046926 bytes (1023k)
```

`myisamchk -eiv` output includes the following information:

- `Data records`

  The number of rows in the table.

- `Deleted blocks`

  How many deleted blocks still have reserved space. You can optimize your table to minimize this space. See Section 7.6.4, "MyISAM Table Optimization".

- `Key`

  The key number.

- `Keyblocks used`

  What percentage of the keyblocks are used. When a table has just been reorganized with `myisamchk`, the values are very high (very near theoretical maximum).

- `Packed`

  MySQL tries to pack key values that have a common suffix. This can only be used for indexes on `CHAR` and `VARCHAR` columns. For long indexed strings that have similar leftmost parts, this can significantly reduce the space used. In the preceding example, the second key is 40 bytes long and a 97% reduction in space is achieved.

- `Max levels`

  How deep the B-tree for this key is. Large tables with long key values get high values.

- `Records`

  How many rows are in the table.

- `M.recordlength`

  The average row length. This is the exact row length for tables with fixed-length rows, because all rows have the same length.

- `Packed`

  MySQL strips spaces from the end of strings. The `Packed` value indicates the percentage of savings achieved by doing this.

- `Recordspace used`

What percentage of the data file is used.

- `Empty space`

  What percentage of the data file is unused.

- `Blocks/Record`

  Average number of blocks per row (that is, how many links a fragmented row is composed of). This is always 1.0 for fixed-format tables. This value should stay as close to 1.0 as possible. If it gets too large, you can reorganize the table. See Section 7.6.4, "MyISAM Table Optimization".

- `Recordblocks`

  How many blocks (links) are used. For fixed-format tables, this is the same as the number of rows.

- `Deleteblocks`

  How many blocks (links) are deleted.

- `Recorddata`

  How many bytes in the data file are used.

- `Deleted data`

  How many bytes in the data file are deleted (unused).

- `Lost space`

  If a row is updated to a shorter length, some space is lost. This is the sum of all such losses, in bytes.

- `Linkdata`

  When the dynamic table format is used, row fragments are linked with pointers (4 to 7 bytes each). `Linkdata` is the sum of the amount of storage used by all such pointers.

4.6.3.6 myisamchk Memory Usage

Memory allocation is important when you run `myisamchk`. `myisamchk` uses no more memory than its memory-related variables are set to. If you are going to use `myisamchk` on very large tables, you should first decide how much memory you want it to use. The default is to use only about 3MB to perform repairs. By using larger values, you can get `myisamchk` to operate faster. For example, if you have more than 512MB RAM available, you could use options such as these (in addition to any other options you might specify):

```
shell> myisamchk --myisam_sort_buffer_size=256M \
          --key_buffer_size=512M \
          --read_buffer_size=64M \
          --write_buffer_size=64M ...
```

Using `--myisam_sort_buffer_size=16M` is probably enough for most cases.

Be aware that `myisamchk` uses temporary files in `TMPDIR`. If `TMPDIR` points to a memory file system, out of memory errors can easily occur. If this happens, run `myisamchk` with the `--tmpdir=dir_name` option to specify a directory located on a file system that has more space.

When performing repair operations, `myisamchk` also needs a lot of disk space:

- Twice the size of the data file (the original file and a copy). This space is not needed if you do a repair with `--quick`; in this case, only the index file is re-created. *This space must be available on the same file system as the original data file*, as the copy is created in the same directory as the original.

- Space for the new index file that replaces the old one. The old index file is truncated at the start of the repair operation, so you usually ignore this space. This space must be available on the same file system as the original data file.

- When using `--recover` or `--sort-recover` (but not when using `--safe-recover`), you need space on disk for sorting. This space is allocated in the temporary directory (specified by `TMPDIR` or `--tmpdir=dir_name`). The following formula yields the amount of space required:

  ```
  (largest_key + row_pointer_length) * number_of_rows * 2
  ```

  You can check the length of the keys and the `row_pointer_length` with `myisamchk -dv tbl_name` (see Section 4.6.3.5, "Obtaining Table Information with myisamchk"). The `row_pointer_length` and `number_of_rows` values are the `Datafile pointer` and `Data records` values in the table description. To determine the `largest_key` value, check the `Key` lines in the table description. The `Len` column indicates the number of bytes for each key part. For a multiple-column index, the key size is the sum of the `Len` values for all key parts.

If you have a problem with disk space during repair, you can try `--safe-recover` instead of `--recover`.

4.6.4 `myisamlog` — Display MyISAM Log File Contents

`myisamlog` processes the contents of a `MyISAM` log file. To create such a file, start the server with a `--log-isam=log_file` option.

Invoke `myisamlog` like this:

```
shell> myisamlog [options] [file_name [tbl_name] ...]
```

The default operation is update (`-u`). If a recovery is done (`-r`), all writes and possibly updates and deletes are done and errors are only counted. The default log file name is `myisam.log` if no `log_file` argument is given. If tables are named on the command line, only those tables are updated.

`myisamlog` supports the following options:

- `-?`, `-I`

  Display a help message and exit.

- `-c N`

  Execute only `N` commands.

- `-f N`

  Specify the maximum number of open files.

- `-i`

  Display extra information before exiting.

- `-o offset`

  Specify the starting offset.

- `-p N`

  Remove `N` components from path.

- `-r`

  Perform a recovery operation.

- `-R record_pos_file record_pos`

  Specify record position file and record position.

- `-u`

  Perform an update operation.

- `-v`

  Verbose mode. Print more output about what the program does. This option can be given multiple times to produce more and more output.

- `-w write_file`

  Specify the write file.

- `-V`

  Display version information.

4.6.5 `myisampack` — Generate Compressed, Read-Only MyISAM Tables

The `myisampack` utility compresses `MyISAM` tables. `myisampack` works by compressing each column in the table separately. Usually, `myisampack` packs the data file 40% to 70%.

When the table is used later, the server reads into memory the information needed to decompress columns. This results in much better performance when accessing individual rows, because you only have to uncompress exactly one row.

MySQL uses `mmap()` when possible to perform memory mapping on compressed tables. If `mmap()` does not work, MySQL falls back to normal read/write file operations.

Please note the following:

- If the `mysqld` server was invoked with external locking disabled, it is not a good idea to invoke `myisampack` if the table might be updated by the server during the packing process. It is safest to compress tables with the server stopped.

- After packing a table, it becomes read only. This is generally intended (such as when accessing packed tables on a CD).

- `myisampack` does not support partitioned tables.

Invoke `myisampack` like this:

```
shell> myisampack [options] file_name ...
```

Each file name argument should be the name of an index (`.MYI`) file. If you are not in the database directory, you should specify the path name to the file. It is permissible to omit the `.MYI` extension.

After you compress a table with `myisampack`, use `myisamchk -rq` to rebuild its indexes. Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility".

`myisampack` supports the following options. It also reads option files and supports the options for processing them described at Section 4.2.7, "Command-Line Options that Affect Option-File Handling".

- `--help`, `-?`

  Display a help message and exit.

- `--backup`, `-b`

  Make a backup of each table's data file using the name *tbl_name*`.OLD`.

- `--character-sets-dir=`*dir_name*

  The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--debug[=`*debug_options*`]`, `-# [`*debug_options*`]`

  Write a debugging log. A typical *debug_options* string is `d:t:o,`*file_name*. The default is `d:t:o`.

- `--force`, `-f`

  Produce a packed table even if it becomes larger than the original or if the intermediate file from an earlier invocation of `myisampack` exists. (`myisampack` creates an intermediate file named *tbl_name*`.TMD` in the database directory while it compresses the table. If you kill `myisampack`, the `.TMD` file might not be deleted.) Normally, `myisampack` exits with an error if it finds that *tbl_name*`.TMD` exists. With `--force`, `myisampack` packs the table anyway.

- `--join=`*big_tbl_name*, `-j `*big_tbl_name*

  Join all tables named on the command line into a single packed table *big_tbl_name*. All tables that are to be combined *must* have identical structure (same column names and types, same indexes, and so forth).

  big_tbl_name must not exist prior to the join operation. All source tables named on the command line to be merged into *big_tbl_name* must exist. The source tables are read for the join operation but not modified. The join operation does not create a `.frm` file for *big_tbl_name*, so after the join operation finishes, copy the `.frm` file from one of the source tables and name it *big_tbl_name*`.frm`.

- `--silent`, `-s`

  Silent mode. Write output only when errors occur.

- `--test`, `-t`

  Do not actually pack the table, just test packing it.

- `--tmpdir=`*dir_name*, `-T `*dir_name*

  Use the named directory as the location where `myisampack` creates temporary files.

- `--verbose`, `-v`

  Verbose mode. Write information about the progress of the packing operation and its result.

- `--version`, `-V`

  Display version information and exit.

- `--wait`, `-w`

  Wait and retry if the table is in use. If the `mysqld` server was invoked with external locking disabled, it is not a good idea to invoke `myisampack` if the table might be updated by the server during the packing process.

The following sequence of commands illustrates a typical table compression session:

```
shell> ls -l station.*
-rw-rw-r--   1 monty    my          994128 Apr 17 19:00 station.MYD
-rw-rw-r--   1 monty    my           53248 Apr 17 19:00 station.MYI
-rw-rw-r--   1 monty    my            5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station

MyISAM file:     station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time:  1997-02-02  3:06:43
Data records:              1192  Deleted blocks:           0
Datafile parts:            1192  Deleted data:             0
Datafile pointer (bytes):     2  Keyfile pointer (bytes):    2
Max datafile length:   54657023  Max keyfile length:   33554431
Recordlength:              834
Record format: Fixed length

table description:
Key Start Len Index    Type               Root  Blocksize    Rec/key
1    2      4   unique  unsigned long      1024      1024            1
2    32     30  multip. text              10240      1024            1

Field Start Length Type
1     1      1
2     2      4
3     6      4
4     10     1
5     11     20
6     31     1
7     32     30
8     62     35
9     97     35
10    132    35
11    167    4
12    171    16
13    187    35
14    222    4
15    226    16
16    242    20
17    262    20
18    282    20
19    302    30
20    332    4
21    336    4
22    340    1
23    341    8
24    349    8
25    357    8
26    365    2
27    367    2
28    369    4
29    373    4
30    377    1
31    378    2
32    380    8
```

```
33   388   4
34   392   4
35   396   4
36   400   4
37   404   1
38   405   4
39   409   4
40   413   4
41   417   4
42   421   4
43   425   4
44   429   20
45   449   30
46   479   1
47   480   1
48   481   79
49   560   79
50   639   79
51   718   79
52   797   8
53   805   1
54   806   1
55   807   20
56   827   4
57   831   4

shell> myisampack station.MYI
Compressing station.MYI: (1192 records)
- Calculating statistics


normal:    20  empty-space:   16  empty-zero:     12  empty-fill:  11
pre-space:  0  end-space:     12  table-lookups:   5  zero:         7
Original trees: 57  After join: 17
- Compressing file
87.14%
Remember to run myisamchk -rq on compressed tables

shell> myisamchk -rq station
- check record delete-chain
- recovering (with sort) MyISAM-table 'station'
Data records: 1192
- Fixing index 1
- Fixing index 2

shell> mysqladmin -uroot flush-tables

shell> ls -l station.*
-rw-rw-r--  1 monty    my         127874 Apr 17 19:00 station.MYD
-rw-rw-r--  1 monty    my          55296 Apr 17 19:04 station.MYI
-rw-rw-r--  1 monty    my           5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station

MyISAM file:     station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time:  1997-04-17 19:04:26
Data records:               1192  Deleted blocks:             0
Datafile parts:             1192  Deleted data:               0
Datafile pointer (bytes):      3  Keyfile pointer (bytes):    1
Max datafile length:    16777215  Max keyfile length:    131071
Recordlength:                834
Record format: Compressed


table description:
Key Start Len Index    Type                Root  Blocksize    Rec/key
1   2     4   unique   unsigned long       10240      1024          1
```

```
2   32    30  multip. text                      54272        1024          1

Field Start Length Type                          Huff tree  Bits
1     1     1      constant                           1       0
2     2     4      zerofill(1)                        2       9
3     6     4      no zeros, zerofill(1)              2       9
4     10    1                                         3       9
5     11    20     table-lookup                       4       0
6     31    1                                         3       9
7     32    30     no endspace, not_always            5       9
8     62    35     no endspace, not_always, no empty  6       9
9     97    35     no empty                           7       9
10    132   35     no endspace, not_always, no empty  6       9
11    167   4      zerofill(1)                        2       9
12    171   16     no endspace, not_always, no empty  5       9
13    187   35     no endspace, not_always, no empty  6       9
14    222   4      zerofill(1)                        2       9
15    226   16     no endspace, not_always, no empty  5       9
16    242   20     no endspace, not_always            8       9
17    262   20     no endspace, no empty              8       9
18    282   20     no endspace, no empty              5       9
19    302   30     no endspace, no empty              6       9
20    332   4      always zero                        2       9
21    336   4      always zero                        2       9
22    340   1                                         3       9
23    341   8      table-lookup                       9       0
24    349   8      table-lookup                      10       0
25    357   8      always zero                        2       9
26    365   2                                         2       9
27    367   2      no zeros, zerofill(1)              2       9
28    369   4      no zeros, zerofill(1)              2       9
29    373   4      table-lookup                      11       0
30    377   1                                         3       9
31    378   2      no zeros, zerofill(1)              2       9
32    380   8      no zeros                           2       9
33    388   4      always zero                        2       9
34    392   4      table-lookup                      12       0
35    396   4      no zeros, zerofill(1)             13       9
36    400   4      no zeros, zerofill(1)              2       9
37    404   1                                         2       9
38    405   4      no zeros                           2       9
39    409   4      always zero                        2       9
40    413   4      no zeros                           2       9
41    417   4      always zero                        2       9
42    421   4      no zeros                           2       9
43    425   4      always zero                        2       9
44    429   20     no empty                           3       9
45    449   30     no empty                           3       9
46    479   1                                        14       4
47    480   1                                        14       4
48    481   79     no endspace, no empty             15       9
49    560   79     no empty                           2       9
50    639   79     no empty                           2       9
51    718   79     no endspace                       16       9
52    797   8      no empty                           2       9
53    805   1                                        17       1
54    806   1                                         3       9
55    807   20     no empty                           3       9
56    827   4      no zeros, zerofill(2)              2       9
57    831   4      no zeros, zerofill(1)              2       9
```

myisampack displays the following kinds of information:

- normal

  The number of columns for which no extra packing is used.

- empty-space

  The number of columns containing values that are only spaces. These occupy one bit.

- empty-zero

  The number of columns containing values that are only binary zeros. These occupy one bit.

- empty-fill

  The number of integer columns that do not occupy the full byte range of their type. These are changed to a smaller type. For example, a `BIGINT` column (eight bytes) can be stored as a `TINYINT` column (one byte) if all its values are in the range from `-128` to `127`.

- pre-space

  The number of decimal columns that are stored with leading spaces. In this case, each value contains a count for the number of leading spaces.

- end-space

  The number of columns that have a lot of trailing spaces. In this case, each value contains a count for the number of trailing spaces.

- table-lookup

  The column had only a small number of different values, which were converted to an `ENUM` before Huffman compression.

- zero

  The number of columns for which all values are zero.

- Original trees

  The initial number of Huffman trees.

- After join

  The number of distinct Huffman trees left after joining trees to save some header space.

After a table has been compressed, the `Field` lines displayed by `myisamchk -dvv` include additional information about each column:

- Type

  The data type. The value may contain any of the following descriptors:

  - constant

    All rows have the same value.

  - no endspace

    Do not store endspace.

  - no endspace, not_always

    Do not store endspace and do not do endspace compression for all values.

- `no endspace, no empty`

  Do not store endspace. Do not store empty values.

- `table-lookup`

  The column was converted to an `ENUM`.

- `zerofill(N)`

  The most significant N bytes in the value are always 0 and are not stored.

- `no zeros`

  Do not store zeros.

- `always zero`

  Zero values are stored using one bit.

- `Huff tree`

  The number of the Huffman tree associated with the column.

- `Bits`

  The number of bits used in the Huffman tree.

After you run `myisampack`, use `myisamchk` to re-create any indexes. At this time, you can also sort the index blocks and create statistics needed for the MySQL optimizer to work more efficiently:

```
shell> myisamchk -rq --sort-index --analyze tbl_name.MYI
```

After you have installed the packed table into the MySQL database directory, you should execute `mysqladmin flush-tables` to force `mysqld` to start using the new table.

To unpack a packed table, use the `--unpack` option to `myisamchk`.

4.6.6 `mysqlaccess` — Client for Checking Access Privileges

`mysqlaccess` is a diagnostic tool that Yves Carlier has provided for the MySQL distribution. It checks the access privileges for a host name, user name, and database combination. Note that `mysqlaccess` checks access using only the `user`, `db`, and `host` tables. It does not check table, column, or routine privileges specified in the `tables_priv`, `columns_priv`, or `procs_priv` tables.

Invoke `mysqlaccess` like this:

```
shell> mysqlaccess [host_name [user_name [db_name]]] [options]
```

`mysqlaccess` supports the following options.

Table 4.13 `mysqlaccess` Options

Format	Description
--brief	Generate reports in single-line tabular format

Format	Description
--commit	Copy the new access privileges from the temporary tables to the original grant tables
--copy	Reload the temporary grant tables from original ones
--db	Specify the database name
--debug	Specify the debug level
--help	Display help message and exit
--host	Connect to MySQL server on given host
--howto	Display some examples that show how to use mysqlaccess
--old_server	Assume that the server is an old MySQL server (prior to MySQL 3.21)
--password	Password to use when connecting to server
--plan	Display suggestions and ideas for future releases
--preview	Show the privilege differences after making changes to the temporary grant tables
--relnotes	Display release notes
--rhost	Connect to MySQL server on given host
--rollback	Undo the most recent changes to the temporary grant tables.
--spassword	Password to use when connecting to server as the superuser
--superuser	Specify the user name for connecting as the superuser
--table	Generate reports in table format
--user	MySQL user name to use when connecting to server
--version	Display version information and exit

- `--help`, `-?`

  Display a help message and exit.

- `--brief`, `-b`

  Generate reports in single-line tabular format.

- `--commit`

  Copy the new access privileges from the temporary tables to the original grant tables. The grant tables must be flushed for the new privileges to take effect. (For example, execute a `mysqladmin reload` command.)

- `--copy`

  Reload the temporary grant tables from original ones.

- `--db=db_name`, `-d db_name`

  Specify the database name.

- `--debug=N`

  Specify the debug level. `N` can be an integer from 0 to 3.

- `--host=host_name`, `-h host_name`

  The host name to use in the access privileges.

- `--howto`

  Display some examples that show how to use `mysqlaccess`.

- `--old_server`

  Assume that the server is an old MySQL server (before MySQL 3.21) that does not yet know how to handle full `WHERE` clauses.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you omit the `password` value following the `--password` or `-p` option on the command line, `mysqlaccess` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security".

- `--plan`

  Display suggestions and ideas for future releases.

- `--preview`

  Show the privilege differences after making changes to the temporary grant tables.

- `--relnotes`

  Display the release notes.

- `--rhost=host_name`, `-H host_name`

  Connect to the MySQL server on the given host.

- `--rollback`

  Undo the most recent changes to the temporary grant tables.

- `--spassword[=password]`, `-P[password]`

  The password to use when connecting to the server as the superuser. If you omit the `password` value following the `--spassword` or `-p` option on the command line, `mysqlaccess` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security".

- `--superuser=user_name`, `-U user_name`

  Specify the user name for connecting as the superuser.

- `--table`, `-t`

  Generate reports in table format.

- `--user=user_name`, `-u user_name`

  The user name to use in the access privileges.

- `--version`, `-v`

  Display version information and exit.

If your MySQL distribution is installed in some nonstandard location, you must change the location where `mysqlaccess` expects to find the `mysql` client. Edit the `mysqlaccess` script at approximately line 18. Search for a line that looks like this:

```
$MYSQL     = '/usr/local/bin/mysql';    # path to mysql executable
```

Change the path to reflect the location where `mysql` actually is stored on your system. If you do not do this, a `Broken pipe` error will occur when you run `mysqlaccess`.

4.6.7 `mysqlbinlog` — Utility for Processing Binary Log Files

The server's binary log consists of files containing "events" that describe modifications to database contents. The server writes these files in binary format. To display their contents in text format, use the `mysqlbinlog` utility. You can also use `mysqlbinlog` to display the contents of relay log files written by a slave server in a replication setup because relay logs have the same format as binary logs. The binary log and relay log are discussed further in Section 5.4.4, "The Binary Log", and Section 16.2.2, "Replication Relay and Status Logs".

Invoke `mysqlbinlog` like this:

```
shell> mysqlbinlog [options] log_file ...
```

For example, to display the contents of the binary log file named `binlog.000003`, use this command:

```
shell> mysqlbinlog binlog.0000003
```

The output includes events contained in `binlog.000003`. For statement-based logging, event information includes the SQL statement, the ID of the server on which it was executed, the timestamp when the statement was executed, how much time it took, and so forth. For row-based logging, the event indicates a row change rather than an SQL statement. See Section 16.1.2, "Replication Formats", for information about logging modes.

Events are preceded by header comments that provide additional information. For example:

```
# at 141
#100309  9:28:36 server id 123  end_log_pos 245
  Query thread_id=3350  exec_time=11  error_code=0
```

In the first line, the number following `at` indicates the file offset, or starting position, of the event in the binary log file.

The second line starts with a date and time indicating when the statement started on the server where the event originated. For replication, this timestamp is propagated to slave servers. `server id` is the `server_id` value of the server where the event originated. `end_log_pos` indicates where the next event starts (that is, it is the end position of the current event + 1). `thread_id` indicates which thread executed the event. `exec_time` is the time spent executing the event, on a master server. On a slave, it is the difference of the end execution time on the slave minus the beginning execution time on the master. The difference serves as an indicator of how much replication lags behind the master. `error_code` indicates the result from executing the event. Zero means that no error occurred.

Note

When using event groups, the file offsets of events may be grouped together and the comments of events may be grouped together. Do not mistake these grouped events for blank file offsets.

The output from `mysqlbinlog` can be re-executed (for example, by using it as input to `mysql`) to redo the statements in the log. This is useful for recovery operations after a server crash. For other usage examples, see the discussion later in this section and in Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log".

Normally, you use `mysqlbinlog` to read binary log files directly and apply them to the local MySQL server. It is also possible to read binary logs from a remote server by using the `--read-from-remote-server` option. To read remote binary logs, the connection parameter options can be given to indicate how to connect to the server. These options are `--host`, `--password`, `--port`, `--protocol`, `--socket`, and `--user`; they are ignored except when you also use the `--read-from-remote-server` option.

When running `mysqlbinlog` against a large binary log, be careful that the filesystem has enough space for the resulting files. To configure the directory that `mysqlbinlog` uses for temporary files, use the `TMPDIR` environment variable.

`mysqlbinlog` supports the following options, which can be specified on the command line or in the `[mysqlbinlog]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.14 `mysqlbinlog` Options

Format	Description	Introduced
--base64-output	Print binary log entries using base-64 encoding	5.1.5
--bind-address	Use specified network interface to connect to MySQL Server	5.1.22-ndb-6.3.4
--character-sets-dir	Directory where character sets are installed	
--database	List entries for just this database	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	5.1.21
--debug-info	Print debugging information, memory, and CPU statistics when program exits	5.1.21
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--disable-log-bin	Disable binary logging	
--force-if-open	Read binary log files even if open or not closed properly	5.1.15
--force-read	If mysqlbinlog reads a binary log event that it does not recognize, it prints a warning	
--help	Display help message and exit	
--hexdump	Display a hex dump of the log in comments	5.1.2
--host	Connect to MySQL server on given host	
--local-load	Prepare local temporary files for LOAD DATA INFILE in the specified directory	

Format	Description	Introduced
--no-defaults	Read no option files	
--offset	Skip the first N entries in the log	
--password	Password to use when connecting to server	
--port	TCP/IP port number to use for connection	
--position	Deprecated. Use --start-position	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--read-from-remote-server	Read binary log from MySQL server rather than local log file	
--result-file	Direct output to named file	
--server-id	Extract only those events created by the server having the given server ID	5.1.4
--server-id-bits	Tell mysqlbinlog how to interpret server IDs in binary log when log was written by a mysqld having its server-id-bits set to less than the maximum; supported only by MySQL Cluster version of mysqlbinlog	5.1.47-ndb-7.1.6
--set-charset	Add a SET NAMES charset_name statement to the output	5.1.12
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	5.1.41
--short-form	Display only the statements contained in the log	
--socket	For connections to localhost, the Unix socket file to use	
--start-datetime	Read binary log from first event with timestamp equal to or later than datetime argument	
--start-position	Read binary log from first event with position equal to or greater than argument	
--stop-datetime	Stop reading binary log at first event with timestamp equal to or greater than datetime argument	
--stop-position	Stop reading binary log at first event with position equal to or greater than argument	
--to-last-log	Do not stop at the end of requested binary log from a MySQL server, but rather continue printing to end of last binary log	
--user	MySQL user name to use when connecting to server	
--verbose	Reconstruct row events as SQL statements	5.1.28
--version	Display version information and exit	

- `--help`, `-?`

  Display a help message and exit.

- `--base64-output[=value]`

  This option determines when events should be displayed encoded as base-64 strings using `BINLOG` statements. The option has these permissible values (not case sensitive):

- `AUTO` ("automatic") or `UNSPEC` ("unspecified") displays `BINLOG` statements automatically when necessary (that is, for format description events and row events). If no `--base64-output` option is given, the effect is the same as `--base64-output=AUTO`.

  > **Note**
  >
  > Automatic `BINLOG` display is the only safe behavior if you intend to use the output of `mysqlbinlog` to re-execute binary log file contents. The other option values are intended only for debugging or testing purposes because they may produce output that does not include all events in executable form.

- `ALWAYS` displays `BINLOG` statements whenever possible. If the `--base64-output` option is given without a value, the effect is the same as `--base64-output=ALWAYS`.

- `NEVER` causes `BINLOG` statements not to be displayed. `mysqlbinlog` exits with an error if a row event is found that must be displayed using `BINLOG`.

- `DECODE-ROWS` specifies to `mysqlbinlog` that you intend for row events to be decoded and displayed as commented SQL statements by also specifying the `--verbose` option. Like `NEVER`, `DECODE-ROWS` suppresses display of `BINLOG` statements, but unlike `NEVER`, it does not exit with an error if a row event is found.

The `--base64-output` option was introduced in MySQL 5.1.5, to be given as `--base64-output` or `--skip-base64-output` (with the sense of `AUTO` or `NEVER`). The option values described in the preceding list may be used as of MySQL 5.1.24, with the exception of `UNSPEC` and `DECODE-ROWS`, which are available as of MySQL 5.1.28.

For examples that show the effect of `--base64-output` and `--verbose` on row event output, see Section 4.6.7.2, "mysqlbinlog Row Event Display".

- `--bind-address=ip_address`

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of `mysqlbinlog` that is supplied with MySQL Cluster, beginning with MySQL Cluster NDB 6.3.4. It is not available in standard MySQL 5.1 releases.

- `--character-sets-dir=dir_name`

  The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--database=db_name`, `-d db_name`

  This option causes `mysqlbinlog` to output entries from the binary log (local log only) that occur while *db_name* is been selected as the default database by `USE`.

  The `--database` option for `mysqlbinlog` is similar to the `--binlog-do-db` option for `mysqld`, but can be used to specify only one database. If `--database` is given multiple times, only the last instance is used.

  The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--binlog-do-db` depend on whether statement-based or row-based logging is in use.

  Statement-based logging. The `--database` option works as follows:

- While *db_name* is the default database, statements are output whether they modify tables in *db_name* or a different database.

- Unless *db_name* is selected as the default database, statements are not output, even if they modify tables in *db_name*.

- There is an exception for `CREATE DATABASE`, `ALTER DATABASE`, and `DROP DATABASE`. The database being *created, altered, or dropped* is considered to be the default database when determining whether to output the statement.

Suppose that the binary log was created by executing these statements using statement-based-logging:

```
INSERT INTO test.t1 (i) VALUES(100);
INSERT INTO db2.t2 (j)  VALUES(200);
USE test;
INSERT INTO test.t1 (i) VALUES(101);
INSERT INTO t1 (i)      VALUES(102);
INSERT INTO db2.t2 (j)  VALUES(201);
USE db2;
INSERT INTO test.t1 (i) VALUES(103);
INSERT INTO db2.t2 (j)  VALUES(202);
INSERT INTO t2 (j)      VALUES(203);
```

`mysqlbinlog --database=test` does not output the first two `INSERT` statements because there is no default database. It outputs the three `INSERT` statements following `USE test`, but not the three `INSERT` statements following `USE db2`.

`mysqlbinlog --database=db2` does not output the first two `INSERT` statements because there is no default database. It does not output the three `INSERT` statements following `USE test`, but does output the three `INSERT` statements following `USE db2`.

Row-based logging.   `mysqlbinlog` outputs only entries that change tables belonging to *db_name*. The default database has no effect on this. Suppose that the binary log just described was created using row-based logging rather than statement-based logging. `mysqlbinlog --database=test` outputs only those entries that modify `t1` in the test database, regardless of whether `USE` was issued or what the default database is.

If a server is running with `binlog_format` set to `MIXED` and you want it to be possible to use `mysqlbinlog` with the `--database` option, you must ensure that tables that are modified are in the database selected by `USE`. (In particular, no cross-database updates should be used.)

This option did not work correctly for `mysqlbinlog` with row-based logging prior to MySQL 5.1.37. (Bug #42941)

> **Note**
>
> Prior to MySQL Cluster NDB 7.0.28 and MySQL Cluster NDB 7.1.17, this option did not work correctly with MySQL Cluster tables unless, unless the binary log was generated using `--log-bin-use-v1-row-events=0`. (Bug #13067813)

- `--debug[=debug_options]`, `-# [debug_options]`

Write a debugging log. A typical *debug_options* string is `d:t:o,file_name`. The default is `d:t:o,/tmp/mysqlbinlog.trace`.

- `--debug-check`

Print some debugging information when the program exits. This option was added in MySQL 5.1.21.

- `--debug-info`

Print debugging information and memory and CPU usage statistics when the program exits. This option was added in MySQL 5.1.21.

- `--defaults-extra-file=`*`file_name`*

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-file=`*`file_name`*

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is the full path name to the file.

- `--defaults-group-suffix=`*`str`*

Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqlbinlog` normally reads the `[client]` and `[mysqlbinlog]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlbinlog` also reads the `[client_other]` and `[mysqlbinlog_other]` groups.

- `--disable-log-bin`, `-D`

Disable binary logging. This is useful for avoiding an endless loop if you use the `--to-last-log` option and are sending the output to the same MySQL server. This option also is useful when restoring after a crash to avoid duplication of the statements you have logged.

This option requires that you have the `SUPER` privilege. It causes `mysqlbinlog` to include a `SET sql_log_bin = 0` statement in its output to disable binary logging of the remaining output. The `SET` statement is ineffective unless you have the `SUPER` privilege.

- `--force-if-open`, `-F`

Read binary log files even if they are open or were not closed properly. This option was added in MySQL 5.1.15.

- `--force-read`, `-f`

With this option, if `mysqlbinlog` reads a binary log event that it does not recognize, it prints a warning, ignores the event, and continues. Without this option, `mysqlbinlog` stops if it reads such an event.

- `--hexdump`, `-H`

Display a hex dump of the log in comments, as described in Section 4.6.7.1, "mysqlbinlog Hex Dump Format". The hex output can be helpful for replication debugging. This option was added in MySQL 5.1.2.

- `--host=`*`host_name`*, `-h` *`host_name`*

Get the binary log from the MySQL server on the given host.

- `--local-load=`*`dir_name`*, `-l` *`dir_name`*

Prepare local temporary files for `LOAD DATA INFILE` in the specified directory.

> **Important**
>
> These temporary files are not automatically removed by `mysqlbinlog` or any
> other MySQL program.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file,
  `--no-defaults` can be used to prevent them from being read.

- `--offset=`*N*, `-o` *N*

  Skip the first *N* entries in the log.

- `--password[=`*password*`]`, `-p[`*password*`]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot*
  have a space between the option and the password. If you omit the *password* value following the `--password` or `-p` option on the command line, `mysqlbinlog` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--port=`*port_num*, `-P` *port_num*

  The TCP/IP port number to use for connecting to a remote server.

- `--position=`*N*

  Deprecated. Use `--start-position` instead. `--position` is removed in MySQL 5.5.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection
  parameters normally would cause a protocol to be used other than the one you want. For details on the
  permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--read-from-remote-server`, `-R`

  Read the binary log from a MySQL server rather than reading a local log file. Any connection parameter
  options are ignored unless this option is given as well. These options are `--host`, `--password`, `--port`, `--protocol`, `--socket`, and `--user`.

  This option requires that the remote server be running. It works only for binary log files on the remote
  server, not relay log files.

- `--result-file=`*name*, `-r` *name*

  Direct output to the given file.

- `--server-id=`*id*

Display only those events created by the server having the given server ID. This option is available as of MySQL 5.1.4.

- `--server-id-bits=`*N*

Use only the first *N* bits of the `server_id` to identify the server. If the binary log was written by a `mysqld` with server-id-bits set to less than 32 and user data stored in the most significant bit, running `mysqlbinlog` with `--server-id-bits` set to 32 enables this data to be seen.

This option was added in MySQL Cluster NDB 7.0.17 and MySQL Cluster NDB 7.1.6, and is supported only by the versions of `mysqlbinlog` supplied with these and later releases of MySQL Cluster.

- `--set-charset=`*charset_name*

Add a `SET NAMES `*charset_name* statement to the output to specify the character set to be used for processing log files. This option was added in MySQL 5.1.12.

- `--shared-memory-base-name=`*name*

On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

The server must be started with the `--shared-memory` option to enable shared-memory connections.

This option was added in MySQL 5.1.41.

- `--short-form`, `-s`

Display only the statements contained in the log, without any extra information or row-based events. This is for testing only, and should not be used in production systems.

- `--socket=`*path*, `-S `*path*

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--start-datetime=`*datetime*

Start reading the binary log at the first event having a timestamp equal to or later than the *datetime* argument. The *datetime* value is relative to the local time zone on the machine where you run `mysqlbinlog`. The value should be in a format accepted for the `DATETIME` or `TIMESTAMP` data types. For example:

```
shell> mysqlbinlog --start-datetime="2005-12-25 11:25:56" binlog.000003
```

This option is useful for point-in-time recovery. See Section 7.3, "Example Backup and Recovery Strategy".

- `--start-position=`*N*, `-j `*N*

Start reading the binary log at the first event having a position equal to or greater than *N*. This option applies to the first log file named on the command line.

This option is useful for point-in-time recovery. See Section 7.3, "Example Backup and Recovery Strategy".

- `--stop-datetime=`*datetime*

Stop reading the binary log at the first event having a timestamp equal to or later than the *datetime* argument. This option is useful for point-in-time recovery. See the description of the `--start-datetime` option for information about the *datetime* value.

This option is useful for point-in-time recovery. See Section 7.3, "Example Backup and Recovery Strategy".

- `--stop-position=`*N*

  Stop reading the binary log at the first event having a position equal to or greater than *N*. This option applies to the last log file named on the command line.

  This option is useful for point-in-time recovery. See Section 7.3, "Example Backup and Recovery Strategy".

- `--to-last-log`, `-t`

  Do not stop at the end of the requested binary log from a MySQL server, but rather continue printing until the end of the last binary log. If you send the output to the same MySQL server, this may lead to an endless loop. This option requires `--read-from-remote-server`.

- `--user=`*user_name*, `-u` *user_name*

  The MySQL user name to use when connecting to a remote server.

- `--verbose`, `-v`

  Reconstruct row events and display them as commented SQL statements. If this option is given twice, the output includes comments to indicate column data types and some metadata. This option was added in MySQL 5.1.28.

  For examples that show the effect of `--base64-output` and `--verbose` on row event output, see Section 4.6.7.2, "mysqlbinlog Row Event Display".

- `--version`, `-V`

  Display version information and exit.

  In MySQL 5.1, the version number shown for `mysqlbinlog` is always 3.3.

You can also set the following variable by using `--`*var_name*`=`*value* syntax:

- `open_files_limit`

  Specify the number of open file descriptors to reserve.

You can pipe the output of `mysqlbinlog` into the `mysql` client to execute the events contained in the binary log. This technique is used to recover from a crash when you have an old backup (see Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log"). For example:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p
```

Or:

```
shell> mysqlbinlog binlog.[0-9]* | mysql -u root -p
```

You can also redirect the output of `mysqlbinlog` to a text file instead, if you need to modify the statement log first (for example, to remove statements that you do not want to execute for some reason). After editing the file, execute the statements that it contains by using it as input to the `mysql` program:

```
shell> mysqlbinlog binlog.000001 > tmpfile
shell> ... edit tmpfile ...
shell> mysql -u root -p < tmpfile
```

When `mysqlbinlog` is invoked with the `--start-position` option, it displays only those events with an offset in the binary log greater than or equal to a given position (the given position must match the start of one event). It also has options to stop and start when it sees an event with a given date and time. This enables you to perform point-in-time recovery using the `--stop-datetime` option (to be able to say, for example, "roll forward my databases to how they were today at 10:30 a.m.").

If you have more than one binary log to execute on the MySQL server, the safe method is to process them all using a single connection to the server. Here is an example that demonstrates what may be *unsafe*:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p # DANGER!!
shell> mysqlbinlog binlog.000002 | mysql -u root -p # DANGER!!
```

Processing binary logs this way using multiple connections to the server causes problems if the first log file contains a `CREATE TEMPORARY TABLE` statement and the second log contains a statement that uses the temporary table. When the first `mysql` process terminates, the server drops the temporary table. When the second `mysql` process attempts to use the table, the server reports "unknown table."

To avoid problems like this, use a *single* `mysql` process to execute the contents of all binary logs that you want to process. Here is one way to do so:

```
shell> mysqlbinlog binlog.000001 binlog.000002 | mysql -u root -p
```

Another approach is to write all the logs to a single file and then process the file:

```
shell> mysqlbinlog binlog.000001 >  /tmp/statements.sql
shell> mysqlbinlog binlog.000002 >> /tmp/statements.sql
shell> mysql -u root -p -e "source /tmp/statements.sql"
```

`mysqlbinlog` can produce output that reproduces a `LOAD DATA INFILE` operation without the original data file. `mysqlbinlog` copies the data to a temporary file and writes a `LOAD DATA LOCAL INFILE` statement that refers to the file. The default location of the directory where these files are written is system-specific. To specify a directory explicitly, use the `--local-load` option.

Because `mysqlbinlog` converts `LOAD DATA INFILE` statements to `LOAD DATA LOCAL INFILE` statements (that is, it adds `LOCAL`), both the client and the server that you use to process the statements must be configured with the `LOCAL` capability enabled. See Section 6.1.6, "Security Issues with LOAD DATA LOCAL".

Warning

The temporary files created for `LOAD DATA LOCAL` statements are *not* automatically deleted because they are needed until you actually execute those statements. You should delete the temporary files yourself after you no longer need the statement log. The files can be found in the temporary file directory and have names like `original_file_name-#-#`.

4.6.7.1 mysqlbinlog Hex Dump Format

The `--hexdump` option causes `mysqlbinlog` to produce a hex dump of the binary log contents:

```
shell> mysqlbinlog --hexdump master-bin.000001
```

The hex output consists of comment lines beginning with `#`, so the output might look like this for the preceding command:

```
/*!40019 SET @@session.max_insert_delayed_threads=0*/;
/*!50003 SET @OLD_COMPLETION_TYPE=@@COMPLETION_TYPE,COMPLETION_TYPE=0*/;
# at 4
#051024 17:24:13 server id 1  end_log_pos 98
# Position  Timestamp   Type   Master ID        Size       Master Pos    Flags
# 00000004 9d fc 5c 43    0f    01 00 00 00    5e 00 00 00    62 00 00 00    00 00
# 00000017 04 00 35 2e 30 2e 31 35   2d 64 65 62 75 67 2d 6c  |..5.0.15.debug.l|
# 00000027 6f 67 00 00 00 00 00 00   00 00 00 00 00 00 00 00  |og..............|
# 00000037 00 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00  |................|
# 00000047 00 00 00 00 9d fc 5c 43   13 38 0d 00 08 00 12 00  |.......C.8......|
# 00000057 04 04 04 04 12 00 00 4b   00 04 1a                 |.......K...|
#      Start: binlog v 4, server v 5.0.15-debug-log created 051024 17:24:13
#      at startup
ROLLBACK;
```

Hex dump output currently contains the elements in the following list. This format is subject to change. (For more information about binary log format, see MySQL Internals: The Binary Log.

- `Position`: The byte position within the log file.

- `Timestamp`: The event timestamp. In the example shown, `'9d fc 5c 43'` is the representation of `'051024 17:24:13'` in hexadecimal.

- `Type`: The event type code. In the example shown, `'0f'` indicates a `FORMAT_DESCRIPTION_EVENT`. The following table lists the possible type codes.

Type	Name	Meaning
00	UNKNOWN_EVENT	This event should never be present in the log.
01	START_EVENT_V3	This indicates the start of a log file written by MySQL 4 or earlier.
02	QUERY_EVENT	The most common type of events. These contain statements executed on the master.
03	STOP_EVENT	Indicates that master has stopped.
04	ROTATE_EVENT	Written when the master switches to a new log file.
05	INTVAR_EVENT	Used for AUTO_INCREMENT values or when the LAST_INSERT_ID() function is used in the statement.
06	LOAD_EVENT	Used for LOAD DATA INFILE in MySQL 3.23.
07	SLAVE_EVENT	Reserved for future use.
08	CREATE_FILE_EVENT	Used for LOAD DATA INFILE statements. This indicates the start of execution of such a statement. A temporary file is created on the slave. Used in MySQL 4 only.
09	APPEND_BLOCK_EVENT	Contains data for use in a LOAD DATA INFILE statement. The data is stored in the temporary file on the slave.

Type	Name	Meaning
0a	EXEC_LOAD_EVENT	Used for `LOAD DATA INFILE` statements. The contents of the temporary file is stored in the table on the slave. Used in MySQL 4 only.
0b	DELETE_FILE_EVENT	Rollback of a `LOAD DATA INFILE` statement. The temporary file should be deleted on the slave.
0c	NEW_LOAD_EVENT	Used for `LOAD DATA INFILE` in MySQL 4 and earlier.
0d	RAND_EVENT	Used to send information about random values if the `RAND()` function is used in the statement.
0e	USER_VAR_EVENT	Used to replicate user variables.
0f	FORMAT_DESCRIPTION_EVENT	This indicates the start of a log file written by MySQL 5 or later.
10	XID_EVENT	Event indicating commit of an XA transaction.
11	BEGIN_LOAD_QUERY_EVENT	Used for `LOAD DATA INFILE` statements in MySQL 5 and later.
12	EXECUTE_LOAD_QUERY_EVENT	Used for `LOAD DATA INFILE` statements in MySQL 5 and later.
13	TABLE_MAP_EVENT	Information about a table definition. Used in MySQL 5.1.5 and later.
14	PRE_GA_WRITE_ROWS_EVENT	Row data for a single table that should be created. Used in MySQL 5.1.5 to 5.1.17.
15	PRE_GA_UPDATE_ROWS_EVENT	Row data for a single table that needs to be updated. Used in MySQL 5.1.5 to 5.1.17.
16	PRE_GA_DELETE_ROWS_EVENT	Row data for a single table that should be deleted. Used in MySQL 5.1.5 to 5.1.17.
17	WRITE_ROWS_EVENT	Row data for a single table that should be created. Used in MySQL 5.1.18 and later.
18	UPDATE_ROWS_EVENT	Row data for a single table that needs to be updated. Used in MySQL 5.1.18 and later.
19	DELETE_ROWS_EVENT	Row data for a single table that should be deleted. Used in MySQL 5.1.18 and later.
1a	INCIDENT_EVENT	Something out of the ordinary happened. Added in MySQL 5.1.18.

- `Master ID`: The server ID of the master that created the event.

- `Size`: The size in bytes of the event.

- `Master Pos`: The position of the next event in the original master log file.

- `Flags`: 16 flags. The following flags are used. The others are reserved for future use.

Flag	Name	Meaning
01	LOG_EVENT_BINLOG_IN_USE_F	Log file correctly closed. (Used only in `FORMAT_DESCRIPTION_EVENT`.) If this flag is set (if the flags are, for example, `'01 00'`) in a `FORMAT_DESCRIPTION_EVENT`, the log file has not been

Flag	Name	Meaning
		properly closed. Most probably this is because of a master crash (for example, due to power failure).
02		Reserved for future use.
04	`LOG_EVENT_THREAD_SPECIFIC_F`	Set if the event is dependent on the connection it was executed in (for example, `'04 00'`), for example, if the event uses temporary tables.
08	`LOG_EVENT_SUPPRESS_USE_F`	Set in some circumstances when the event is not dependent on the default database.

4.6.7.2 mysqlbinlog Row Event Display

The following examples illustrate how `mysqlbinlog` displays row events that specify data modifications. These correspond to events with the `WRITE_ROWS_EVENT`, `UPDATE_ROWS_EVENT`, and `DELETE_ROWS_EVENT` type codes. The `--base64-output=DECODE-ROWS` and `--verbose` options may be used to affect row event output. These options are available as of MySQL 5.1.28.

Suppose that the server is using row-based binary logging and that you execute the following sequence of statements:

```
CREATE TABLE t
(
  id   INT NOT NULL,
  name VARCHAR(20) NOT NULL,
  date DATE NULL
) ENGINE = InnoDB;

START TRANSACTION;
INSERT INTO t VALUES(1, 'apple', NULL);
UPDATE t SET name = 'pear', date = '2009-01-01' WHERE id = 1;
DELETE FROM t WHERE id = 1;
COMMIT;
```

By default, `mysqlbinlog` displays row events encoded as base-64 strings using `BINLOG` statements. Omitting extraneous lines, the output for the row events produced by the preceding statement sequence looks like this:

```
shell> mysqlbinlog log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAANoAAAAAABEAAAAAAAAABHRlc3QAAXQAAXQAAwMPCgIUAAAQ=
fAS3SBcBAAAAKAAAAAIBAAAQABEAAAAAAAEAA//8AQAAAAVhcHBsZQ==
'/*!*/;
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAC4BAAAAABEAAAAAAAAABHRlc3QAAXQAAXQAAwMPCgIUAAAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEAAAAAAAEAA////AEAAAAFYXBwbGGX4AQAAAARwZWFyIbIP
'/*!*/;
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F
```

```
BINLOG '
fAS3SBMBAAAALAAAAJABAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBkBAAAAKgAAALoBAAAQABEAAAAAAAEAA//4AQAAAARwZWFyIbIP
'/*!*/;
```

To see the row events as comments in the form of "pseudo-SQL" statements, run `mysqlbinlog` with the `--verbose` or `-v` option. The output will contain lines beginning with `###`:

```
shell> mysqlbinlog -v log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAANoAAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBcBAAAAKAAAAAIBAAAQABEAAAAAAAEAA//8AQAAAVhcHBsZQ==
'/*!*/;
### INSERT INTO test.t
### SET
###    @1=1
###    @2='apple'
###    @3=NULL
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAC4BAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEAAAAAAAEAA////AEAAAAFYXBwbGX4AQAAAARwZWFyIbIP
'/*!*/;
### UPDATE test.t
### WHERE
###    @1=1
###    @2='apple'
###    @3=NULL
### SET
###    @1=1
###    @2='pear'
###    @3='2009:01:01'
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAJABAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBkBAAAAKgAAALoBAAAQABEAAAAAAAEAA//4AQAAAARwZWFyIbIP
'/*!*/;
### DELETE FROM test.t
### WHERE
###    @1=1
###    @2='pear'
###    @3='2009:01:01'
```

Specify `--verbose` or `-v` twice to also display data types and some metadata for each column. The output will contain an additional comment following each column change:

```
shell> mysqlbinlog -vv log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAANoAAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBcBAAAAKAAAAAIBAAAQABEAAAAAAAEAA//8AQAAAVhcHBsZQ==
```

```
'/*!*/;
### INSERT INTO test.t
### SET
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='apple' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3=NULL /* VARSTRING(20) meta=0 nullable=1 is_null=1 */
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAC4BAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPDAgIUAAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEAAAAAAAEA////AEAAAAFYXBwbGGX4AQAAAARwZWFyIbIP
'/*!*/;
### UPDATE test.t
### WHERE
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='apple' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3=NULL /* VARSTRING(20) meta=0 nullable=1 is_null=1 */
### SET
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='pear' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3='2009:01:01' /* DATE meta=0 nullable=1 is_null=0 */
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAJABAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPDAgIUAAQ=
fAS3SBkBAAAAKgAAALoBAAAQABEAAAAAAAEA//4AQAAAARwZWFyIbIP
'/*!*/;
### DELETE FROM test.t
### WHERE
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='pear' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3='2009:01:01' /* DATE meta=0 nullable=1 is_null=0 */
```

You can tell mysqlbinlog to suppress the BINLOG statements for row events by using the `--base64-output=DECODE-ROWS` option. This is similar to `--base64-output=NEVER` but does not exit with an error if a row event is found. The combination of `--base64-output=DECODE-ROWS` and `--verbose` provides a convenient way to see row events only as SQL statements:

```
shell> mysqlbinlog -v --base64-output=DECODE-ROWS log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F
### INSERT INTO test.t
### SET
###   @1=1
###   @2='apple'
###   @3=NULL
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F
### UPDATE test.t
### WHERE
###   @1=1
###   @2='apple'
###   @3=NULL
### SET
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
...
# at 400
```

413

```
#080828 15:03:08 server id 1   end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F
### DELETE FROM test.t
### WHERE
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
```

> **Note**
>
> You should not suppress `BINLOG` statements if you intend to re-execute `mysqlbinlog` output.

The SQL statements produced by `--verbose` for row events are much more readable than the corresponding `BINLOG` statements. However, they do not correspond exactly to the original SQL statements that generated the events. The following limitations apply:

- The original column names are lost and replaced by `@N`, where `N` is a column number.

- Character set information is not available in the binary log, which affects string column display:

  - There is no distinction made between corresponding binary and nonbinary string types (`BINARY` and `CHAR`, `VARBINARY` and `VARCHAR`, `BLOB` and `TEXT`). The output uses a data type of `STRING` for fixed-length strings and `VARSTRING` for variable-length strings.

  - For multibyte character sets, the maximum number of bytes per character is not present in the binary log, so the length for string types is displayed in bytes rather than in characters. For example, `STRING(4)` will be used as the data type for values from either of these column types:

    ```
    CHAR(4) CHARACTER SET latin1
    CHAR(2) CHARACTER SET ucs2
    ```

  - Due to the storage format for events of type `UPDATE_ROWS_EVENT`, `UPDATE` statements are displayed with the `WHERE` clause preceding the `SET` clause.

Proper interpretation of row events requires the information from the format description event at the beginning of the binary log. Because `mysqlbinlog` does not know in advance whether the rest of the log contains row events, by default it displays the format description event using a `BINLOG` statement in the initial part of the output.

If the binary log is known not to contain any events requiring a `BINLOG` statement (that is, no row events), the `--base64-output=NEVER` option can be used to prevent this header from being written.

4.6.8 `mysqldumpslow` — Summarize Slow Query Log Files

The MySQL slow query log contains information about queries that take a long time to execute (see Section 5.4.5, "The Slow Query Log"). `mysqldumpslow` parses MySQL slow query log files and prints a summary of their contents.

Normally, `mysqldumpslow` groups queries that are similar except for the particular values of number and string data values. It "abstracts" these values to `N` and `'S'` when displaying summary output. The `-a` and `-n` options can be used to modify value abstracting behavior.

Invoke `mysqldumpslow` like this:

```
shell> mysqldumpslow [options] [log_file ...]
```

`mysqldumpslow` supports the following options.

Table 4.15 `mysqldumpslow` Options

Format	Description
-a	Do not abstract all numbers to N and strings to S
-n	Abstract numbers with at least the specified digits
--debug	Write debugging information
-g	Only consider statements that match the pattern
--help	Display help message and exit
-h	Host name of the server in the log file name
-i	Name of the server instance
-l	Do not subtract lock time from total time
-r	Reverse the sort order
-s	How to sort output
-t	Display only first num queries
--verbose	Verbose mode

- `--help`

  Display a help message and exit.

- `-a`

  Do not abstract all numbers to `N` and strings to `'S'`.

- `--debug`, `-d`

  Run in debug mode.

- `-g pattern`

  Consider only queries that match the (`grep`-style) pattern.

- `-h host_name`

  Host name of MySQL server for `*-slow.log` file name. The value can contain a wildcard. The default is `*` (match all).

- `-i name`

  Name of server instance (if using `mysql.server` startup script).

- `-l`

  Do not subtract lock time from total time.

- `-n N`

  Abstract numbers with at least `N` digits within names.

- `-r`

  Reverse the sort order.

- `-s sort_type`

How to sort the output. The value of *sort_type* should be chosen from the following list:

- `t`, `at`: Sort by query time or average query time

- `l`, `al`: Sort by lock time or average lock time

- `r`, `ar`: Sort by rows sent or average rows sent

- `c`: Sort by count

By default, `mysqldumpslow` sorts by average query time (equivalent to `-s at`).

- `-t` *N*

  Display only the first *N* queries in the output.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

Example of usage:

```
shell> mysqldumpslow

Reading mysql slow query log from /usr/local/mysql/data/mysqld51-apple-slow.log
Count: 1  Time=4.32s (4s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
 insert into t2 select * from t1

Count: 3  Time=2.53s (7s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
 insert into t2 select * from t1 limit N

Count: 3  Time=2.13s (6s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
 insert into t1 select * from t1
```

4.6.9 `mysqlhotcopy` — A Database Backup Program

`mysqlhotcopy` is a Perl script that was originally written and contributed by Tim Bunce. It uses `FLUSH TABLES`, `LOCK TABLES`, and `cp` or `scp` to make a database backup. It is a fast way to make a backup of the database or single tables, but it can be run only on the same machine where the database directories are located. `mysqlhotcopy` works only for backing up `MyISAM` and `ARCHIVE` tables. It runs on Unix and NetWare.

To use `mysqlhotcopy`, you must have read access to the files for the tables that you are backing up, the `SELECT` privilege for those tables, the `RELOAD` privilege (to be able to execute `FLUSH TABLES`), and the `LOCK TABLES` privilege (to be able to lock the tables).

```
shell> mysqlhotcopy db_name [/path/to/new_directory]
```

```
shell> mysqlhotcopy db_name_1 ... db_name_n /path/to/new_directory
```

Back up tables in the given database that match a regular expression:

```
shell> mysqlhotcopy db_name./regex/
```

The regular expression for the table name can be negated by prefixing it with a tilde ("~"):

```
shell> mysqlhotcopy db_name./~regex/
```

`mysqlhotcopy` supports the following options, which can be specified on the command line or in the `[mysqlhotcopy]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.16 `mysqlhotcopy` Options

Format	Description
--addtodest	Do not rename target directory (if it exists); merely add files to it
--allowold	Do not abort if a target exists; rename it by adding an _old suffix
--checkpoint	Insert checkpoint entries
--chroot	Base directory of the chroot jail in which mysqld operates
--debug	Write debugging log
--dryrun	Report actions without performing them
--flushlog	Flush logs after all tables are locked
--help	Display help message and exit
--host	Connect to MySQL server on given host
--keepold	Do not delete previous (renamed) target when done
--method	The method for copying files
--noindices	Do not include full index files in the backup
--password	Password to use when connecting to server
--port	TCP/IP port number to use for connection
--quiet	Be silent except for errors
--regexp	Copy all databases with names that match the given regular expression
--resetmaster	Reset the binary log after locking all the tables
--resetslave	Reset the master.info file after locking all the tables
--socket	For connections to localhost, the Unix socket file to use
--tmpdir	The temporary directory
--user	MySQL user name to use when connecting to server

- `--help`, `-?`

  Display a help message and exit.

- `--addtodest`

  Do not rename target directory (if it exists); merely add files to it.

- `--allowold`

  Do not abort if a target exists; rename it by adding an `_old` suffix.

- `--checkpoint=db_name.tbl_name`

  Insert checkpoint entries into the specified database `db_name` and table `tbl_name`.

- `--chroot=dir_name`

  Base directory of the `chroot` jail in which `mysqld` operates. The `dir_name` value should match that of the `--chroot` option given to `mysqld`.

- `--debug`

  Enable debug output.

- `--dryrun`, `-n`

  Report actions without performing them.

- `--flushlog`

  Flush logs after all tables are locked.

- `--host=host_name`, `-h host_name`

  The host name of the local host to use for making a TCP/IP connection to the local server. By default, the connection is made to `localhost` using a Unix socket file.

- `--keepold`

  Do not delete previous (renamed) target when done.

- `--method=command`

  The method for copying files (`cp` or `scp`). The default is `cp`.

- `--noindices`

  Do not include full index files for `MyISAM` tables in the backup. This makes the backup smaller and faster. The indexes for reloaded tables can be reconstructed later with `myisamchk -rq`.

- `--password=password`, `-ppassword`

  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use when connecting to the local server.

- `--quiet`, `-q`

  Be silent except for errors.

- `--record_log_pos=db_name.tbl_name`

  Record master and slave status in the specified database `db_name` and table `tbl_name`.

- `--regexp=expr`

  Copy all databases with names that match the given regular expression.

- `--resetmaster`

  Reset the binary log after locking all the tables.

- `--resetslave`

  Reset the `master.info` file after locking all the tables.

- `--socket=`*`path`*, `-S `*`path`*

  The Unix socket file to use for connections to `localhost`.

- `--suffix=`*`str`*

  The suffix to use for names of copied databases.

- `--tmpdir=`*`dir_name`*

  The temporary directory. The default is `/tmp`.

- `--user=`*`user_name`*, `-u `*`user_name`*

  The MySQL user name to use when connecting to the server.

Use `perldoc` for additional `mysqlhotcopy` documentation, including information about the structure of the tables needed for the `--checkpoint` and `--record_log_pos` options:

```
shell> perldoc mysqlhotcopy
```

4.6.10 `mysqlmanager` — The MySQL Instance Manager

⚠️ **Important**

MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

`mysqlmanager` is the MySQL Instance Manager (IM). This program monitors and manages MySQL Database Server instances. MySQL Instance Manager is available for Unix-like operating systems, as well as Windows. It runs as a daemon that listens on a TCP/IP port. On Unix, it also listens on a Unix socket file.

MySQL Instance Manager can be used in place of the `mysqld_safe` script to start and stop one or more instances of MySQL Server. Because Instance Manager can manage multiple server instances, it can also be used in place of the `mysqld_multi` script. Instance Manager offers these capabilities:

- Instance Manager can start and stop instances, and report on the status of instances.

- Server instances can be treated as guarded or unguarded:

  - When Instance Manager starts, it starts each guarded instance. If the instance crashes, Instance Manager detects this and restarts it. When Instance Manager stops, it stops the instance.

  - A nonguarded instance is not started when Instance Manager starts or monitored by it. If the instance crashes after being started, Instance Manager does not restart it. When Instance Manager exits, it does not stop the instance if it is running.

  Instances are guarded by default. An instance can be designated as nonguarded by including the `nonguarded` option in the configuration file.

- Instance Manager provides an interactive interface for configuring instances, so that the need to edit the configuration file manually is reduced or eliminated.

- Instance Manager provides remote instance management. That is, it runs on the host where you want to control MySQL Server instances, but you can connect to it from a remote host to perform instance-management operations.

The following sections describe MySQL Instance Manager operation in more detail.

4.6.10.1 MySQL Instance Manager Command Options

> ⚠️ **Important**
>
> MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

The MySQL Instance Manager supports a number of command options. For a brief listing, invoke `mysqlmanager` with the `--help` option. Options may be given on the command line or in the Instance Manager configuration file. On Windows, the standard configuration file is `my.ini` in the directory where Instance Manager is installed. On Unix, the standard file is `/etc/my.cnf`. To specify a different configuration file, start Instance Manager with the `--defaults-file` option.

`mysqlmanager` supports the following options. The options for managing entries in the password file are described further in Section 4.6.10.4, "Instance Manager User and Password Management".

- `--help`, `-?`

  Display a help message and exit.

- `--add-user`

  Add a new user (specified with the `--username` option) to the password file. This option was added in MySQL 5.1.12.

- `--angel-pid-file=file_name`

  The file in which the angel process records its process ID when `mysqlmanager` runs in daemon mode (that is, when the `--run-as-service` option is given). The default file name is `mysqlmanager.angel.pid`.

  If the `--angel-pid-file` option is not given, the default angel PID file has the same name as the PID file except that any PID file extension is replaced with an extension of `.angel.pid`. (For example, `mysqlmanager.pid` becomes `mysqlmanager.angel.pid`.)

  This option was added in MySQL 5.1.11.

- `--bind-address=IP`

  The IP address to bind to.

- `--check-password-file`

  Check the validity and consistency of the password file. This option was added in MySQL 5.1.12.

- `--clean-password-file`

  Drop all users from the password file. This option was added in MySQL 5.1.12.

- `--debug=debug_options`, `-# debug_options`

Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. This option was added in MySQL 5.1.10.

- `--default-mysqld-path=`*`file_name`*

The path name of the MySQL Server binary. This path name is used for all server instance sections in the configuration file for which no `mysqld-path` option is present. The default value of this option is the compiled-in path name, which depends on how the MySQL distribution was configured. Example: `--default-mysqld-path=/usr/sbin/mysqld`

- `--defaults-file=`*`file_name`*

Read Instance Manager and MySQL Server settings from the given file. All configuration changes made by the Instance Manager will be written to this file. This must be the first option on the command line if it is used, and the file must exist.

If this option is not given, Instance Manager uses its standard configuration file. On Windows, the standard file is `my.ini` in the directory where Instance Manager is installed. On Unix, the standard file is `/etc/my.cnf`.

- `--drop-user`

Drop a user (specified with the `--username` option) from the password file. This option was added in MySQL 5.1.12.

- `--edit-user`

Change an entry for an existing user (specified with the `--username` option) in the password file. This option was added in MySQL 5.1.12.

- `--install`

On Windows, install Instance Manager as a Windows service. The service name is `MySQL Manager`.

- `--list-users`

List the users in the password file. This option was added in MySQL 5.1.12.

- `--log=`*`file_name`*

The path to the Instance Manager log file. This option has no effect unless the `--run-as-service` option is also given. If the file name specified for the option is a relative name, the log file is created under the directory from which Instance Manager is started. To ensure that the file is created in a specific directory, specify it as a full path name.

If `--run-as-service` is given without `--log`, the log file is `mysqlmanager.log` in the data directory.

If `--run-as-service` is not given, log messages go to the standard output. To capture log output, you can redirect Instance Manager output to a file:

```
mysqlmanager > im.log
```

- `--monitoring-interval=`*`seconds`*

The interval in seconds for monitoring server instances. The default value is 20 seconds. Instance Manager tries to connect to each monitored (guarded) instance using the nonexisting

`MySQL_Instance_Manager` user account to check whether it is available/not hanging. If the result of the connection attempt indicates that the instance is unavailable, Instance Manager performs several attempts to restart the instance.

Normally, the `MySQL_Instance_Manager` account does not exist, so the connection attempts by Instance Manager cause the monitored instance to produce messages in its general query log similar to the following:

```
Access denied for user 'MySQL_Instance_M'@'localhost' »
    (using password: YES)
```

The `nonguarded` option in the appropriate server instance section disables monitoring for a particular instance. If the instance dies after being started, Instance Manager will not restart it. Instance Manager tries to connect to a nonguarded instance only when you request the instance's status (for example, with the `SHOW INSTANCES` status.

See Section 4.6.10.5, "MySQL Server Instance Status Monitoring", for more information.

- `--mysqld-safe-compatible`

  Run in a `mysqld_safe`-compatible manner. For details, see Section 4.6.10.3, "Starting the MySQL Server with MySQL Instance Manager". This option was added in MySQL 5.1.12.

- `--password=`*`password`*, `-p `*`password`*

  Specify the password for an entry to be added to or modified in the password file. Unlike the `--password`/`-P` option for most MySQL programs, the password value is required, not optional. See also Section 4.6.10.4, "Instance Manager User and Password Management". This option was added in MySQL 5.1.12.

- `--password-file=`*`file_name`*

  The name of the file where the Instance Manager looks for users and passwords. On Windows, the default is `mysqlmanager.passwd` in the directory where Instance Manager is installed. On Unix, the default file is `/etc/mysqlmanager.passwd`. See also Section 4.6.10.4, "Instance Manager User and Password Management".

- `--pid-file=`*`file_name`*

  The process ID file to use. On Windows, the default file is `mysqlmanager.pid` in the directory where Instance Manager is installed. On Unix, the default is `mysqlmanager.pid` in the data directory.

- `--port=`*`port_num`*

  The port number to use when listening for TCP/IP connections from clients. The default port number (assigned by IANA) is 2273.

- `--print-defaults`

  Print the current defaults and exit. This must be the first option on the command line if it is used.

- `--print-password-line`

  Prepare an entry for the password file, print it to the standard output, and exit. You can redirect the output from Instance Manager to a file to save the entry in the file.

  Prior to MySQL 5.1.12, this option was named `--passwd`.

- `--remove`

  On Windows, removes Instance Manager as a Windows service. This assumes that Instance Manager has been run with `--install` previously.

- `--run-as-service`

  On Unix, daemonize and start an angel process. The angel process monitors Instance Manager and restarts it if it crashes. (The angel process itself is simple and unlikely to crash.)

- `--socket=`*path*

  On Unix, the socket file to use for incoming connections. The default file is named `/tmp/mysqlmanager.sock`. This option has no meaning on Windows.

- `--standalone`

  This option is used on Windows to run Instance Manager in standalone mode. You should specify it when you start Instance Manager from the command line.

- `--user=`*user_name*

  On Unix, the user name of the system account to use for starting and running `mysqlmanager`. This option generates a warning and has no effect unless you start `mysqlmanager` as `root` (so that it can change its effective user ID), or as the named user. It is recommended that you configure `mysqlmanager` to run using the same account used to run the `mysqld` server. ("User" in this context refers to a system login account, not a MySQL user listed in the grant tables.)

- `--username=`*user_name*, `-u` *user_name*

  Specify the user name for an entry to be added to or modified in the password file. This option was added in MySQL 5.1.12.

- `--version`, `-V`

  Display version information and exit.

- `--wait-timeout=`*N*

  The number of seconds to wait for activity on an incoming connection before closing it. The default is 28800 seconds (8 hours).

  This option was added in MySQL 5.1.7. Before that, the timeout is 30 seconds and cannot be changed.

4.6.10.2 MySQL Instance Manager Configuration Files

> ⚠️ **Important**
>
> MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

Instance Manager uses its standard configuration file unless it is started with a `--defaults-file` option that specifies a different file. On Windows, the standard file is `my.ini` in the directory where Instance Manager is installed. On Unix, the standard file is `/etc/my.cnf`.

Instance Manager reads options for itself from the `[manager]` section of the configuration file, and options for server instances from `[mysqld]` or `[mysqld`*N*`]` sections. The `[manager]` section contains any of the options listed in Section 4.6.10.1, "MySQL Instance Manager Command Options", except for those

specified as having to be given as the first option on the command line. Here is a sample `[manager]` section:

```
# MySQL Instance Manager options section
[manager]
default-mysqld-path = /usr/local/mysql/libexec/mysqld
socket=/tmp/manager.sock
pid-file=/tmp/manager.pid
password-file = /home/cps/.mysqlmanager.passwd
monitoring-interval = 2
port = 1999
bind-address = 192.168.1.5
```

Each `[mysqld]` or `[mysqldN]` instance section specifies options given by Instance Manager to a server instance at startup. These are mainly common MySQL Server options (see Section 5.1.3, "Server Command Options"). In addition, a `[mysqldN]` section can contain the options in the following list, which are specific to Instance Manager. These options are interpreted by Instance Manager itself; it does not pass them to the server when it attempts to start that server.

> **⊗ Warning**
>
> The Instance Manager-specific options must not be used in a `[mysqld]` section. If a server is started without using Instance Manager, it will not recognize these options and will fail to start properly.

- `mysqld-path = file_name`

  The path name of the `mysqld` server binary to use for the server instance.

- `nonguarded`

  This option disables Instance Manager monitoring functionality for the server instance. By default, an instance is guarded: At Instance Manager start time, it starts the instance. It also monitors the instance status and attempts to restart it if it fails. At Instance Manager exit time, it stops the instance. None of these things happen for nonguarded instances.

- `shutdown-delay = seconds`

  The number of seconds Instance Manager should wait for the server instance to shut down. The default value is 35 seconds. After the delay expires, Instance Manager assumes that the instance is hanging and attempts to terminate it. If you use `InnoDB` with large tables, you should increase this value.

Here are some sample instance sections:

```
[mysqld1]
mysqld-path=/usr/local/mysql/libexec/mysqld
socket=/tmp/mysql.sock
port=3307
server_id=1
skip-stack-trace
core-file
log-bin
log-error
log=mylog
log-slow-queries

[mysqld2]
nonguarded
port=3308
server_id=2
```

```
mysqld-path= /home/cps/mysql/trees/mysql-5.1/sql/mysqld
socket      = /tmp/mysql.sock5
pid-file    = /tmp/hostname.pid5
datadir= /home/cps/mysql_data/data_dir1
language=/home/cps/mysql/trees/mysql-5.1/sql/share/english
log-bin
log=/tmp/fordel.log
```

4.6.10.3 Starting the MySQL Server with MySQL Instance Manager

> ⚠️ **Important**
>
> MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

This section discusses how Instance Manager starts server instances when it starts. However, before you start Instance Manager, you should set up a password file for it. Otherwise, you will not be able to connect to Instance Manager to control it after it starts. For details about creating Instance Manager accounts, see Section 4.6.10.4, "Instance Manager User and Password Management".

On Unix, the `mysqld` MySQL database server normally is started with the `mysql.server` script, which usually resides in the `/etc/init.d/` folder. That script invokes the `mysqld_safe` script by default. However, you can use Instance Manager instead if you modify the `/etc/my.cnf` configuration file by adding `use-manager` to the `[mysql.server]` section:

```
[mysql.server]
use-manager
```

Before MySQL 5.1.12, Instance Manager always tries to start at least one server instance: When it starts, it reads its configuration file if it exists to find server instance sections and prepare a list of instances. Instance sections have names of the form `[mysqld]` or `[mysqldN]`, where N is an unsigned integer (for example, `[mysqld1]`, `[mysqld2]`, and so forth).

After preparing the list of instances, Instance Manager starts the guarded instances in the list. If there are no instances, Instance Manager creates an instance named `mysqld` and attempts to start it with default (compiled-in) configuration values. This means that the Instance Manager cannot find the `mysqld` program if it is not installed in the default location. (Section 2.1.4, "Installation Layouts", describes default locations for components of MySQL distributions.) If you have installed the MySQL server in a nonstandard location, you should create the Instance Manager configuration file.

The startup behavior just described is similar to that of `mysqld_safe`, which always attempts to start a server. However, it lacks the flexibility required for some operations because it is not possible to run Instance Manager in such a way that it refrains from starting any server instances. For example, you cannot invoke Instance Manager for the purpose of configuring an instance without also starting it (a task that a MySQL installer application might want to perform). Consequently, MySQL 5.1.12 introduces the following changes:

- A new option, `--mysqld-safe-compatible`, may be used to cause Instance Manager to run with startup behavior similar to that used before MySQL 5.1.12: If Instance Manager finds a `[mysqld]` instance section in the configuration file, it will start it. If Instance Manager finds no `[mysqld]` section, it creates one using default configuration values, writes a `[mysqld]` section to the configuration file if it is accessible, and starts the `mysqld` instance. Instance Manager also starts any other guarded instances listed in the configuration file.

- Without `--mysqld-safe-compatible`, Instance Manager reads its configuration file if it exists and starts instances for any guarded instance sections that it finds. If there are none, it starts no instances.

Instance Manager also stops all guarded server instances when it shuts down.

The permissible options for `[mysqldN]` server instance sections are described in Section 4.6.10.2, "MySQL Instance Manager Configuration Files". In these sections, you can use a special `mysqld-path=path-to-mysqld-binary` option that is recognized only by Instance Manager. Use this option to let Instance Manager know where the `mysqld` binary resides. If there are multiple instances, it may also be necessary to set other options such as `datadir` and `port`, to ensure that each instance has a different data directory and TCP/IP port number. Section 5.5, "Running Multiple MySQL Instances on One Machine", discusses the configuration values that must differ for each instance when you run multiple instance on the same machine.

> **Warning**
>
> The `[mysqld]` instance section, if it exists, must not contain any Instance Manager-specific options.

The typical Unix startup/shutdown cycle for a MySQL server with the MySQL Instance Manager enabled is as follows:

1. The `/etc/init.d/mysql` script starts MySQL Instance Manager.

2. Instance Manager starts the guarded server instances and monitors them.

3. If a server instance fails, Instance Manager restarts it.

4. If Instance Manager is shut down (for example, with the `/etc/init.d/mysql stop` command), it shuts down all server instances.

4.6.10.4 Instance Manager User and Password Management

> **Important**
>
> MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

The Instance Manager stores its user information in a password file. On Windows, the default is `mysqlmanager.passwd` in the directory where Instance Manager is installed. On Unix, the default file is `/etc/mysqlmanager.passwd`. To specify a different location for the password file, use the `--password-file` option.

If the password file does not exist or contains no password entries, you cannot connect to the Instance Manager.

> **Note**
>
> Any Instance Manager process that is running to monitor server instances does not notice changes to the password file. You must stop it and restart it after making password entry changes.

Entries in the password file have the following format, where the two fields are the account user name and encrypted password, separated by a colon:

```
petr:*35110DC9B4D8140F5DE667E28C72DD2597B5C848
```

Instance Manager password encryption is the same as that used by MySQL Server. It is a one-way operation; no means are provided for decrypting encrypted passwords.

Instance Manager accounts differ somewhat from MySQL Server accounts:

- MySQL Server accounts are associated with a host name, user name, and password (see Section 6.3.1, "User Names and Passwords").

- Instance Manager accounts are associated with a user name and password only.

This means that a client can connect to Instance Manager with a given user name from any host. To limit connections so that clients can connect only from the local host, start Instance Manager with the `--bind-address=127.0.0.1` option so that it listens only to the local network interface. Remote clients will not be able to connect. Local clients can connect like this:

```
shell> mysql -h 127.0.0.1 -P 2273
```

Before MySQL 5.1.12, the only option for creating password file entries is `--passwd`, which causes Instance Manager to prompt for user name and password values and display the resulting entry. You can save the output in the `/etc/mysqlmanager.passwd` password file to store it. Here is an example:

```
shell> mysqlmanager --passwd >> /etc/mysqlmanager.passwd
Creating record for new user.
Enter user name: mike
Enter password: mikepass
Re-type password: mikepass
```

At the prompts, enter the user name and password for the new Instance Manager user. You must enter the password twice. It does not echo to the screen, so double entry guards against entering a different password than you intend (if the two passwords do not match, no entry is generated).

The preceding command causes the following line to be added to `/etc/mysqlmanager.passwd`:

```
mike:*BBF1F551DD9DD96A01E66EC7DDC073911BAD17BA
```

Use of the `--passwd` option fails if `mysqlmanager` is invoked directly from an IBM 5250 terminal. To work around this, use a command like the following from the command line to generate the password entry:

```
shell> mysql -B --skip-column-name \
       -e 'SELECT CONCAT("user_name",":",PASSWORD("pass_val"));'
```

The output from the command can be used an entry in the `/etc/mysqlmanager.passwd` file.

Beginning with MySQL 5.1.12, the `--passwd` option is renamed to `--print-password-line` and there are several other options for managing user accounts from the command line. For example, the `--username` and `--password` options are available on the command line for specifying the user name and password for an account entry. You can use them to generate an entry with no prompting like this (type the command on a single line):

```
shell> mysqlmanager --print-password-line
       --username=mike --password=mikepass >> /etc/mysqlmanager.passwd
```

If you omit the `--username` or `--password` option, Instance Manager prompts for the required value.

`--print-password-line` causes Instance Manager to send the resulting account entry to its output, which you can append to the password file. The following list describes other account-management options that cause Instance Manager to operate directly on the password file. (These options make Instance Manager scriptable for account-management purposes.) For operations on the password file to succeed, the file must exist and it must be accessible by Instance Manager. (The exception is `--clean-password-file`, which creates the file if it does not exist. Alternatively, if there is no password file, manually create it as an empty file and ensure that its ownership and access modes permit it to be read and written by Instance Manager.) The default password file is used unless you specify a `--password-file` option.

To ensure consistent treatment of the password file, it should be owned by the system account that you use for running Instance Manager to manage server instances, and you should invoke it from that account when you use it to manage accounts in the password file.

- Create a new user:

```
mysqlmanager --add-user --username=user_name [--password=password]
```

This command adds a new entry with the given user name and password to the password file. The `--username` (or `-u`) option is required. `mysqlmanager` prompts for the password if it is not given on the command line with the `--password` (or `-p`) option. The command fails if the user already exists.

- Drop an existing user:

```
mysqlmanager --drop-user --username=user_name
```

This command removes the entry with the given user name from the password file. The user name is required. The command fails if the user does not exist.

- Change the password for an existing user:

```
mysqlmanager --edit-user --username=user_name [--password=password]
```

This command changes the given user's password in the password file. The user name is required. `mysqlmanager` prompts for the password it is not given on the command line. The command fails if the user does not exist.

- List existing users:

```
mysqlmanager --list-users
```

This command lists the user names of the accounts in the password file.

- Check the password file:

```
mysqlmanager --check-password-file
```

This command performs a consistency and validity check of the password file. The command fails if there is something wrong with the file.

- Empty the password file:

```
mysqlmanager --clean-password-file
```

This command empties the password file, which has the effect of dropping all users listed in it. The option creates the password file if it does not exist, so it can be used to initialize a new password file to be used for other account-management operations. Take care not to use this option to reinitialize a file containing accounts that you do not want to drop.

4.6.10.5 MySQL Server Instance Status Monitoring

Important

MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

To monitor the status of each guarded server instance, the MySQL Instance Manager attempts to connect to the instance at regular intervals using the `MySQL_Instance_Manager@localhost` user account with a password of `check_connection`.

You are *not* required to create this account for MySQL Server; in fact, it is expected that it will not exist. Instance Manager can tell that a server is operational if the server accepts the connection attempt but refuses access for the account by returning a login error. However, these failed connection attempts are logged by the server to its general query log (see Section 5.4.3, "The General Query Log").

Instance Manager also attempts a connection to nonguarded server instances when you use the `SHOW INSTANCES` or `SHOW INSTANCE STATUS` command. This is the only status monitoring done for nonguarded instances.

Instance Manager knows if a server instance fails at startup because it receives a status from the attempt. For an instance that starts but later crashes, Instance Manager receives a signal because it is the parent process of the instance.

Beginning with MySQL 5.1.12, Instance Manager tracks instance states so that it can determine which commands are permitted for each instance. For example, commands that modify an instance's configuration are permitted only while the instance is offline.

Each instance is in one of the states described in the following table. Guarded instances can be in any of the states. Nonguarded instances can only be offline or online. Instance state information is displayed in the `status` column of the `SHOW INSTANCES` and `SHOW INSTANCE STATUS` commands.

State	Meaning
`offline`	The instance has not been started and is not running.
`starting`	The instance is starting (initializing). Nonguarded instances cannot be in this state. A nonguarded instance goes directly from offline to online.
`stopping`	The instance is stopping. Nonguarded instances cannot be in this state. A nonguarded instance goes directly from online to offline, or stays offline if startup fails.
`online`	The instance has started and is running.
`failed`	The instance was online but it crashed and is being restarted by Instance Manager, or else the instance failed to start at all and Instance Manager is again attempting to start it. Nonguarded instances cannot be in this state.
`crashed`	Instance Manager failed to start the instance after several attempts. (Instance Manager will try again later.) Nonguarded instances cannot be in this state.
`abandoned`	Instance Manager was not able to start the instance, has given up, and will make no further attempts until instructed otherwise. To tell Instance Manager to try again, you must first use `STOP INSTANCE` to put the instance in offline state, and then use `START INSTANCE` to start the instance. If it is necessary to make configuration changes for the instance, you must do so after putting the instance offline and before starting it. (Instance Manager accepts configuration-changing commands only for offline instances.) Nonguarded instances cannot be in this state.

4.6.10.6 Connecting to MySQL Instance Manager

Important

MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

After you set up a password file for the MySQL Instance Manager and Instance Manager is running, you can connect to it. The MySQL client/server protocol is used to communicate with the Instance Manager. For example, you can connect to it using the standard `mysql` client program:

```
shell> mysql --port=2273 --host=im.example.org --user=mysql --password
```

Instance Manager supports the version of the MySQL client/server protocol used by the client tools and libraries distributed with MySQL 4.1 or later, so other programs that use the MySQL C API also can connect to it.

4.6.10.7 MySQL Instance Manager Commands

> **Important**
>
> MySQL Instance Manager has been deprecated and is removed in MySQL 5.5.

After you connect to MySQL Instance Manager, you can issue commands. The following general principles apply to Instance Manager command execution:

- Commands that take an instance name fail if the name is not a valid instance name.

- Commands that take an instance name (other than `CREATE INSTANCE`) fail if the instance does not exist.

- As of MySQL 5.1.12, commands for an instance require that the instance be in an appropriate state. You cannot configure or start an instance that is not offline. You cannot start an instance that is online.

- Instance Manager maintains information about instance configuration in an internal (in-memory) cache. Initially, this information comes from the configuration file if it exists, but some commands change the configuration of an instance. Commands that modify the configuration file fail if the file does not exist or is not accessible to Instance Manager.

  As of MySQL 5.1.12, configuration-changing commands modify both the in-memory cache and the server instance section recorded in the configuration file to maintain consistency between them. For this to occur, the instance must be offline and the configuration file must be accessible and not malformed. If the configuration file cannot be updated, the command fails and the cache remains unchanged.

- On Windows, the standard file is `my.ini` in the directory where Instance Manager is installed. On Unix, the standard configuration file is `/etc/my.cnf`. To specify a different configuration file, start Instance Manager with the `--defaults-file` option.

- If a `[mysqld]` instance section exists in the configuration file, it must not contain any Instance Manager-specific options (see Section 4.6.10.2, "MySQL Instance Manager Configuration Files"). Therefore, you must not add any of these options if you change the configuration for an instance named `mysqld`.

The following list describes the commands that Instance Manager accepts, with examples.

- `CREATE INSTANCE` *instance_name* [*option_name*[=*option_value*], ...]

  This command configures a new instance by creating an [*instance_name*] section in the configuration file. The command fails if *instance_name* is not a valid instance name or the instance already exists.

  The created section instance is empty if no options are given. Otherwise, the options are added to the section. Options should be given in the same format used when you write options in option files. (See Section 4.2.6, "Using Option Files" for a description of the permissible syntax.) If you specify multiple options, separate them by commas.

For example, to create an instance section named `[mysqld98]`, you might write something like this were you to modify the configuration file directly:

```
[mysqld98]
basedir=/var/mysql98
```

To achieve the same effect using `CREATE INSTANCE`, issue this command to Instance Manager:

```
mysql> CREATE INSTANCE mysqld98 basedir="/var/mysql98";
Query OK, 0 rows affected (0,00 sec)
```

`CREATE INSTANCE` creates the instance but does not start it.

If the instance name is the (deprecated) name `mysqld`, the option list cannot include any options that are specific to Instance Manager, such as `nonguarded` (see Section 4.6.10.2, "MySQL Instance Manager Configuration Files").

This command was added in MySQL 5.1.12.

- `DROP INSTANCE` *instance_name*

  This command removes the configuration for *instance_name* from the configuration file.

  ```
  mysql> DROP INSTANCE mysqld98;
  Query OK, 0 rows affected (0,00 sec)
  ```

  The command fails if *instance_name* is not a valid instance name, the instance does not exist, or is not offline.

  This command was added in MySQL 5.1.12.

- `START INSTANCE` *instance_name*

  This command attempts to start an offline instance. The command is asynchronous; it does not wait for the instance to start.

  ```
  mysql> START INSTANCE mysqld4;
  Query OK, 0 rows affected (0,00 sec)
  ```

- `STOP INSTANCE` *instance_name*

  This command attempts to stop an instance. The command is synchronous; it waits for the instance to stop.

  ```
  mysql> STOP INSTANCE mysqld4;
  Query OK, 0 rows affected (0,00 sec)
  ```

- `SHOW INSTANCES`

  Shows the names and status of all loaded instances.

  ```
  mysql> SHOW INSTANCES;
  +---------------+---------+
  | instance_name | status  |
  +---------------+---------+
  ```

```
| mysqld3      | offline |
| mysqld4      | online  |
| mysqld2      | offline |
+--------------+---------+
```

- SHOW INSTANCE STATUS *instance_name*

  Shows status and version information for an instance.

```
mysql> SHOW INSTANCE STATUS mysqld3;
+--------------+--------+---------+
| instance_name | status | version |
+--------------+--------+---------+
| mysqld3      | online | unknown |
+--------------+--------+---------+
```

- SHOW INSTANCE OPTIONS *instance_name*

  Shows the options used by an instance.

```
mysql> SHOW INSTANCE OPTIONS mysqld3;
+--------------+------------------------------------------------+
| option_name  | value                                          |
+--------------+------------------------------------------------+
| instance_name | mysqld3                                        |
| mysqld-path  | /home/cps/mysql/trees/mysql-4.1/sql/mysqld     |
| port         | 3309                                           |
| socket       | /tmp/mysql.sock3                               |
| pid-file     | hostname.pid3                                  |
| datadir      | /home/cps/mysql_data/data_dir1/                |
| language     | /home/cps/mysql/trees/mysql-4.1/sql/share/english |
+--------------+------------------------------------------------+
```

- SHOW *instance_name* LOG FILES

  The command lists all log files used by the instance. The result set contains the path to the log file and the log file size. If no log file path is specified in the instance section of the configuration file (for example, `log=/var/mysql.log`), the Instance Manager tries to guess its placement. If Instance Manager is unable to guess the log file placement you should specify the log file location explicitly by using a log option in the appropriate instance section of the configuration file.

```
mysql> SHOW mysqld LOG FILES;
+-------------+------------------------------------+----------+
| Logfile     | Path                               | Filesize |
+-------------+------------------------------------+----------+
| ERROR LOG   | /home/cps/var/mysql/owlet.err      | 9186     |
| GENERAL LOG | /home/cps/var/mysql/owlet.log      | 471503   |
| SLOW LOG    | /home/cps/var/mysql/owlet-slow.log | 4463     |
+-------------+------------------------------------+----------+
```

  SHOW ... LOG FILES displays information only about log files. If a server instance uses log tables (see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations"), no information about those tables is shown.

  Log options are described in Section 5.1.3, "Server Command Options".

- SHOW *instance_name* LOG {ERROR | SLOW | GENERAL} *size*[,*offset_from_end*]

  This command retrieves a portion of the specified log file. Because most users are interested in the latest log messages, the *size* parameter defines the number of bytes to retrieve from the end of the log.

To retrieve data from the middle of the log file, specify the optional *offset_from_end* parameter. The following example retrieves 21 bytes of data, starting 23 bytes before the end of the log file and ending 2 bytes before the end:

```
mysql> SHOW mysqld LOG GENERAL 21, 2;
+--------------------+
| Log                |
+--------------------+
| using password: YES |
+--------------------+
```

- SET *instance_name.option_name*[*=option_value*]

  This command edits the specified instance's configuration section to change or add instance options. The option is added to the section is it is not already present. Otherwise, the new setting replaces the existing one.

  ```
  mysql> SET mysqld2.port=3322;
  Query OK, 0 rows affected (0.00 sec)
  ```

  As of MySQL 5.1.12, you can specify multiple options (separated by commas), and SET can be used only for offline instances. Each option must indicate the instance name:

  ```
  mysql> SET mysqld2.port=3322, mysqld3.nonguarded;
  Query OK, 0 rows affected (0.00 sec)
  ```

  Before MySQL 5.1.12, only a single option can be specified. Also, changes made to the configuration file do not take effect until the MySQL server is restarted. In addition, these changes are not stored in the instance manager's local cache of instance settings until a FLUSH INSTANCES command is executed.

- UNSET *instance_name.option_name*

  This command removes an option from an instance's configuration section.

  ```
  mysql> UNSET mysqld2.port;
  Query OK, 0 rows affected (0.00 sec)
  ```

  As of MySQL 5.1.12, you can specify multiple options (separated by commas), and UNSET can be used only for offline instances. Each option must indicate the instance name:

  ```
  mysql> UNSET mysqld2.port, mysqld4.nonguarded;
  Query OK, 0 rows affected (0.00 sec)
  ```

  Before MySQL 5.1.12, only a single option can be specified. Also, changes made to the configuration file do not take effect until the MySQL server is restarted. In addition, these changes are not stored in the instance manager's local cache of instance settings until a FLUSH INSTANCES command is executed.

- FLUSH INSTANCES

  As of MySQL 5.1.12, FLUSH INSTANCES cannot be used unless all instances are offline. The command causes Instance Manager to reread the configuration file, update its in-memory configuration cache, and start any guarded instances.

Before MySQL 5.1.12, this command forces Instance Manager reread the configuration file and to refresh internal structures. This command should be performed after editing the configuration file. The command does not restart instances.

```
mysql> FLUSH INSTANCES;
Query OK, 0 rows affected (0.04 sec)
```

4.6.11 `mysql_convert_table_format` — Convert Tables to Use a Given Storage Engine

mysql_convert_table_format converts the tables in a database to use a particular storage engine (MyISAM by default). mysql_convert_table_format is written in Perl and requires that the DBI and DBD::mysql Perl modules be installed (see Section 2.15, "Perl Installation Notes").

Invoke mysql_convert_table_format like this:

```
shell> mysql_convert_table_format [options]db_name
```

The *db_name* argument indicates the database containing the tables to be converted.

mysql_convert_table_format supports the options described in the following list.

- --help

  Display a help message and exit.

- --force

  Continue even if errors occur.

- --host=*host_name*

  Connect to the MySQL server on the given host.

- --password=*password*

  The password to use when connecting to the server. Note that the password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- --port=*port_num*

  The TCP/IP port number to use for the connection.

- --socket=*path*

  For connections to localhost, the Unix socket file to use.

- --type=*engine_name*

  Specify the storage engine that the tables should be converted to use. The default is MyISAM if this option is not given.

- --user=*user_name*

The MySQL user name to use when connecting to the server.

- `--verbose`

  Verbose mode. Print more information about what the program does.

- `--version`

  Display version information and exit.

4.6.12 `mysql_find_rows` — Extract SQL Statements from Files

`mysql_find_rows` reads files containing SQL statements and extracts statements that match a given regular expression or that contain `USE db_name` or `SET` statements. The utility was written for use with update log files (as used prior to MySQL 5.0) and as such expects statements to be terminated with semicolon (`;`) characters. It may be useful with other files that contain SQL statements as long as statements are terminated with semicolons.

Invoke `mysql_find_rows` like this:

```
shell> mysql_find_rows [options] [file_name ...]
```

Each `file_name` argument should be the name of file containing SQL statements. If no file names are given, `mysql_find_rows` reads the standard input.

Examples:

```
mysql_find_rows --regexp=problem_table --rows=20 < update.log
mysql_find_rows --regexp=problem_table  update-log.1 update-log.2
```

`mysql_find_rows` supports the following options:

- `--help`, `--Information`

  Display a help message and exit.

- `--regexp=pattern`

  Display queries that match the pattern.

- `--rows=N`

  Quit after displaying `N` queries.

- `--skip-use-db`

  Do not include `USE db_name` statements in the output.

- `--start_row=N`

  Start output from this row.

4.6.13 `mysql_fix_extensions` — Normalize Table File Name Extensions

`mysql_fix_extensions` converts the extensions for `MyISAM` (or `ISAM`) table files to their canonical forms. It looks for files with extensions matching any lettercase variant of `.frm`, `.myd`, `.myi`, `.isd`, and `.ism` and renames them to have extensions of `.frm`, `.MYD`, `.MYI`, `.ISD`, and `.ISM`, respectively. This can

be useful after transferring the files from a system with case-insensitive file names (such as Windows) to a system with case-sensitive file names.

Invoke `mysql_fix_extensions` like this, where *`data_dir`* is the path name to the MySQL data directory.

```
shell> mysql_fix_extensions data_dir
```

4.6.14 `mysql_setpermission` — Interactively Set Permissions in Grant Tables

`mysql_setpermission` is a Perl script that was originally written and contributed by Luuk de Boer. It interactively sets permissions in the MySQL grant tables. `mysql_setpermission` is written in Perl and requires that the `DBI` and `DBD::mysql` Perl modules be installed (see Section 2.15, "Perl Installation Notes").

Invoke `mysql_setpermission` like this:

```
shell> mysql_setpermission [options]
```

`options` should be either `--help` to display the help message, or options that indicate how to connect to the MySQL server. The account used when you connect determines which permissions you have when attempting to modify existing permissions in the grant tables.

`mysql_setpermissions` also reads options from the `[client]` and `[perl]` groups in the `.my.cnf` file in your home directory, if the file exists.

`mysql_setpermission` supports the following options:

- `--help`

  Display a help message and exit.

- `--host=`*`host_name`*

  Connect to the MySQL server on the given host.

- `--password=`*`password`*

  The password to use when connecting to the server. Note that the password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--port=`*`port_num`*

  The TCP/IP port number to use for the connection.

- `--socket=`*`path`*

  For connections to `localhost`, the Unix socket file to use.

- `--user=`*`user_name`*

  The MySQL user name to use when connecting to the server.

4.6.15 `mysql_waitpid` — Kill Process and Wait for Its Termination

`mysql_waitpid` signals a process to terminate and waits for the process to exit. It uses the `kill()` system call and Unix signals, so it runs on Unix and Unix-like systems.

Invoke `mysql_waitpid` like this:

```
shell> mysql_waitpid [options] pid wait_time
```

`mysql_waitpid` sends signal 0 to the process identified by `pid` and waits up to `wait_time` seconds for the process to terminate. `pid` and `wait_time` must be positive integers.

If process termination occurs within the wait time or the process does not exist, `mysql_waitpid` returns 0. Otherwise, it returns 1.

If the `kill()` system call cannot handle signal 0, `mysql_waitpid()` uses signal 1 instead.

`mysql_waitpid` supports the following options:

- `--help`, `-?`, `-I`

  Display a help message and exit.

- `--verbose`, `-v`

  Verbose mode. Display a warning if signal 0 could not be used and signal 1 is used instead.

- `--version`, `-V`

  Display version information and exit.

4.6.16 `mysql_zap` — Kill Processes That Match a Pattern

`mysql_zap` kills processes that match a pattern. It uses the `ps` command and Unix signals, so it runs on Unix and Unix-like systems.

Invoke `mysql_zap` like this:

```
shell> mysql_zap [-signal] [-?Ift] pattern
```

A process matches if its output line from the `ps` command contains the pattern. By default, `mysql_zap` asks for confirmation for each process. Respond `y` to kill the process, or `q` to exit `mysql_zap`. For any other response, `mysql_zap` does not attempt to kill the process.

If the `-signal` option is given, it specifies the name or number of the signal to send to each process. Otherwise, `mysql_zap` tries first with `TERM` (signal 15) and then with `KILL` (signal 9).

`mysql_zap` supports the following additional options:

- `--help`, `-?`, `-I`

  Display a help message and exit.

- `-f`

  Force mode. `mysql_zap` attempts to kill each process without confirmation.

- `-t`

  Test mode. Display information about each process but do not kill it.

4.7 MySQL Program Development Utilities

This section describes some utilities that you may find useful when developing MySQL programs.

In shell scripts, you can use the `my_print_defaults` program to parse option files and see what options would be used by a given program. The following example shows the output that `my_print_defaults` might produce when asked to show the options found in the `[client]` and `[mysql]` groups:

```
shell> my_print_defaults client mysql
--port=3306
--socket=/tmp/mysql.sock
--no-auto-rehash
```

Note for developers: Option file handling is implemented in the C client library simply by processing all options in the appropriate group or groups before any command-line arguments. This works well for programs that use the last instance of an option that is specified multiple times. If you have a C or C++ program that handles multiply specified options this way but that doesn't read option files, you need add only two lines to give it that capability. Check the source code of any of the standard MySQL clients to see how to do this.

Several other language interfaces to MySQL are based on the C client library, and some of them provide a way to access option file contents. These include Perl and Python. For details, see the documentation for your preferred interface.

4.7.1 `msql2mysql` — Convert mSQL Programs for Use with MySQL

Initially, the MySQL C API was developed to be very similar to that for the mSQL database system. Because of this, mSQL programs often can be converted relatively easily for use with MySQL by changing the names of the C API functions.

The `msql2mysql` utility performs the conversion of mSQL C API function calls to their MySQL equivalents. `msql2mysql` converts the input file in place, so make a copy of the original before converting it. For example, use `msql2mysql` like this:

```
shell> cp client-prog.c client-prog.c.orig
shell> msql2mysql client-prog.c
client-prog.c converted
```

Then examine `client-prog.c` and make any post-conversion revisions that may be necessary.

`msql2mysql` uses the `replace` utility to make the function name substitutions. See Section 4.8.2, "`replace` — A String-Replacement Utility".

4.7.2 `mysql_config` — Display Options for Compiling Clients

`mysql_config` provides you with useful information for compiling your MySQL client and connecting it to MySQL. It is a shell script, so it is available only on Unix and Unix-like systems.

`mysql_config` supports the following options.

- `--cflags`

Compiler flags to find include files and critical compiler flags and defines used when compiling the `libmysqlclient` library. The options returned are tied to the specific compiler that was used when the library was created and might clash with the settings for your own compiler. Use `--include` for more portable options that contain only include paths.

- `--include`

  Compiler options to find MySQL include files.

- `--libmysqld-libs`, `--embedded`

  Libraries and options required to link with the MySQL embedded server.

- `--libs`

  Libraries and options required to link with the MySQL client library.

- `--libs_r`

  Libraries and options required to link with the thread-safe MySQL client library.

- `--plugindir`

  The default plugin directory path name, defined when configuring MySQL. This option was added in MySQL 5.1.24.

- `--port`

  The default TCP/IP port number, defined when configuring MySQL.

- `--socket`

  The default Unix socket file, defined when configuring MySQL.

- `--version`

  Version number for the MySQL distribution.

If you invoke `mysql_config` with no options, it displays a list of all options that it supports, and their values:

```
shell> mysql_config
Usage: /usr/local/mysql/bin/mysql_config [options]
Options:
  --cflags           [-I/usr/local/mysql/include/mysql -mcpu=pentiumpro]
  --include          [-I/usr/local/mysql/include/mysql]
  --libs             [-L/usr/local/mysql/lib/mysql -lmysqlclient -lz
                      -lz -lcrypt -lnsl -lm]
  --libs_r           [-L/usr/local/mysql/lib/mysql -lmysqlclient_r
                      -lz -lpthread -lcrypt -lnsl -lm -lpthread]
  --socket           [/tmp/mysql.sock]
  --port             [3306]
  --version          [5.1.69]
  --libmysqld-libs [-L/usr/local/mysql/lib/mysql -lmysqld -ldl
                      -lz -lpthread -lcrypt -lnsl -lm -lpthread -lrt]
```

You can use `mysql_config` within a command line using backticks to include the output that it produces for particular options. For example, to compile and link a MySQL client program, use `mysql_config` as follows:

```
gcc -c `mysql_config --cflags` progname.c
gcc -o progname progname.o `mysql_config --libs`
```

4.7.3 `my_print_defaults` — Display Options from Option Files

`my_print_defaults` displays the options that are present in option groups of option files. The output indicates what options will be used by programs that read the specified option groups. For example, the `mysqlcheck` program reads the `[mysqlcheck]` and `[client]` option groups. To see what options are present in those groups in the standard option files, invoke `my_print_defaults` like this:

```
shell> my_print_defaults mysqlcheck client
--user=myusername
--password=secret
--host=localhost
```

The output consists of options, one per line, in the form that they would be specified on the command line.

`my_print_defaults` supports the following options.

- `--help`, `-?`

  Display a help message and exit.

- `--config-file=file_name`, `--defaults-file=file_name`, `-c file_name`

  Read only the given option file.

- `--debug=debug_options`, `-# debug_options`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o,/tmp/my_print_defaults.trace`.

- `--defaults-extra-file=file_name`, `--extra-file=file_name`, `-e file_name`

  Read this option file after the global option file but (on Unix) before the user option file.

- `--defaults-group-suffix=suffix`, `-g suffix`

  In addition to the groups named on the command line, read groups that have the given suffix.

- `--no-defaults`, `-n`

  Return an empty string.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

4.7.4 `resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols

`resolve_stack_dump` resolves a numeric stack dump to symbols.

Invoke `resolve_stack_dump` like this:

```
shell> resolve_stack_dump [options] symbols_file [numeric_dump_file]
```

The symbols file should include the output from the `nm --numeric-sort mysqld` command. The numeric dump file should contain a numeric stack track from `mysqld`. If no numeric dump file is named on the command line, the stack trace is read from the standard input.

`resolve_stack_dump` supports the following options.

- `--help`, `-h`

  Display a help message and exit.

- `--numeric-dump-file=file_name`, `-n file_name`

  Read the stack trace from the given file.

- `--symbols-file=file_name`, `-s file_name`

  Use the given symbols file.

- `--version`, `-V`

  Display version information and exit.

For more information, see Section 22.4.1.5, "Using a Stack Trace".

4.8 Miscellaneous Programs

4.8.1 `perror` — Explain Error Codes

For most system errors, MySQL displays, in addition to an internal text message, the system error code in one of the following styles:

```
message ... (errno: #)
message ... (Errcode: #)
```

You can find out what the error code means by examining the documentation for your system or by using the `perror` utility.

`perror` prints a description for a system error code or for a storage engine (table handler) error code.

Invoke `perror` like this:

```
shell> perror [options] errorcode ...
```

Example:

```
shell> perror 13 64
OS error code  13:  Permission denied
OS error code  64:  Machine is not on the network
```

To obtain the error message for a MySQL Cluster error code, invoke `perror` with the `--ndb` option:

```
shell> perror --ndb errorcode
```

The meaning of system error messages may be dependent on your operating system. A given error code may mean different things on different operating systems.

`perror` supports the following options.

- `--help`, `--info`, `-I`, `-?`

  Display a help message and exit.

- `--ndb`

  Print the error message for a MySQL Cluster error code.

- `--silent`, `-s`

  Silent mode. Print only the error message.

- `--verbose`, `-v`

  Verbose mode. Print error code and message. This is the default behavior.

- `--version`, `-V`

  Display version information and exit.

4.8.2 `replace` — A String-Replacement Utility

The `replace` utility program changes strings in place in files or on the standard input.

Invoke `replace` in one of the following ways:

```
shell> replace from to [from to] ... -- file_name [file_name] ...
shell> replace from to [from to] ... < file_name
```

`from` represents a string to look for and `to` represents its replacement. There can be one or more pairs of strings.

Use the `--` option to indicate where the string-replacement list ends and the file names begin. In this case, any file named on the command line is modified in place, so you may want to make a copy of the original before converting it. `replace` prints a message indicating which of the input files it actually modifies.

If the `--` option is not given, `replace` reads the standard input and writes to the standard output.

`replace` uses a finite state machine to match longer strings first. It can be used to swap strings. For example, the following command swaps `a` and `b` in the given files, `file1` and `file2`:

```
shell> replace a b b a -- file1 file2 ...
```

The `replace` program is used by `msql2mysql`. See Section 4.7.1, "`msql2mysql` — Convert mSQL Programs for Use with MySQL".

`replace` supports the following options.

- `-?`, `-I`

Display a help message and exit.

- `-#debug_options`

  Enable debugging.

- `-s`

  Silent mode. Print less information what the program does.

- `-v`

  Verbose mode. Print more information about what the program does.

- `-V`

  Display version information and exit.

4.8.3 `resolveip` — Resolve Host name to IP Address or Vice Versa

The `resolveip` utility resolves host names to IP addresses and vice versa.

Invoke `resolveip` like this:

```
shell> resolveip [options] {host_name|ip-addr} ...
```

`resolveip` supports the following options.

- `--help`, `--info`, `-?`, `-I`

  Display a help message and exit.

- `--silent`, `-s`

  Silent mode. Produce less output.

- `--version`, `-V`

  Display version information and exit.

Chapter 5 MySQL Server Administration

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End of Product Lifecycle.   Active development for MySQL Database Server version 5.1 has ended. Oracle offers various support offerings which may be of interest. For details and more information, see the MySQL section of the Lifetime Support Policy for Oracle Technology Products (http://www.oracle.com/us/support/lifetime-support/index.html). Please consider upgrading to a recent version.

MySQL Server (`mysqld`) is the main program that does most of the work in a MySQL installation. This chapter provides an overview of MySQL Server and covers general server administration:

• Server configuration

• The data directory, particularly the `mysql` system database

• The server log files

• Management of multiple servers on a single machine

For additional information on administrative topics, see also:

• Chapter 6, *Security*

• Chapter 7, *Backup and Recovery*

• Chapter 16, *Replication*

5.1 The MySQL Server

`mysqld` is the MySQL server. The following discussion covers these MySQL server configuration topics:

- Startup options that the server supports. You can specify these options on the command line, through configuration files, or both.

- Server system variables. These variables reflect the current state and values of the startup options, some of which can be modified while the server is running.

- Server status variables. These variables contain counters and statistics about runtime operation.

- How to set the server SQL mode. This setting modifies certain aspects of SQL syntax and semantics, for example for compatibility with code from other database systems, or to control the error handling for particular situations.

- The server shutdown process. There are performance and reliability considerations depending on the type of table (transactional or nontransactional) and whether you use replication.

> **Note**
>
> Not all storage engines are supported by all MySQL server binaries and configurations. To find out how to determine which storage engines your MySQL server installation supports, see Section 13.7.5.17, "SHOW ENGINES Syntax".

5.1.1 Server Option and Variable Reference

The following table provides a list of all the command line options, server and status variables applicable within `mysqld`.

The table lists command-line options (Cmd-line), options valid in configuration files (Option file), server system variables (System Var), and status variables (Status var) in one unified list, with notification of where each option/variable is valid. If a server option set on the command line or in an option file differs from the name of the corresponding server system or status variable, the variable name is noted immediately below the corresponding option. For status variables, the scope of the variable is shown (Scope) as either global, session, or both. Please see the corresponding sections for details on setting and using the options and variables. Where appropriate, a direct link to further information on the item as available.

For a version of this table that is specific to MySQL Cluster, see Section 17.3.2.5, "MySQL Cluster mysqld Option and Variable Reference".

Table 5.1 Option/Variable Summary

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
abort-slave-event-count	Yes	Yes				
Aborted_clients				Yes	Global	No
Aborted_connects				Yes	Global	No
allow-suspicious-udfs	Yes	Yes				
ansi	Yes	Yes				
auto_increment_increment			Yes		Both	Yes
auto_increment_offset			Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
autocommit			Yes		Session	Yes
automatic_sp_privileges			Yes		Global	Yes
back_log			Yes		Global	No
basedir	Yes	Yes	Yes		Global	No
big-tables	Yes	Yes			Session	Yes
- *Variable*: big_tables			Yes		Session	Yes
bind-address	Yes	Yes				
Binlog_cache_disk_use				Yes	Global	No
binlog_cache_size	Yes	Yes	Yes		Global	Yes
Binlog_cache_use				Yes	Global	No
binlog_direct_non_transactional_updates	Yes	Yes	Yes		Both	Yes
binlog-do-db	Yes	Yes				
binlog-format	Yes	Yes			Both	Yes
- *Variable*: binlog_format			Yes		Both	Yes
binlog-ignore-db	Yes	Yes				
binlog-row-event-max-size	Yes	Yes				
bootstrap	Yes	Yes				
bulk_insert_buffer_size	Yes	Yes	Yes		Both	Yes
Bytes_received				Yes	Both	No
Bytes_sent				Yes	Both	No
character_set_client			Yes		Both	Yes
character-set-client-handshake	Yes	Yes				
character_set_connection			Yes		Both	Yes
character_set_database[a]			Yes		Both	Yes
character-set-filesystem	Yes	Yes			Both	Yes
- *Variable*: character_set_filesystem			Yes		Both	Yes
character_set_results			Yes		Both	Yes
character-set-server	Yes	Yes			Both	Yes
- *Variable*: character_set_server			Yes		Both	Yes
character_set_system			Yes		Global	No
character-sets-dir	Yes	Yes			Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
- *Variable*: character_sets_dir			Yes		Global	No
chroot	Yes	Yes				
collation_connection			Yes		Both	Yes
collation_database[b]			Yes		Both	Yes
collation-server	Yes	Yes			Both	Yes
- *Variable*: collation_server			Yes		Both	Yes
Com_admin_commands				Yes	Both	No
Com_alter_db				Yes	Both	No
Com_alter_db_upgrade				Yes	Both	No
Com_alter_event				Yes	Both	No
Com_alter_function				Yes	Both	No
Com_alter_procedure				Yes	Both	No
Com_alter_server				Yes	Both	No
Com_alter_table				Yes	Both	No
Com_alter_tablespace				Yes	Both	No
Com_analyze				Yes	Both	No
Com_assign_to_keycache				Yes	Both	No
Com_backup_table				Yes	Both	No
Com_begin				Yes	Both	No
Com_binlog				Yes	Both	No
Com_call_procedure				Yes	Both	No
Com_change_db				Yes	Both	No
Com_change_master				Yes	Both	No
Com_check				Yes	Both	No
Com_checksum				Yes	Both	No
Com_commit				Yes	Both	No
Com_create_db				Yes	Both	No
Com_create_event				Yes	Both	No
Com_create_function				Yes	Both	No
Com_create_index				Yes	Both	No
Com_create_procedure				Yes	Both	No
Com_create_server				Yes	Both	No
Com_create_table				Yes	Both	No
Com_create_trigger				Yes	Both	No
Com_create_udf				Yes	Both	No
Com_create_user				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Com_create_view				Yes	Both	No
Com_dealloc_sql				Yes	Both	No
Com_delete				Yes	Both	No
Com_delete_multi				Yes	Both	No
Com_do				Yes	Both	No
Com_drop_db				Yes	Both	No
Com_drop_event				Yes	Both	No
Com_drop_function				Yes	Both	No
Com_drop_index				Yes	Both	No
Com_drop_procedure				Yes	Both	No
Com_drop_server				Yes	Both	No
Com_drop_table				Yes	Both	No
Com_drop_trigger				Yes	Both	No
Com_drop_user				Yes	Both	No
Com_drop_view				Yes	Both	No
Com_empty_query				Yes	Both	No
Com_execute_sql				Yes	Both	No
Com_flush				Yes	Both	No
Com_grant				Yes	Both	No
Com_ha_close				Yes	Both	No
Com_ha_open				Yes	Both	No
Com_ha_read				Yes	Both	No
Com_help				Yes	Both	No
Com_insert				Yes	Both	No
Com_insert_select				Yes	Both	No
Com_install_plugin				Yes	Both	No
Com_kill				Yes	Both	No
Com_load				Yes	Both	No
Com_lock_tables				Yes	Both	No
Com_optimize				Yes	Both	No
Com_preload_keys				Yes	Both	No
Com_prepare_sql				Yes	Both	No
Com_purge				Yes	Both	No
Com_purge_before_date				Yes	Both	No
Com_release_savepoint				Yes	Both	No
Com_rename_table				Yes	Both	No
Com_rename_user				Yes	Both	No
Com_repair				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Com_replace				Yes	Both	No
Com_replace_select				Yes	Both	No
Com_reset				Yes	Both	No
Com_restore_table				Yes	Both	No
Com_revoke				Yes	Both	No
Com_revoke_all				Yes	Both	No
Com_rollback				Yes	Both	No
Com_rollback_to_savepoint				Yes	Both	No
Com_savepoint				Yes	Both	No
Com_select				Yes	Both	No
Com_set_option				Yes	Both	No
Com_show_authors				Yes	Both	No
Com_show_binlog_events				Yes	Both	No
Com_show_binlogs				Yes	Both	No
Com_show_charsets				Yes	Both	No
Com_show_collations				Yes	Both	No
Com_show_column_types				Yes	Both	No
Com_show_contributors				Yes	Both	No
Com_show_create_db				Yes	Both	No
Com_show_create_event				Yes	Both	No
Com_show_create_func				Yes	Both	No
Com_show_create_proc				Yes	Both	No
Com_show_create_table				Yes	Both	No
Com_show_create_trigger				Yes	Both	No
Com_show_databases				Yes	Both	No
Com_show_engine_logs				Yes	Both	No
Com_show_engine_mutex				Yes	Both	No
Com_show_engine_status				Yes	Both	No
Com_show_errors				Yes	Both	No
Com_show_events				Yes	Both	No
Com_show_fields				Yes	Both	No
Com_show_function_code				Yes	Both	No
Com_show_function_status				Yes	Both	No
Com_show_grants				Yes	Both	No
Com_show_keys				Yes	Both	No
Com_show_logs				Yes	Both	No
Com_show_master_status				Yes	Both	No
Com_show_ndb_status				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Com_show_new_master				Yes	Both	No
Com_show_open_tables				Yes	Both	No
Com_show_plugins				Yes	Both	No
Com_show_privileges				Yes	Both	No
Com_show_procedure_code				Yes	Both	No
Com_show_procedure_status				Yes	Both	No
Com_show_processlist				Yes	Both	No
Com_show_profile				Yes	Both	No
Com_show_profiles				Yes	Both	No
Com_show_slave_hosts				Yes	Both	No
Com_show_slave_status				Yes	Both	No
Com_show_status				Yes	Both	No
Com_show_storage_engines				Yes	Both	No
Com_show_table_status				Yes	Both	No
Com_show_tables				Yes	Both	No
Com_show_triggers				Yes	Both	No
Com_show_variables				Yes	Both	No
Com_show_warnings				Yes	Both	No
Com_slave_start				Yes	Both	No
Com_slave_stop				Yes	Both	No
Com_stmt_close				Yes	Both	No
Com_stmt_execute				Yes	Both	No
Com_stmt_fetch				Yes	Both	No
Com_stmt_prepare				Yes	Both	No
Com_stmt_reprepare				Yes	Both	No
Com_stmt_reset				Yes	Both	No
Com_stmt_send_long_data				Yes	Both	No
Com_truncate				Yes	Both	No
Com_uninstall_plugin				Yes	Both	No
Com_unlock_tables				Yes	Both	No
Com_update				Yes	Both	No
Com_update_multi				Yes	Both	No
Com_xa_commit				Yes	Both	No
Com_xa_end				Yes	Both	No
Com_xa_prepare				Yes	Both	No
Com_xa_recover				Yes	Both	No
Com_xa_rollback				Yes	Both	No
Com_xa_start				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
completion_type	Yes	Yes	Yes		Both	Yes
Compression				Yes	Session	No
concurrent_insert	Yes	Yes	Yes		Global	Yes
connect_timeout	Yes	Yes	Yes		Global	Yes
Connections				Yes	Global	No
console	Yes	Yes				
core-file	Yes	Yes				
Created_tmp_disk_tables				Yes	Both	No
Created_tmp_files				Yes	Global	No
Created_tmp_tables				Yes	Both	No
datadir	Yes	Yes	Yes		Global	No
date_format			Yes		Both	No
datetime_format			Yes		Both	No
debug	Yes	Yes	Yes		Both	Yes
debug_sync			Yes		Both	Yes
debug-sync-timeout	Yes	Yes				
default-character-set	Yes	Yes				
default-storage-engine	Yes	Yes	Yes		Both	Yes
default-table-type	Yes	Yes				
default-time-zone	Yes	Yes				
default_week_format	Yes	Yes	Yes		Both	Yes
defaults-extra-file	Yes					
defaults-file	Yes					
defaults-group-suffix	Yes					
delay-key-write	Yes	Yes			Global	Yes
- *Variable*: delay_key_write			Yes		Global	Yes
Delayed_errors				Yes	Global	No
delayed_insert_limit	Yes	Yes	Yes		Global	Yes
Delayed_insert_threads				Yes	Global	No
delayed_insert_timeout	Yes	Yes	Yes		Global	Yes
delayed_queue_size	Yes	Yes	Yes		Global	Yes
Delayed_writes				Yes	Global	No
des-key-file	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
disconnect-slave-event-count	Yes	Yes				
div_precision_increment	Yes	Yes	Yes		Both	Yes
enable-locking	Yes	Yes				
enable-named-pipe	Yes	Yes				
- *Variable*: named_pipe						
enable-pstack	Yes	Yes				
engine-condition-pushdown	Yes	Yes			Both	Yes
- *Variable*: engine_condition_pushdown			Yes		Both	Yes
error_count			Yes		Session	No
event-scheduler	Yes	Yes			Global	Yes
- *Variable*: event_scheduler			Yes		Global	Yes
exit-info	Yes	Yes				
expire_logs_days	Yes	Yes	Yes		Global	Yes
external-locking	Yes	Yes				
- *Variable*: skip_external_locking						
federated	Yes	Yes				
flush	Yes	Yes	Yes		Global	Yes
Flush_commands				Yes	Global	No
flush_time	Yes	Yes	Yes		Global	Yes
foreign_key_checks			Yes		Session	Yes
ft_boolean_syntax	Yes	Yes	Yes		Global	Yes
ft_max_word_len	Yes	Yes	Yes		Global	No
ft_min_word_len	Yes	Yes	Yes		Global	No
ft_query_expansion_limit	Yes	Yes	Yes		Global	No
ft_stopword_file	Yes	Yes	Yes		Global	No
gdb	Yes	Yes				
general-log	Yes	Yes			Global	Yes
- *Variable*: general_log			Yes		Global	Yes
general_log_file	Yes	Yes	Yes		Global	Yes
group_concat_max_len	Yes	Yes	Yes		Both	Yes
Handler_commit				Yes	Both	No
Handler_delete				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Handler_discover				Yes	Both	No
Handler_prepare				Yes	Both	No
Handler_read_first				Yes	Both	No
Handler_read_key				Yes	Both	No
Handler_read_next				Yes	Both	No
Handler_read_prev				Yes	Both	No
Handler_read_rnd				Yes	Both	No
Handler_read_rnd_next				Yes	Both	No
Handler_rollback				Yes	Both	No
Handler_savepoint				Yes	Both	No
Handler_savepoint_rollback				Yes	Both	No
Handler_update				Yes	Both	No
Handler_write				Yes	Both	No
have_archive			Yes		Global	No
have_blackhole_engine			Yes		Global	No
have_community_features			Yes		Global	No
have_compress			Yes		Global	No
have_crypt			Yes		Global	No
have_csv			Yes		Global	No
have_dynamic_loading			Yes		Global	No
have_example_engine			Yes		Global	No
have_federated_engine			Yes		Global	No
have_geometry			Yes		Global	No
have_innodb			Yes		Global	No
have_isam			Yes		Global	No
have_merge_engine			Yes		Global	No
have_ndbcluster			Yes		Global	No
have_openssl			Yes		Global	No
have_partition_engine			Yes		Global	No
have_partitioning			Yes		Global	No
have_query_cache			Yes		Global	No
have_raid			Yes		Global	No
have_row_based_replication			Yes		Global	No
have_rtree_keys			Yes		Global	No
have_ssl			Yes		Global	No
have_symlink			Yes		Global	No
help	Yes	Yes				
hostname			Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
identity			Yes		Session	Yes
ignore-builtin-innodb	Yes	Yes			Global	No
- *Variable*: ignore_builtin_innodb			Yes		Global	No
init_connect	Yes	Yes	Yes		Global	Yes
init-file	Yes	Yes			Global	No
- *Variable*: init_file			Yes		Global	No
init-rpl-role	Yes	Yes				
init_slave	Yes	Yes	Yes		Global	Yes
innodb	Yes	Yes				
innodb_adaptive_flushing	Yes	Yes	Yes		Global	Yes
innodb_adaptive_hash_index	Yes	Yes	Yes		Global	No
innodb_additional_mem_pool_size	Yes	Yes	Yes		Global	No
innodb_autoextend_increment	Yes	Yes	Yes		Global	Yes
innodb_autoinc_lock_mode	Yes	Yes	Yes		Global	No
innodb_buffer_pool_awe_mem_mb	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_pages_data				Yes	Global	No
Innodb_buffer_pool_pages_dirty				Yes	Global	No
Innodb_buffer_pool_pages_flushed				Yes	Global	No
Innodb_buffer_pool_pages_free				Yes	Global	No
Innodb_buffer_pool_pages_latched				Yes	Global	No
Innodb_buffer_pool_pages_misc				Yes	Global	No
Innodb_buffer_pool_pages_total				Yes	Global	No
Innodb_buffer_pool_read_ahead				Yes	Global	No
Innodb_buffer_pool_read_ahead_evicted				Yes	Global	No
Innodb_buffer_pool_read_ahead_rnd				Yes	Global	No
Innodb_buffer_pool_read_ahead_seq				Yes	Global	No
Innodb_buffer_pool_read_requests				Yes	Global	No
Innodb_buffer_pool_reads				Yes	Global	No
innodb_buffer_pool_size	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_wait_free				Yes	Global	No
Innodb_buffer_pool_write_requests				Yes	Global	No
innodb_change_buffering	Yes	Yes	Yes		Global	Yes
innodb_change_buffering_debug	Yes	Yes	Yes		Global	Yes
innodb_checksums	Yes	Yes	Yes		Global	No
innodb_commit_concurrency	Yes	Yes	Yes		Global	Yes
innodb_concurrency_tickets	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_data_file_path	Yes	Yes	Yes		Global	No
Innodb_data_fsyncs				Yes	Global	No
innodb_data_home_dir	Yes	Yes	Yes		Global	No
Innodb_data_pending_fsyncs				Yes	Global	No
Innodb_data_pending_reads				Yes	Global	No
Innodb_data_pending_writes				Yes	Global	No
Innodb_data_read				Yes	Global	No
Innodb_data_reads				Yes	Global	No
Innodb_data_writes				Yes	Global	No
Innodb_data_written				Yes	Global	No
Innodb_dblwr_pages_written				Yes	Global	No
Innodb_dblwr_writes				Yes	Global	No
innodb_doublewrite	Yes	Yes	Yes		Global	No
innodb_fast_shutdown	Yes	Yes	Yes		Global	Yes
innodb_file_format	Yes	Yes	Yes		Global	Yes
innodb_file_format_check	Yes	Yes	Yes		Global	Yes
innodb_file_io_threads	Yes	Yes	Yes		Global	No
innodb_file_per_table	Yes	Yes	Yes		Global	No
innodb_flush_log_at_trx_commit	Yes	Yes	Yes		Global	Yes
innodb_flush_method	Yes	Yes	Yes		Global	No
innodb_force_recovery	Yes	Yes	Yes		Global	No
Innodb_have_atomic_builtins				Yes	Global	No
innodb_io_capacity	Yes	Yes	Yes		Global	No
innodb_limit_optimistic_insert_debug	Yes	Yes	Yes		Global	Yes
innodb_lock_wait_timeout	Yes	Yes	Yes		Varies	No
innodb_locks_unsafe_for_binlog	Yes	Yes	Yes		Global	No
innodb_log_arch_dir	Yes	Yes	Yes		Global	No
innodb_log_archive	Yes	Yes	Yes		Global	No
innodb_log_buffer_size	Yes	Yes	Yes		Global	No
innodb_log_file_size	Yes	Yes	Yes		Global	No
innodb_log_files_in_group	Yes	Yes	Yes		Global	No
innodb_log_group_home_dir	Yes	Yes	Yes		Global	No
Innodb_log_waits				Yes	Global	No
Innodb_log_write_requests				Yes	Global	No
Innodb_log_writes				Yes	Global	No
innodb_max_dirty_pages_pct	Yes	Yes	Yes		Global	Yes
innodb_max_purge_lag	Yes	Yes	Yes		Global	Yes
innodb_mirrored_log_groups	Yes	Yes	Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_old_blocks_pct	Yes	Yes	Yes		Global	Yes
innodb_old_blocks_time	Yes	Yes	Yes		Global	Yes
innodb_open_files	Yes	Yes	Yes		Global	No
Innodb_os_log_fsyncs				Yes	Global	No
Innodb_os_log_pending_fsyncs				Yes	Global	No
Innodb_os_log_pending_writes				Yes	Global	No
Innodb_os_log_written				Yes	Global	No
Innodb_page_size				Yes	Global	No
Innodb_pages_created				Yes	Global	No
Innodb_pages_read				Yes	Global	No
Innodb_pages_written				Yes	Global	No
innodb_random_read_ahead	Yes	Yes	Yes		Global	Yes
innodb_read_ahead_threshold	Yes	Yes	Yes		Global	Yes
innodb_read_io_threads	Yes	Yes	Yes		Global	No
innodb_replication_delay	Yes	Yes	Yes		Global	Yes
innodb_rollback_on_timeout	Yes	Yes	Yes		Global	No
Innodb_row_lock_current_waits				Yes	Global	No
Innodb_row_lock_time				Yes	Global	No
Innodb_row_lock_time_avg				Yes	Global	No
Innodb_row_lock_time_max				Yes	Global	No
Innodb_row_lock_waits				Yes	Global	No
Innodb_rows_deleted				Yes	Global	No
Innodb_rows_inserted				Yes	Global	No
Innodb_rows_read				Yes	Global	No
Innodb_rows_updated				Yes	Global	No
innodb_spin_wait_delay	Yes	Yes	Yes		Global	Yes
innodb_stats_method	Yes	Yes	Yes		Global	Yes
innodb_stats_on_metadata	Yes	Yes	Yes		Global	Varies
innodb_stats_sample_pages	Yes	Yes	Yes		Global	Yes
innodb-status-file	Yes	Yes				
innodb_strict_mode	Yes	Yes	Yes		Both	Yes
innodb_support_xa	Yes	Yes	Yes		Both	Yes
innodb_sync_spin_loops	Yes	Yes	Yes		Global	Yes
innodb_table_locks	Yes	Yes	Yes		Both	Yes
innodb_thread_concurrency	Yes	Yes	Yes		Global	Yes
innodb_thread_sleep_delay	Yes	Yes	Yes		Global	Yes
innodb_trx_purge_view_update_only_debug	Yes	Yes	Yes		Global	Yes
innodb_trx_rseg_n_slots_debug	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_use_legacy_cardinality_algorithm	Yes	Yes	Yes		Global	Yes
innodb_use_sys_malloc	Yes	Yes	Yes		Global	No
innodb_version			Yes		Global	No
innodb_write_io_threads	Yes	Yes	Yes		Global	No
insert_id			Yes		Session	Yes
install	Yes					
install-manual	Yes					
interactive_timeout	Yes	Yes	Yes		Both	Yes
join_buffer_size	Yes	Yes	Yes		Both	Yes
keep_files_on_create	Yes	Yes	Yes		Both	Yes
Key_blocks_not_flushed				Yes	Global	No
Key_blocks_unused				Yes	Global	No
Key_blocks_used				Yes	Global	No
key_buffer_size	Yes	Yes	Yes		Global	Yes
key_cache_age_threshold	Yes	Yes	Yes		Global	Yes
key_cache_block_size	Yes	Yes	Yes		Global	Yes
key_cache_division_limit	Yes	Yes	Yes		Global	Yes
Key_read_requests				Yes	Global	No
Key_reads				Yes	Global	No
Key_write_requests				Yes	Global	No
Key_writes				Yes	Global	No
language	Yes	Yes	Yes		Global	No
large_files_support			Yes		Global	No
large_page_size			Yes		Global	No
large-pages	Yes	Yes			Global	No
- *Variable*: large_pages			Yes		Global	No
last_insert_id			Yes		Session	Yes
Last_query_cost				Yes	Session	No
lc_time_names			Yes		Both	Yes
license			Yes		Global	No
local_infile			Yes		Global	Yes
local-service	Yes					
locked_in_memory			Yes		Global	No
log	Yes	Yes	Yes		Global	Varies
log-bin	Yes	Yes	Yes		Global	No
log_bin			Yes		Global	No
log-bin-index	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
log-bin-trust-function-creators	Yes	Yes			Global	Yes
- *Variable*: log_bin_trust_function_creators			Yes		Global	Yes
log-bin-trust-routine-creators	Yes	Yes			Global	Yes
- *Variable*: log_bin_trust_routine_creators			Yes		Global	Yes
log-bin-use-v1-row-events	Yes	Yes			Global	No
- *Variable*: log_bin_use_v1_row_events			Yes		Global	No
log_bin_use_v1_row_events	Yes	Yes	Yes		Global	No
log-error	Yes	Yes			Global	No
- *Variable*: log_error			Yes		Global	No
log-isam	Yes	Yes				
log-output	Yes	Yes			Global	Yes
- *Variable*: log_output			Yes		Global	Yes
log-queries-not-using-indexes	Yes	Yes			Global	Yes
- *Variable*: log_queries_not_using_indexes			Yes		Global	Yes
log-short-format	Yes	Yes				
log-slave-updates	Yes	Yes			Global	No
- *Variable*: log_slave_updates			Yes		Global	No
log_slave_updates	Yes	Yes	Yes		Global	No
log-slow-admin-statements	Yes	Yes				
log-slow-queries	Yes	Yes			Global	Varies
- *Variable*: log_slow_queries			Yes		Global	Varies
log-slow-slave-statements	Yes	Yes				
log-tc	Yes	Yes				
log-tc-size	Yes	Yes				
log-warnings	Yes	Yes			Both	Yes
- *Variable*: log_warnings			Yes		Both	Yes
long_query_time	Yes	Yes	Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
low-priority-updates	Yes	Yes			Both	Yes
- *Variable*: low_priority_updates			Yes		Both	Yes
lower_case_file_system			Yes		Global	No
lower_case_table_names	Yes	Yes	Yes		Global	No
master-connect-retry	Yes	Yes				
master-host	Yes	Yes				
master-info-file	Yes	Yes				
master-password	Yes	Yes				
master-port	Yes	Yes				
master-retry-count	Yes	Yes				
master-ssl	Yes	Yes				
master-ssl-ca	Yes	Yes				
master-ssl-capath	Yes	Yes				
master-ssl-cert	Yes	Yes				
master-ssl-cipher	Yes	Yes				
master-ssl-key	Yes	Yes				
master-user	Yes	Yes				
max_allowed_packet	Yes	Yes	Yes		Both	Yes
max_binlog_cache_size	Yes	Yes	Yes		Global	Yes
max-binlog-dump-events	Yes	Yes				
max_binlog_size	Yes	Yes	Yes		Global	Yes
max_connect_errors	Yes	Yes	Yes		Global	Yes
max_connections	Yes	Yes	Yes		Global	Yes
max_delayed_threads	Yes	Yes	Yes		Both	Yes
max_error_count	Yes	Yes	Yes		Both	Yes
max_heap_table_size	Yes	Yes	Yes		Both	Yes
max_insert_delayed_threads			Yes		Both	Yes
max_join_size	Yes	Yes	Yes		Both	Yes
max_length_for_sort_data	Yes	Yes	Yes		Both	Yes
max_long_data_size	Yes	Yes	Yes		Global	No
max_prepared_stmt_count	Yes	Yes	Yes		Global	Yes
max_relay_log_size	Yes	Yes	Yes		Global	Yes
max_seeks_for_key	Yes	Yes	Yes		Both	Yes
max_sort_length	Yes	Yes	Yes		Both	Yes
max_sp_recursion_depth	Yes	Yes	Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
max_tmp_tables			Yes		Both	Yes
Max_used_connections				Yes	Global	No
max_user_connections	Yes	Yes	Yes		Both	Yes
max_write_lock_count	Yes	Yes	Yes		Global	Yes
memlock	Yes	Yes				
- *Variable*: locked_in_memory						
merge	Yes	Yes				
min-examined-row-limit	Yes	Yes	Yes		Both	Yes
multi_range_count	Yes	Yes	Yes		Both	Yes
myisam-block-size	Yes	Yes				
myisam_data_pointer_size	Yes	Yes	Yes		Global	Yes
myisam_max_sort_file_size	Yes	Yes	Yes		Global	Yes
myisam_mmap_size	Yes	Yes	Yes		Global	No
myisam-recover	Yes	Yes				
- *Variable*: myisam_recover_options						
myisam_recover_options			Yes		Global	No
myisam_repair_threads	Yes	Yes	Yes		Both	Yes
myisam_sort_buffer_size	Yes	Yes	Yes		Both	Yes
myisam_stats_method	Yes	Yes	Yes		Both	Yes
myisam_use_mmap	Yes	Yes	Yes		Global	Yes
named_pipe			Yes		Global	No
Ndb_api_bytes_received_count				Yes	Global	No
Ndb_api_bytes_received_count_session				Yes	Session	No
Ndb_api_bytes_received_count_slave				Yes	Global	No
Ndb_api_bytes_sent_count				Yes	Global	No
Ndb_api_bytes_sent_count_session				Yes	Session	No
Ndb_api_bytes_sent_count_slave				Yes	Global	No
Ndb_api_event_bytes_count				Yes	Global	No
Ndb_api_event_bytes_count_injector				Yes	Global	No
Ndb_api_event_data_count				Yes	Global	No
Ndb_api_event_data_count_injector				Yes	Global	No
Ndb_api_event_nondata_count				Yes	Global	No
Ndb_api_event_nondata_count_injector				Yes	Global	No
Ndb_api_pk_op_count				Yes	Global	No
Ndb_api_pk_op_count_session				Yes	Session	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Ndb_api_pk_op_count_slave				Yes	Global	No
Ndb_api_pruned_scan_count				Yes	Global	No
Ndb_api_pruned_scan_count_session				Yes	Session	No
Ndb_api_pruned_scan_count_slave				Yes	Global	No
Ndb_api_range_scan_count				Yes	Global	No
Ndb_api_range_scan_count_session				Yes	Session	No
Ndb_api_range_scan_count_slave				Yes	Global	No
Ndb_api_read_row_count				Yes	Global	No
Ndb_api_read_row_count_session				Yes	Session	No
Ndb_api_read_row_count_slave				Yes	Global	No
Ndb_api_scan_batch_count				Yes	Global	No
Ndb_api_scan_batch_count_session				Yes	Session	No
Ndb_api_scan_batch_count_slave				Yes	Global	No
Ndb_api_table_scan_count				Yes	Global	No
Ndb_api_table_scan_count_session				Yes	Session	No
Ndb_api_table_scan_count_slave				Yes	Global	No
Ndb_api_trans_abort_count				Yes	Global	No
Ndb_api_trans_abort_count_session				Yes	Session	No
Ndb_api_trans_abort_count_slave				Yes	Global	No
Ndb_api_trans_close_count				Yes	Global	No
Ndb_api_trans_close_count_session				Yes	Session	No
Ndb_api_trans_close_count_slave				Yes	Global	No
Ndb_api_trans_commit_count				Yes	Global	No
Ndb_api_trans_commit_count_session				Yes	Session	No
Ndb_api_trans_commit_count_slave				Yes	Global	No
Ndb_api_trans_local_read_row_count				Yes	Global	No
Ndb_api_trans_local_read_row_count_session				Yes	Session	No
Ndb_api_trans_local_read_row_count_slave				Yes	Global	No
Ndb_api_trans_start_count				Yes	Global	No
Ndb_api_trans_start_count_session				Yes	Session	No
Ndb_api_trans_start_count_slave				Yes	Global	No
Ndb_api_uk_op_count				Yes	Global	No
Ndb_api_uk_op_count_session				Yes	Session	No
Ndb_api_uk_op_count_slave				Yes	Global	No
Ndb_api_wait_exec_complete_count				Yes	Global	No
Ndb_api_wait_exec_complete_count_session				Yes	Session	No
Ndb_api_wait_exec_complete_count_slave				Yes	Global	No
Ndb_api_wait_meta_request_count				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Ndb_api_wait_meta_request_count_session				Yes	Session	No
Ndb_api_wait_meta_request_count_slave				Yes	Global	No
Ndb_api_wait_nanos_count				Yes	Global	No
Ndb_api_wait_nanos_count_session				Yes	Session	No
Ndb_api_wait_nanos_count_slave				Yes	Global	No
Ndb_api_wait_scan_result_count				Yes	Global	No
Ndb_api_wait_scan_result_count_session				Yes	Session	No
Ndb_api_wait_scan_result_count_slave				Yes	Global	No
ndb_autoincrement_prefetch_sz	Yes	Yes	Yes		Both	Yes
ndb-batch-size	Yes	Yes	Yes		Global	No
ndb-blob-read-batch-bytes	Yes	Yes	Yes		Both	Yes
ndb-blob-write-batch-bytes	Yes	Yes	Yes		Both	Yes
ndb_cache_check_time	Yes	Yes	Yes		Global	Yes
ndb-cluster-connection-pool	Yes	Yes	Yes	Yes	Global	No
Ndb_cluster_node_id				Yes	Both	No
Ndb_config_from_host				Yes	Both	No
Ndb_config_from_port				Yes	Both	No
Ndb_conflict_fn_epoch				Yes	Global	No
Ndb_conflict_fn_epoch_trans				Yes	Global	No
Ndb_conflict_fn_max				Yes	Global	No
Ndb_conflict_fn_old				Yes	Global	No
Ndb_conflict_trans_conflict_commit_count				Yes	Global	No
Ndb_conflict_trans_detect_iter_count				Yes	Global	No
Ndb_conflict_trans_reject_count				Yes	Global	No
Ndb_conflict_trans_row_reject_count				Yes	Global	No
ndb-connectstring	Yes	Yes				
ndb-deferred-constraints	Yes	Yes			Both	Yes
- *Variable*: ndb_deferred_constraints			Yes		Both	Yes
ndb_deferred_constraints	Yes	Yes	Yes		Both	Yes
ndb-distribution	Yes	Yes			Global	Yes
- *Variable*: ndb_distribution			Yes		Global	Yes
ndb_distribution	Yes	Yes	Yes		Global	Yes
ndb_eventbuffer_max_alloc	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Ndb_execute_count				Yes	Global	No
ndb_extra_logging	Yes	Yes	Yes		Global	Yes
ndb_force_send	Yes	Yes	Yes		Both	Yes
ndb_index_stat_cache_entries	Yes	Yes	Yes		Both	Yes
ndb_index_stat_enable	Yes	Yes	Yes		Both	Yes
ndb_index_stat_option	Yes	Yes	Yes		Both	Yes
ndb_index_stat_update_freq	Yes	Yes	Yes		Both	Yes
ndb_join_pushdown			Yes		Both	Yes
ndb-log-apply-status	Yes	Yes			Global	No
- *Variable*: ndb_log_apply_status			Yes		Global	No
ndb_log_apply_status	Yes	Yes	Yes		Global	No
ndb_log_bin	Yes		Yes		Both	Yes
ndb_log_binlog_index	Yes		Yes		Global	Yes
ndb-log-empty-epochs	Yes	Yes	Yes		Global	Yes
ndb_log_empty_epochs	Yes	Yes	Yes		Global	Yes
ndb-log-orig	Yes	Yes			Global	No
- *Variable*: ndb_log_orig			Yes		Global	No
ndb_log_orig	Yes	Yes	Yes		Global	No
ndb-log-transaction-id	Yes	Yes			Global	No
- *Variable*: ndb_log_transaction_id			Yes		Global	No
ndb_log_transaction_id			Yes		Global	No
ndb-log-update-as-write	Yes	Yes	Yes		Global	Yes
ndb_log_updated_only	Yes	Yes	Yes		Global	Yes
ndb-mgmd-host	Yes	Yes				
ndb-nodeid	Yes	Yes		Yes	Global	No
Ndb_number_of_data_nodes				Yes	Global	No
ndb_optimization_delay		Yes			Global	Yes
ndb_optimized_node_selection	Yes	Yes	Yes		Global	No
Ndb_pruned_scan_count				Yes	Global	No
Ndb_pushed_queries_defined				Yes	Global	No
Ndb_pushed_queries_dropped				Yes	Global	No
Ndb_pushed_queries_executed				Yes	Global	No
Ndb_pushed_reads				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
ndb_report_thresh_binlog_epoch_slip	Yes	Yes	Yes		Global	Yes
ndb_report_thresh_binlog_mem_usage	Yes	Yes	Yes		Global	Yes
Ndb_scan_count				Yes	Global	No
ndb_table_no_logging			Yes		Session	Yes
ndb_table_temporary			Yes		Session	Yes
ndb-transid-mysql-connection-map	Yes					
ndb_use_copying_alter_table			Yes		Both	No
ndb_use_exact_count			Yes		Both	Yes
ndb_use_transaction	Yes	Yes	Yes		Both	Yes
ndb_version			Yes		Global	No
ndb_version_string			Yes		Global	No
ndb-wait-connected	Yes	Yes	Yes		Global	No
ndb-wait-setup	Yes	Yes	Yes		Global	No
ndbcluster	Yes	Yes				
- *Variable*: have_ndbcluster						
ndbinfo_database			Yes		Global	No
ndbinfo_max_bytes	Yes		Yes		Both	Yes
ndbinfo_max_rows	Yes		Yes		Both	Yes
ndbinfo_offline			Yes		Global	Yes
ndbinfo_show_hidden	Yes		Yes		Both	Yes
ndbinfo_table_prefix	Yes		Yes		Both	Yes
ndbinfo_version			Yes		Global	No
net_buffer_length	Yes	Yes	Yes		Both	Yes
net_read_timeout	Yes	Yes	Yes		Both	Yes
net_retry_count	Yes	Yes	Yes		Both	Yes
net_write_timeout	Yes	Yes	Yes		Both	Yes
new	Yes	Yes	Yes		Both	Yes
no-defaults	Yes					
Not_flushed_delayed_rows				Yes	Global	No
old	Yes	Yes	Yes		Global	No
old-alter-table	Yes	Yes			Both	Yes
- *Variable*: old_alter_table			Yes		Both	Yes
old_passwords			Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
old-style-user-limits	Yes	Yes				
one-thread	Yes	Yes				
Open_files				Yes	Global	No
open-files-limit	Yes	Yes			Global	No
- *Variable*: open_files_limit			Yes		Global	No
Open_streams				Yes	Global	No
Open_table_definitions				Yes	Global	No
Open_tables				Yes	Both	No
Opened_files				Yes	Global	No
Opened_table_definitions				Yes	Both	No
Opened_tables				Yes	Both	No
optimizer_prune_level	Yes	Yes	Yes		Both	Yes
optimizer_search_depth	Yes	Yes	Yes		Both	Yes
optimizer_switch	Yes	Yes	Yes		Both	Yes
partition	Yes	Yes				
- *Variable*: have_partitioning						
pid-file	Yes	Yes			Global	No
- *Variable*: pid_file			Yes		Global	No
plugin	Yes	Yes				
plugin_dir	Yes	Yes	Yes		Global	No
plugin-load	Yes	Yes				
port	Yes	Yes	Yes		Global	No
port-open-timeout	Yes	Yes				
preload_buffer_size	Yes	Yes	Yes		Both	Yes
Prepared_stmt_count				Yes	Global	No
prepared_stmt_count			Yes		Global	No
print-defaults	Yes					
profiling			Yes		Session	Yes
profiling_history_size	Yes	Yes	Yes		Both	Yes
protocol_version			Yes		Global	No
pseudo_thread_id			Yes		Session	Yes
Qcache_free_blocks				Yes	Global	No
Qcache_free_memory				Yes	Global	No
Qcache_hits				Yes	Global	No
Qcache_inserts				Yes	Global	No
Qcache_lowmem_prunes				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Qcache_not_cached				Yes	Global	No
Qcache_queries_in_cache				Yes	Global	No
Qcache_total_blocks				Yes	Global	No
Queries				Yes	Both	No
query_alloc_block_size	Yes	Yes	Yes		Both	Yes
query_cache_limit	Yes	Yes	Yes		Global	Yes
query_cache_min_res_unit	Yes	Yes	Yes		Global	Yes
query_cache_size	Yes	Yes	Yes		Global	Yes
query_cache_type	Yes	Yes	Yes		Both	Yes
query_cache_wlock_invalidate	Yes	Yes	Yes		Both	Yes
query_prealloc_size	Yes	Yes	Yes		Both	Yes
Questions				Yes	Both	No
rand_seed1			Yes		Session	Yes
rand_seed2			Yes		Session	Yes
range_alloc_block_size	Yes	Yes	Yes		Both	Yes
read_buffer_size	Yes	Yes	Yes		Both	Yes
read_only	Yes	Yes	Yes		Global	Yes
read_rnd_buffer_size	Yes	Yes	Yes		Both	Yes
relay-log	Yes	Yes			Global	No
- *Variable*: relay_log			Yes		Global	No
relay-log-index	Yes	Yes			Global	No
- *Variable*: relay_log_index			Yes		Global	No
relay_log_index	Yes	Yes	Yes		Global	No
relay-log-info-file	Yes	Yes				
- *Variable*: relay_log_info_file						
relay_log_info_file	Yes	Yes	Yes		Global	No
relay_log_purge	Yes	Yes	Yes		Global	Yes
relay_log_space_limit	Yes	Yes	Yes		Global	No
remove	Yes					
replicate-do-db	Yes	Yes				
replicate-do-table	Yes	Yes				
replicate-ignore-db	Yes	Yes				
replicate-ignore-table	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
replicate-rewrite-db	Yes	Yes				
replicate-same-server-id	Yes	Yes				
replicate-wild-do-table	Yes	Yes				
replicate-wild-ignore-table	Yes	Yes				
report-host	Yes	Yes			Global	No
- *Variable*: report_host			Yes		Global	No
report-password	Yes	Yes			Global	No
- *Variable*: report_password			Yes		Global	No
report-port	Yes	Yes			Global	No
- *Variable*: report_port			Yes		Global	No
report-user	Yes	Yes			Global	No
- *Variable*: report_user			Yes		Global	No
rpl_recovery_rank			Yes		Global	Yes
Rpl_status				Yes	Global	No
safe-mode	Yes	Yes				
safe-show-database	Yes	Yes				
safe-user-create	Yes	Yes				
safemalloc-mem-limit	Yes	Yes				
secure-auth	Yes	Yes			Global	Yes
- *Variable*: secure_auth			Yes		Global	Yes
secure-file-priv	Yes	Yes			Global	No
- *Variable*: secure_file_priv			Yes		Global	No
Select_full_join				Yes	Both	No
Select_full_range_join				Yes	Both	No
Select_range				Yes	Both	No
Select_range_check				Yes	Both	No
Select_scan				Yes	Both	No
server-id	Yes	Yes			Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
- *Variable*: server_id			Yes		Global	Yes
server-id-bits	Yes	Yes			Global	No
- *Variable*: server_id_bits			Yes		Global	No
server_id_bits	Yes	Yes	Yes		Global	No
set-variable	Yes	Yes				
shared_memory	Yes	Yes	Yes		Global	No
shared_memory_base_name	Yes	Yes	Yes		Global	No
show-slave-auth-info	Yes	Yes				
skip-character-set-client-handshake	Yes	Yes				
skip-concurrent-insert	Yes	Yes				
- *Variable*: concurrent_insert						
skip-event-scheduler	Yes	Yes				
skip_external_locking	Yes	Yes	Yes		Global	No
skip-grant-tables	Yes	Yes				
skip-host-cache	Yes	Yes				
skip-locking	Yes	Yes				
skip-merge	Yes	Yes				
skip-name-resolve	Yes	Yes			Global	No
- *Variable*: skip_name_resolve			Yes		Global	No
skip-ndbcluster	Yes	Yes				
skip-networking	Yes	Yes			Global	No
- *Variable*: skip_networking			Yes		Global	No
skip-new	Yes	Yes				
skip-partition	Yes	Yes				
skip-safemalloc	Yes	Yes				
skip-show-database	Yes	Yes			Global	No
- *Variable*: skip_show_database			Yes		Global	No
skip-slave-start	Yes	Yes				
skip-ssl	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
skip-stack-trace	Yes	Yes				
skip-symbolic-links	Yes					
skip-symlink	Yes	Yes				
skip-thread-priority	Yes	Yes				
slave_allow_batching	Yes	Yes	Yes		Global	Yes
slave_compressed_protocol	Yes	Yes	Yes		Global	Yes
slave_exec_mode	Yes	Yes	Yes		Global	Yes
Slave_heartbeat_period				Yes	Global	No
slave-load-tmpdir	Yes	Yes			Global	No
- *Variable*: slave_load_tmpdir			Yes		Global	No
slave-max-allowed-packet	Yes	Yes				
- *Variable*: slave_max_allowed_packet						
slave_max_allowed_packet			Yes		Global	Yes
slave-net-timeout	Yes	Yes			Global	Yes
- *Variable*: slave_net_timeout			Yes		Global	Yes
Slave_open_temp_tables				Yes	Global	No
Slave_received_heartbeats				Yes	Global	No
Slave_retried_transactions				Yes	Global	No
Slave_running				Yes	Global	No
slave-skip-errors	Yes	Yes			Global	No
- *Variable*: slave_skip_errors			Yes		Global	No
slave_transaction_retries	Yes	Yes	Yes		Global	Yes
slave_type_conversions	Yes	Yes	Yes		Global	No
Slow_launch_threads				Yes	Both	No
slow_launch_time	Yes	Yes	Yes		Global	Yes
Slow_queries				Yes	Both	No
slow-query-log	Yes	Yes			Global	Yes
- *Variable*: slow_query_log			Yes		Global	Yes
slow_query_log_file	Yes	Yes	Yes		Global	Yes
socket	Yes	Yes	Yes		Global	No
sort_buffer_size	Yes	Yes	Yes		Both	Yes
Sort_merge_passes				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Sort_range				Yes	Both	No
Sort_rows				Yes	Both	No
Sort_scan				Yes	Both	No
sporadic-binlog-dump-fail	Yes	Yes				
sql_auto_is_null			Yes		Session	Yes
sql_big_selects			Yes		Session	Yes
sql_big_tables			Yes		Session	Yes
sql_buffer_result			Yes		Session	Yes
sql_log_bin			Yes		Session	Yes
sql_log_off			Yes		Session	Yes
sql_log_update			Yes		Session	Yes
sql_low_priority_updates			Yes		Both	Yes
sql_max_join_size			Yes		Both	Yes
sql-mode	Yes	Yes			Both	Yes
- *Variable*: sql_mode			Yes		Both	Yes
sql_notes			Yes		Session	Yes
sql_quote_show_create			Yes		Session	Yes
sql_safe_updates			Yes		Session	Yes
sql_select_limit			Yes		Both	Yes
sql_slave_skip_counter			Yes		Global	Yes
sql_warnings			Yes		Session	Yes
ssl	Yes	Yes				
Ssl_accept_renegotiates				Yes	Global	No
Ssl_accepts				Yes	Global	No
ssl-ca	Yes	Yes			Global	No
- *Variable*: ssl_ca			Yes		Global	No
Ssl_callback_cache_hits				Yes	Global	No
ssl-capath	Yes	Yes			Global	No
- *Variable*: ssl_capath			Yes		Global	No
ssl-cert	Yes	Yes			Global	No
- *Variable*: ssl_cert			Yes		Global	No
Ssl_cipher				Yes	Both	No
ssl-cipher	Yes	Yes			Global	No
- *Variable*: ssl_cipher			Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Ssl_cipher_list				Yes	Both	No
Ssl_client_connects				Yes	Global	No
Ssl_connect_renegotiates				Yes	Global	No
Ssl_ctx_verify_depth				Yes	Global	No
Ssl_ctx_verify_mode				Yes	Global	No
Ssl_default_timeout				Yes	Both	No
Ssl_finished_accepts				Yes	Global	No
Ssl_finished_connects				Yes	Global	No
ssl-key	Yes	Yes			Global	No
- *Variable*: ssl_key			Yes		Global	No
Ssl_session_cache_hits				Yes	Global	No
Ssl_session_cache_misses				Yes	Global	No
Ssl_session_cache_mode				Yes	Global	No
Ssl_session_cache_overflows				Yes	Global	No
Ssl_session_cache_size				Yes	Global	No
Ssl_session_cache_timeouts				Yes	Global	No
Ssl_sessions_reused				Yes	Both	No
Ssl_used_session_cache_entries				Yes	Global	No
Ssl_verify_depth				Yes	Both	No
Ssl_verify_mode				Yes	Both	No
Ssl_version				Yes	Both	No
standalone	Yes	Yes				
storage_engine			Yes		Both	Yes
symbolic-links	Yes	Yes				
sync_binlog	Yes	Yes	Yes		Global	Yes
sync_frm	Yes	Yes	Yes		Global	Yes
sysdate-is-now	Yes	Yes				
system_time_zone			Yes		Global	No
table_cache	Yes	Yes	Yes		Global	Yes
table_definition_cache			Yes		Global	Yes
table_lock_wait_timeout	Yes	Yes	Yes		Global	Yes
Table_locks_immediate				Yes	Global	No
Table_locks_waited				Yes	Global	No
table_open_cache			Yes		Global	Yes
table_type			Yes		Both	Yes
tc-heuristic-recover	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Tc_log_max_pages_used				Yes	Global	No
Tc_log_page_size				Yes	Global	No
Tc_log_page_waits				Yes	Global	No
temp-pool	Yes	Yes				
thread_cache_size	Yes	Yes	Yes		Global	Yes
thread_concurrency	Yes	Yes	Yes		Global	No
thread_handling	Yes	Yes	Yes		Global	No
thread_stack	Yes	Yes	Yes		Global	No
Threads_cached				Yes	Global	No
Threads_connected				Yes	Global	No
Threads_created				Yes	Global	No
Threads_running				Yes	Global	No
time_format			Yes		Both	No
time_zone			Yes		Both	Yes
timed_mutexes	Yes	Yes	Yes		Global	Yes
timestamp			Yes		Session	Yes
tmp_table_size	Yes	Yes	Yes		Both	Yes
tmpdir	Yes	Yes	Yes		Global	No
transaction_alloc_block_size	Yes	Yes	Yes		Both	Yes
transaction_allow_batching			Yes		Session	Yes
transaction-isolation	Yes	Yes				
- *Variable*: tx_isolation						
transaction_prealloc_size	Yes	Yes	Yes		Both	Yes
tx_isolation			Yes		Both	Yes
unique_checks			Yes		Session	Yes
updatable_views_with_limit	Yes	Yes	Yes		Both	Yes
Uptime				Yes	Global	No
Uptime_since_flush_status				Yes	Global	No
use-symbolic-links	Yes	Yes				
user	Yes	Yes				
verbose	Yes	Yes				
version			Yes		Global	No
version_comment			Yes		Global	No
version_compile_machine			Yes		Global	No
version_compile_os			Yes		Global	No
wait_timeout	Yes	Yes	Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
warning_count			Yes		Session	No

[a]This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

[b]This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

5.1.2 Server Configuration Defaults

The MySQL server has many operating parameters, which you can change at server startup using command-line options or configuration files (option files). It is also possible to change many parameters at runtime. For general instructions on setting parameters at startup or runtime, see Section 5.1.3, "Server Command Options", and Section 5.1.4, "Server System Variables".

MySQL provides a number of preconfigured option files that can be used as a basis for tuning the MySQL server. Look for files named `my-small.cnf`, `my-medium.cnf`, `my-large.cnf`, and `my-huge.cnf`, which are sample option files for small, medium, large, and very large systems. On Windows, the extension is `.ini` rather than `.cnf`.

> **Note**
>
> On Windows, the `.ini` or `.cnf` option file extension might not be displayed.

For a binary distribution, look for the sample files in or under your installation directory. If you have a source distribution, look in the `support-files` directory. To use a sample file as a base configuration file, rename a copy of it and place the copy in the appropriate location. Regarding names and appropriate location, see the general information provided in Section 4.2.6, "Using Option Files". That section also describes option file format and syntax.

5.1.3 Server Command Options

When you start the `mysqld` server, you can specify program options using any of the methods described in Section 4.2.3, "Specifying Program Options". The most common methods are to provide options in an option file or on the command line. However, in most cases it is desirable to make sure that the server uses the same options each time it runs. The best way to ensure this is to list them in an option file. See Section 4.2.6, "Using Option Files". That section also describes option file format and syntax.

`mysqld` reads options from the `[mysqld]` and `[server]` groups. `mysqld_safe` reads options from the `[mysqld]`, `[server]`, `[mysqld_safe]`, and `[safe_mysqld]` groups. `mysql.server` reads options from the `[mysqld]` and `[mysql.server]` groups.

An embedded MySQL server usually reads options from the `[server]`, `[embedded]`, and `[xxxxx_SERVER]` groups, where `xxxxx` is the name of the application into which the server is embedded.

`mysqld` accepts many command options. For a brief summary, execute `mysqld --help`. To see the full list, use `mysqld --verbose --help`.

The following list shows some of the most common server options. Additional options are described in other sections:

- Options that affect security: See Section 6.1.4, "Security-Related mysqld Options and Variables".

- SSL-related options: See Section 6.4.5, "Command Options for Secure Connections".

- Binary log control options: See Section 5.4.4, "The Binary Log".

- Replication-related options: See Section 16.1.3, "Replication and Binary Logging Options and Variables".

- Options for loading plugins such as pluggable storage engines: See Section 5.1.8.1, "Installing and Uninstalling Plugins".

- Options specific to particular storage engines: See Section 14.6.8, "InnoDB Startup Options and System Variables", Section 14.5.1, "MyISAM Startup Options", and MySQL Server Options for MySQL Cluster.

Some options control the size of buffers or caches. For a given buffer, the server might need to allocate internal data structures. These structures typically are allocated from the total memory allocated to the buffer, and the amount of space required might be platform dependent. This means that when you assign a value to an option that controls a buffer size, the amount of space actually available might differ from the value assigned. In some cases, the amount might be less than the value assigned. It is also possible that the server will adjust a value upward. For example, if you assign a value of 0 to an option for which the minimal value is 1024, the server will set the value to 1024.

Values for buffer sizes, lengths, and stack sizes are given in bytes unless otherwise specified.

Some options take file name values. Unless otherwise specified, the default file location is the data directory if the value is a relative path name. To specify the location explicitly, use an absolute path name. Suppose that the data directory is `/var/mysql/data`. If a file-valued option is given as a relative path name, it will be located under `/var/mysql/data`. If the value is an absolute path name, its location is as given by the path name.

You can also set the values of server system variables at server startup by using variable names as options. To assign a value to a server system variable, use an option of the form `--var_name=value`. For example, `--key_buffer_size=32M` sets the `key_buffer_size` variable to a value of 32MB.

When you assign a value to a variable, MySQL might automatically correct the value to stay within a given range, or adjust the value to the closest permissible value if only certain values are permitted.

To restrict the maximum value to which a system variable can be set at runtime with the `SET` statement, specify this maximum by using an option of the form `--maximum-var_name=value` at server startup.

You can change the values of most system variables for a running server with the `SET` statement. See Section 13.7.4.1, "SET Syntax for Variable Assignment".

Section 5.1.4, "Server System Variables", provides a full description for all variables, and additional information for setting them at server startup and runtime. Section 8.12.2, "Tuning Server Parameters", includes information on optimizing the server by tuning system variables.

- `--help`, `-?`

Command-Line Format	`--help`

  Display a short help message and exit. Use both the `--verbose` and `--help` options to see the full message.

- `--allow-suspicious-udfs`

Command-Line Format	`--allow-suspicious-udfs`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

  This option controls whether user-defined functions that have only an `xxx` symbol for the main function can be loaded. By default, the option is off and only UDFs that have at least one auxiliary symbol can be loaded; this prevents attempts at loading functions from shared object files other than those containing legitimate UDFs. See Section 22.3.2.6, "UDF Security Precautions".

- `--ansi`

Command-Line Format	`--ansi`

Use standard (ANSI) SQL syntax instead of MySQL syntax. For more precise control over the server SQL mode, use the `--sql-mode` option instead. See Section 1.8, "MySQL Standards Compliance", and Section 5.1.7, "Server SQL Modes".

- `--basedir=dir_name`, `-b dir_name`

Command-Line Format	`--basedir=dir_name`	
System Variable	Name	`basedir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`directory name`

The path to the MySQL installation directory. All paths are usually resolved relative to this directory.

- `--big-tables`

Command-Line Format	`--big-tables`	
System Variable	Name	`big_tables`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

Enable large result sets by saving all temporary sets in files. This option prevents most "table full" errors, but also slows down queries for which in-memory tables would suffice. Since MySQL 3.23.2, the server is able to handle large result sets automatically by using memory for small temporary tables and switching to disk tables where necessary.

- `--bind-address=addr`

Command-Line Format	`--bind-address=addr`	
Permitted Values	Type	`string`
	Default	`0.0.0.0`

The MySQL server listens on a single network socket for TCP/IP connections. This socket is bound to a single address, but it is possible for an address to map onto multiple network interfaces. The default address is `0.0.0.0`. To specify an address explicitly, use the `--bind-address=addr` option at server startup, where `addr` is an IPv4 address or a host name. If `addr` is a host name, the server resolves the name to an IPv4 address and binds to that address.

The server treats different types of addresses as follows:

- If the address is `0.0.0.0`, the server accepts TCP/IP connections on all server host IPv4 interfaces.

- If the address is a "regular" IPv4 address (such as `127.0.0.1`), the server accepts TCP/IP connections only for that particular IPv4 address.

If you intend to bind the server to a specific address, be sure that the `mysql.user` grant table contains an account with administrative privileges that you can use connect to that address. Otherwise, you will not be able to shut down the server. For example, if you bind to `0.0.0.0`, you can connect to the server using all existing accounts. But if you bind to `127.0.0.1`, the server accepts connections only on that address. In this case, first make sure that the `'root'@'127.0.0.1'` account is present in the `mysql.user` table so that you can still connect to the server to shut it down.

- `--binlog-format={ROW|STATEMENT|MIXED}`

Introduced	5.1.5	
Command-Line Format	`--binlog-format=format`	
System Variable (>= 5.1.8)	**Name**	`binlog_format`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (>= 5.1.5, <= 5.1.7)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
Permitted Values (>= 5.1.8, <= 5.1.11)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.12, <= 5.1.28)	**Type**	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.29)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.14-ndb-6.1.0, <= 5.1.15-ndb-6.1.23)	**Type**	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`

		MIXED
Permitted Values (>= 5.1.16-ndb-6.2.0, <= 5.1.34-ndb-6.2.18)	**Type**	enumeration
	Default	MIXED
	Valid Values	ROW
		STATEMENT
		MIXED
Permitted Values (>= 5.1.19-ndb-6.3.0, <= 5.1.73-ndb-6.3.54)	**Type**	enumeration
	Default	MIXED
	Valid Values	ROW
		STATEMENT
		MIXED
Permitted Values (>= 5.1.32-ndb-7.0.4, <= 5.1.73-ndb-7.0.42)	**Type**	enumeration
	Default	MIXED
	Valid Values	ROW
		STATEMENT
		MIXED
Permitted Values (>= 5.1.39-ndb-7.1.0, <= 5.1.51-ndb-7.2.0)	**Type**	enumeration
	Default	MIXED
	Valid Values	ROW
		STATEMENT
		MIXED

Specify whether to use row-based, statement-based, or mixed replication (statement-based was the default prior to MySQL 5.1.12; in 5.1.12, the default was changed to mixed replication; in 5.1.29, the default was changed back to statement-based). See Section 16.1.2, "Replication Formats". This option was added in MySQL 5.1.5.

Under some conditions, changing this variable at runtime is not possible, or causes replication to fail. See Section 5.4.4.2, "Setting The Binary Log Format", for more information.

> **Important**
>
> Setting the binary logging format without enabling binary logging prevents the MySQL server from starting. This is a known issue in MySQL 5.1 which is fixed in MySQL 5.5. (Bug #42928)

MySQL Cluster.   The default value for this option in all MySQL Cluster NDB 6.1 through 7.1 releases is MIXED. See Section 17.6.2, "General Requirements for MySQL Cluster Replication", for more information.

- --bootstrap

Command-Line Format	--bootstrap

This option is used by the mysql_install_db program to create the MySQL privilege tables without having to start a full MySQL server.

This option is unavailable if MySQL was configured with the `--disable-grant-options` option. See Section 2.11.4, "MySQL Source-Configuration Options".

- `--character-sets-dir=dir_name`

Command-Line Format	`--character-sets-dir=dir_name`	
System Variable	**Name**	`character_sets_dir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`

The directory where character sets are installed. See Section 10.5, "Character Set Configuration".

- `--character-set-client-handshake`

Command-Line Format	`--character-set-client-handshake`	
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

Do not ignore character set information sent by the client. To ignore client information and use the default server character set, use `--skip-character-set-client-handshake`; this makes MySQL behave like MySQL 4.0.

- `--character-set-filesystem=charset_name`

Introduced	5.1.6	
Command-Line Format	`--character-set-filesystem=name`	
System Variable	**Name**	`character_set_filesystem`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`
	Default	`binary`

The file system character set. This option sets the `character_set_filesystem` system variable. It was added in MySQL 5.1.6.

- `--character-set-server=charset_name`, `-C charset_name`

Command-Line Format	`--character-set-server`	
System Variable	**Name**	`character_set_server`
	Variable Scope	Global, Session
	Dynamic Variable	Yes

Permitted Values	Type	string
	Default	latin1

Use *charset_name* as the default server character set. See Section 10.5, "Character Set Configuration". If you use this option to specify a nondefault character set, you should also use `--collation-server` to specify the collation.

- `--chroot=dir_name`, `-r dir_name`

Command-Line Format	--chroot=dir_name
Permitted Values	Type	directory name

Put the `mysqld` server in a closed environment during startup by using the `chroot()` system call. This is a recommended security measure. Use of this option somewhat limits `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE`.

- `--collation-server=collation_name`

Command-Line Format	--collation-server	
System Variable	Name	collation_server
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	string
	Default	latin1_swedish_ci

Use *collation_name* as the default server collation. See Section 10.5, "Character Set Configuration".

- `--console`

Command-Line Format	--console
Platform Specific	Windows

(Windows only.) Write error log messages to `stderr` and `stdout`. `mysqld` does not close the console window if this option is used.

If both `--log-error` and `--console` are specified, whichever option is given last takes precedence.

- `--core-file`

Command-Line Format	--core-file	
Permitted Values	Type	boolean
	Default	OFF

Write a core file if `mysqld` dies. The name and location of the core file is system dependent. On Linux, a core file named `core.pid` is written to the current working directory of the process, which for `mysqld` is the data directory. `pid` represents the process ID of the server process. On OS X, a core file named `core.pid` is written to the `/cores` directory. On Solaris, use the `coreadm` command to specify where to write the core file and how to name it.

For some systems, to get a core file you must also specify the `--core-file-size` option to `mysqld_safe`. See Section 4.3.2, "`mysqld_safe` — MySQL Server Startup Script". On some systems, such as Solaris, you do not get a core file if you are also using the `--user` option. There might be additional restrictions or limitations. For example, it might be necessary to execute `ulimit -c unlimited` before starting the server. Consult your system documentation.

- `--datadir=dir_name`, `-h dir_name`

Command-Line Format	`--datadir=dir_name`	
System Variable	Name	`datadir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`directory name`

The path to the data directory.

- `--debug[=debug_options]`, `-# [debug_options]`

Command-Line Format	`--debug[=debug_options]`	
System Variable	Name	`debug`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (Unix)	Type	`string`
	Default	`d:t:i:o,/tmp/mysqld.trace`
Permitted Values (Windows)	Type	`string`
	Default	`d:t:i:O,\mysqld.trace`

If MySQL is configured with `--with-debug`, you can use this option to get a trace file of what `mysqld` is doing. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:i:o,/tmp/mysqld.trace` on Unix and `d:t:i:O,\mysqld.trace` on Windows.

As of MySQL 5.1.12, using `--with-debug` to configure MySQL with debugging support enables you to use the `--debug="d,parser_debug"` option when you start the server. This causes the Bison parser that is used to process SQL statements to dump a parser trace to the server's standard error output. Typically, this output is written to the error log.

This option may be given multiple times. Values that begin with `+` or `-` are added to or subtracted from the previous value. For example, `--debug=T --debug=+P` sets the value to `P:T`.

For more information, see Section 22.4.3, "The DBUG Package".

- `--debug-sync-timeout[=N]`

Introduced	5.1.41
Command-Line Format	`--debug-sync-timeout[=#]`

Permitted Values	Type	`integer`

Controls whether the Debug Sync facility for testing and debugging is enabled. Use of Debug Sync requires that MySQL be configured with the `--enable-debug-sync` option (see Section 2.11.4, "MySQL Source-Configuration Options"). If Debug Sync is not compiled in, this option is not available. The option value is a timeout in seconds. The default value is 0, which disables Debug Sync. To enable it, specify a value greater than 0; this value also becomes the default timeout for individual synchronization points. If the option is given without a value, the timeout is set to 300 seconds.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

This option was added in MySQL 5.1.41.

- `--default-character-set=charset_name`

Deprecated	5.0.0	
Command-Line Format	`--default-character-set=name`	
Permitted Values	Type	`string`

Use `charset_name` as the default character set. This option is deprecated in favor of `--character-set-server`. See Section 10.5, "Character Set Configuration". `--default-character-set` is removed in MySQL 5.5.

- `--default-collation=collation_name`

Deprecated	4.1.3	
Command-Line Format	`--default-collation=name`	
Permitted Values	Type	`string`

Use `collation_name` as the default collation. This option is deprecated in favor of `--collation-server`. See Section 10.5, "Character Set Configuration". `--default-collation` is removed in MySQL 5.5.

- `--default-storage-engine=type`

Command-Line Format	`--default-storage-engine=name`	
System Variable	Name	`storage_engine`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`enumeration`
	Default	`MyISAM`

Set the default storage engine (table type) for tables. See Chapter 14, *Storage Engines*.

- `--default-table-type=type`

Deprecated	5.0.0, by default-storage-engine
Command-Line Format	`--default-table-type=name`

Permitted Values	Type	string

This option is a synonym for `--default-storage-engine`. It is deprecated and removed in MySQL 5.5.

- `--default-time-zone=timezone`

Command-Line Format	`--default-time-zone=name`	
Permitted Values	Type	string

Set the default server time zone. This option sets the global `time_zone` system variable. If this option is not given, the default time zone is the same as the system time zone (given by the value of the `system_time_zone` system variable.

- `--defaults-extra-file=file_name`

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-file=file_name`

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. `file_name` is the full path name to the file.

- `--defaults-group-suffix=str`

Read not only the usual option groups, but also groups with the usual names and a suffix of `str`. For example, `mysqld` normally reads the `[mysqld]` group. If the `--defaults-group-suffix=_other` option is given, `mysqld` also reads the `[mysqld_other]` group.

- `--delay-key-write[={OFF|ON|ALL}]`

Command-Line Format	`--delay-key-write[=name]`	
System Variable	Name	`delay_key_write`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	enumeration
	Default	ON
	Valid Values	ON
		OFF
		ALL

Specify how to use delayed key writes. Delayed key writing causes key buffers not to be flushed between writes for `MyISAM` tables. `OFF` disables delayed key writes. `ON` enables delayed key writes for those tables that were created with the `DELAY_KEY_WRITE` option. `ALL` delays key writes for all `MyISAM` tables. See Section 8.12.2, "Tuning Server Parameters", and Section 14.5.1, "MyISAM Startup Options".

> **Note**
>
> If you set this variable to `ALL`, you should not use `MyISAM` tables from within another program (such as another MySQL server or `myisamchk`) when the tables are in use. Doing so leads to index corruption.

- `--des-key-file=file_name`

Command-Line Format	`--des-key-file=file_name`

Read the default DES keys from this file. These keys are used by the `DES_ENCRYPT()` and `DES_DECRYPT()` functions.

- `--enable-locking`

This option is deprecated. Use `--external-locking` instead.

- `--enable-named-pipe`

Command-Line Format	`--enable-named-pipe`
Platform Specific	Windows

Enable support for named pipes. This option applies only on Windows. For MySQL 5.1.20 and earlier, this option is available only when using the `mysqld-nt` and `mysqld-debug` servers that support named-pipe connections. For MySQL 5.1.21 and later, `mysqld-nt` is not available, but support is included in the standard `mysqld` and `mysqld-debug` servers.

- `--enable-pstack`

Deprecated	5.1.54	
Command-Line Format	`--enable-pstack`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This option is nonfunctional. It is deprecated as of MySQL 5.1.54 and removed in MySQL 5.5.

- `--engine-condition-pushdown={ON|OFF}`

Command-Line Format	`--engine-condition-pushdown`	
System Variable	**Name**	`engine_condition_pushdown`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`ON`

Sets the `engine_condition_pushdown` system variable. For more information, see Section 8.2.1.5, "Engine Condition Pushdown Optimization".

- `--event-scheduler[=value]`

Introduced	5.1.6	
Command-Line Format	`--event-scheduler[=value]`	
System Variable	**Name**	`event_scheduler`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`ON`
		`OFF`
		`DISABLED`

Enable or disable, and start or stop, the event scheduler. This option was added in MySQL 5.1.6. Note that its permitted values and behavior changed in MySQL 5.1.11, and again in MySQL 5.1.12.

For detailed information, see The `--event-scheduler` Option.

* `--exit-info[=flags]`, `-T [flags]`

Command-Line Format	`--exit-info[=flags]`	
Permitted Values	**Type**	`integer`

This is a bit mask of different flags that you can use for debugging the `mysqld` server. Do not use this option unless you know *exactly* what it does!

* `--external-locking`

Command-Line Format	`--external-locking`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Enable external locking (system locking), which is disabled by default. If you use this option on a system on which `lockd` does not fully work (such as Linux), it is easy for `mysqld` to deadlock.

To disable external locking explicitly, use `--skip-external-locking`.

External locking affects only `MyISAM` table access. For more information, including conditions under which it can and cannot be used, see Section 8.11.4, "External Locking".

* `--flush`

Command-Line Format	`--flush`	
System Variable	**Name**	`flush`
	Variable Scope	Global
	Dynamic Variable	Yes

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Permitted Values	Type	`boolean`
	Default	`OFF`

Flush (synchronize) all changes to disk after each SQL statement. Normally, MySQL does a write of all changes to disk only after each SQL statement and lets the operating system handle the synchronizing to disk. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

- `--gdb`

Command-Line Format	`--gdb`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

Install an interrupt handler for `SIGINT` (needed to stop `mysqld` with `^C` to set breakpoints) and disable stack tracing and core file handling. See Section 22.4, "Debugging and Porting MySQL".

- `--general-log[={0|1}]`

Introduced	5.1.12	
Command-Line Format	`--general-log`	
System Variable	Name	`general_log`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

Specify the initial general query log state. With no argument or an argument of 1, the `--general-log` option enables the log. If omitted or given with an argument of 0, the option disables the log. This option was added in MySQL 5.1.12.

- `--init-file=file_name`

Command-Line Format	`--init-file=file_name`	
System Variable	Name	`init_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`file name`

Read SQL statements from this file at startup. Each statement must be on a single line and should not include comments.

This option is unavailable if MySQL was configured with the `--disable-grant-options` option. See Section 2.11.4, "MySQL Source-Configuration Options".

- `--innodb-xxx`

Set an option for the `InnoDB` storage engine. The `InnoDB` options are listed in Section 14.6.8, "InnoDB Startup Options and System Variables".

- `--install [service_name]`

Command-Line Format	`--install [service_name]`
Platform Specific	Windows

(Windows only) Install the server as a Windows service that starts automatically during Windows startup. The default service name is `MySQL` if no `service_name` value is given. For more information, see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

Note

If the server is started with the `--defaults-file` and `--install` options, `--install` must be first.

- `--install-manual [service_name]`

Command-Line Format	`--install-manual [service_name]`
Platform Specific	Windows

(Windows only) Install the server as a Windows service that must be started manually. It does not start automatically during Windows startup. The default service name is `MySQL` if no `service_name` value is given. For more information, see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

Note

If the server is started with the `--defaults-file` and `--install-manual` options, `--install-manual` must be first.

- `--language=lang_name, -L lang_name`

Command-Line Format	`--language=name`	
System Variable	Name	`language`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`directory name`
	Default	`/usr/local/mysql/share/mysql/english/`

The language to use for error messages. `lang_name` can be given as the language name or as the full path name to the directory where the language files are installed. See Section 10.2, "Setting the Error Message Language".

- `--large-pages`

Command-Line Format	`--large-pages`	
System Variable	Name	`large_pages`

	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Linux	
Permitted Values (Linux)	Type	`boolean`
	Default	`FALSE`

Some hardware/operating system architectures support memory pages greater than the default (usually 4KB). The actual implementation of this support depends on the underlying hardware and operating system. Applications that perform a lot of memory accesses may obtain performance improvements by using large pages due to reduced Translation Lookaside Buffer (TLB) misses.

MySQL supports only the Linux implementation of large page support (which is called HugeTLB in Linux). See Section 8.12.5.2, "Enabling Large Page Support".

`--large-pages` is disabled by default.

- `--local-service`

Command-Line Format	`--local-service`

(Windows only) A `--local-service` option following the service name causes the server to run using the `LocalService` Windows account that has limited system privileges. This account is available only for Windows XP or newer. If both `--defaults-file` and `--local-service` are given following the service name, they can be in any order. See Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

- `--log[=file_name]`, `-l [file_name]`

Deprecated	5.1.29, by general-log
Command-Line Format	`--log[=file_name]`	
System Variable (<= 5.1.22)	Name	`log`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.1.23)	Name	`log`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`file name`

This option enables logging to the general query log, which contains entries that record client connections and SQL statements received from clients. The log output destination can be selected with the `--log-output` option as of MySQL 5.1.6. Before 5.1.6, logging occurs to the general query log file. If you omit the file name, MySQL uses *host_name*`.log` as the file name. See Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations", and Section 5.4.3, "The General Query Log".

As of MySQL 5.1.29, the `--log` option is deprecated and is removed (along with the `log` system variable) in MySQL 5.6. Instead, use the `--general_log` option to enable the general query log and the `--general_log_file=file_name` option to set the general query log file name.

- `--log-error[=file_name]`

Command-Line Format	`--log-error[=file_name]`	
System Variable	Name	`log_error`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`file name`

Log errors and startup messages to this file. See Section 5.4.2, "The Error Log". If you omit the file name, MySQL uses `host_name.err`. If the file name has no extension, the server adds an extension of `.err`.

- `--log-isam[=file_name]`

Command-Line Format	`--log-isam[=file_name]`	
Permitted Values	Type	`file name`

Log all `MyISAM` changes to this file (used only when debugging `MyISAM`).

- `--log-long-format`

Deprecated	4.1.0
Command-Line Format	`--log-long-format`

Log extra information to the binary log and slow query log, if they have been activated. For example, the user name and timestamp are logged for all queries. This option is deprecated, as it now represents the default logging behavior. (See the description for `--log-short-format`.) The `--log-queries-not-using-indexes` option is available for the purpose of logging queries that do not use indexes to the slow query log. `--log-long-format` is removed in MySQL 5.5.

- `--log-output[=value,...]`

Introduced	5.1.6	
Command-Line Format	`--log-output=name`	
System Variable	Name	`log_output`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`set`
	Default	`FILE`
	Valid Values	`TABLE`

	FILE
	NONE

This option determines the destination for general query log and slow query log output. The option value can be given as one or more of the words `TABLE`, `FILE`, or `NONE`. If the option is given without a value, the default is `FILE`. (For MySQL 5.1.6 through 5.1.20, the default is `TABLE`.) `TABLE` select logging to the `general_log` and `slow_log` tables in the `mysql` database as a destination. `FILE` selects logging to log files as a destination. `NONE` disables logging. If `NONE` is present in the option value, it takes precedence over any other words that are present. `TABLE` and `FILE` can both be given to select to both log output destinations.

This option selects log output destinations, but does not enable log output. To do that, use the `--general_log` and `--slow_query_log` options. For `FILE` logging, the `--general_log_file` and `--slow_query_log_file` options determine the log file location. (Before MySQL 5.1.29, enable the logs with the `--log` and `--log-slow-queries` options. The options take an optional file name argument to specify the log file name.) For more information, see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations".

The `--log-output` option was added in MySQL 5.1.6.

- `--log-queries-not-using-indexes`

Command-Line Format	`--log-queries-not-using-indexes`	
System Variable (>= 5.1.11)	**Name**	`log_queries_not_using_indexes`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

If you are using this option with the slow query log enabled, queries that are expected to retrieve all rows are logged. See Section 5.4.5, "The Slow Query Log". This option does not necessarily mean that no index is used. For example, a query that uses a full index scan uses an index but would be logged because the index would not limit the number of rows.

- `--log-short-format`

Command-Line Format	`--log-short-format`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Log less information to the slow query log, if it has been activated.

- `--log-slow-admin-statements`

Command-Line Format	`--log-slow-admin-statements`	
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Include slow administrative statements in the statements written to the slow query log. Administrative statements include `ALTER TABLE`, `ANALYZE TABLE`, `CHECK TABLE`, `CREATE INDEX`, `DROP INDEX`, `OPTIMIZE TABLE`, and `REPAIR TABLE`.

- `--log-slow-queries[=file_name]`

Deprecated	5.1.29, by slow-query-log	
Command-Line Format	`--log-slow-queries[=name]`	
System Variable (<= 5.1.22)	**Name**	`log_slow_queries`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.1.23)	**Name**	`log_slow_queries`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`

This option enables logging to the slow query log, which contains entries for all queries that have taken more than `long_query_time` seconds to execute. See the descriptions of the `--log-long-format` and `--log-short-format` options for details.

The log output destination can be selected with the `--log-output` option as of MySQL 5.1.6. Before 5.1.6, logging occurs to the slow query log file. If you omit the file name, MySQL uses *host_name-slow.log* as the file name. See Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations", and Section 5.4.5, "The Slow Query Log".

As of MySQL 5.1.29, the `--log-slow-queries` option is deprecated and is removed (along with the `log_slow_queries` system variable) in MySQL 5.6. Instead, use the `--slow_query_log` option to enable the slow query log and the `--slow_query_log_file=file_name` option to set the slow query log file name.

- `--log-tc=file_name`

Command-Line Format	`--log-tc=file_name`	
Permitted Values	**Type**	`file name`
	Default	`tc.log`

The name of the memory-mapped transaction coordinator log file (for XA transactions that affect multiple storage engines when the binary log is disabled). The default name is `tc.log`. The file is created under the data directory if not given as a full path name. This option is unused.

- `--log-tc-size=size`

Command-Line Format	`--log-tc-size=#`	
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`24576`

	Max Value	4294967295
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`24576`
	Max Value	`18446744073709547520`

The size in bytes of the memory-mapped transaction coordinator log. The default size is 24KB.

- `--log-warnings[=level]`, `-W [level]`

Command-Line Format	`--log-warnings[=#]`	
System Variable	Name	`log_warnings`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`18446744073709547520`

Print out warnings such as `Aborted connection...` to the error log. This option is enabled (1) by default. To disable it, use `--log-warnings=0`. Specifying the option without a `level` value increments the current value by 1. Enabling this option by setting it greater than 0 is recommended, for example, if you use replication (you get more information about what is happening, such as messages about network failures and reconnections). If the value is greater than 1, aborted connections are written to the error log. See Section B.5.2.11, "Communication Errors and Aborted Connections".

If a slave server was started with `--log-warnings` enabled, the slave prints messages to the error log to provide information about its status, such as the binary log and relay log coordinates where it starts its job, when it is switching to another relay log, when it reconnects after a disconnect, and so forth. As of MySQL 5.1.38, the server logs messages about statements that are unsafe for statement-based logging if `--log-warnings` is greater than 0.

- `--low-priority-updates`

Command-Line Format	`--low-priority-updates`	
System Variable	Name	`low_priority_updates`

	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Give table-modifying operations (`INSERT`, `REPLACE`, `DELETE`, `UPDATE`) lower priority than selects. This can also be done using `{INSERT | REPLACE | DELETE | UPDATE} LOW_PRIORITY ...` to lower the priority of only one query, or by `SET LOW_PRIORITY_UPDATES=1` to change the priority in one thread. This affects only storage engines that use only table-level locking (`MyISAM`, `MEMORY`, `MERGE`). See Section 8.11.2, "Table Locking Issues".

- `--min-examined-row-limit=number`

Introduced	5.1.21	
Command-Line Format	`--min-examined-row-limit=#`	
System Variable	**Name**	`min_examined_row_limit`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`18446744073709547520`

When this option is set, queries which examine fewer than *number* rows are not written to the slow query log. The default is 0.

This option was introduced in MySQL 5.1.21.

- `--memlock`

Command-Line Format	`--memlock`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Lock the `mysqld` process in memory. This option might help if you have a problem where the operating system is causing `mysqld` to swap to disk.

`--memlock` works on systems that support the `mlockall()` system call; this includes Solaris, most Linux distributions that use a 2.4 or newer kernel, and perhaps other Unix systems. On Linux systems, you can tell whether or not `mlockall()` (and thus this option) is supported by checking to see whether or not it is defined in the system `mman.h` file, like this:

```
shell> grep mlockall /usr/include/sys/mman.h
```

If `mlockall()` is supported, you should see in the output of the previous command something like the following:

```
extern int mlockall (int __flags) __THROW;
```

> **Important**
>
> Use of this option may require you to run the server as `root`, which, for reasons of security, is normally not a good idea. See Section 6.1.5, "How to Run MySQL as a Normal User".
>
> On Linux and perhaps other systems, you can avoid the need to run the server as `root` by changing the `limits.conf` file. See the notes regarding the memlock limit in Section 8.12.5.2, "Enabling Large Page Support".
>
> You must not try to use this option on a system that does not support the `mlockall()` system call; if you do so, `mysqld` will very likely crash as soon as you try to start it.

- `--myisam-block-size=N`

Command-Line Format	`--myisam-block-size=#`	
Permitted Values	**Type**	`integer`
	Default	`1024`
	Min Value	`1024`
	Max Value	`16384`

The block size to be used for `MyISAM` index pages.

- `--myisam-recover[=option[,option]...]]`

Command-Line Format	`--myisam-recover[=name]`	
Permitted Values	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`OFF`
		`DEFAULT`
		`BACKUP`
		`FORCE`
		`QUICK`

Set the `MyISAM` storage engine recovery mode. The option value is any combination of the values of `DEFAULT`, `BACKUP`, `FORCE`, or `QUICK`. If you specify multiple values, separate them by commas. Specifying the option with no argument is the same as specifying `DEFAULT`, and specifying with an explicit value of `""` disables recovery (same as not giving the option). If recovery is enabled, each time `mysqld` opens a `MyISAM` table, it checks whether the table is marked as crashed or was not closed properly. (The last option works only if you are running with external locking disabled.) If this is the case, `mysqld` runs a check on the table. If the table was corrupted, `mysqld` attempts to repair it.

The following options affect how the repair works.

Option	Description
`DEFAULT`	Recovery without backup, forcing, or quick checking.
`BACKUP`	If the data file was changed during recovery, save a backup of the `tbl_name.MYD` file as `tbl_name-datetime.BAK`.
`FORCE`	Run recovery even if we would lose more than one row from the `.MYD` file.
`QUICK`	Do not check the rows in the table if there are not any delete blocks.

Before the server automatically repairs a table, it writes a note about the repair to the error log. If you want to be able to recover from most problems without user intervention, you should use the options `BACKUP,FORCE`. This forces a repair of a table even if some rows would be deleted, but it keeps the old data file as a backup so that you can later examine what happened.

See Section 14.5.1, "MyISAM Startup Options".

- `--no-defaults`

Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--old-alter-table`

Command-Line Format	`--old-alter-table`	
System Variable	Name	`old_alter_table`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

When this option is given, the server does not use the optimized method of processing an `ALTER TABLE` operation. It reverts to using a temporary table, copying over the data, and then renaming the temporary table to the original, as used by MySQL 5.0 and earlier. For more information on the operation of `ALTER TABLE`, see Section 13.1.7, "ALTER TABLE Syntax".

- `--old-style-user-limits`

Command-Line Format	`--old-style-user-limits`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

Enable old-style user limits. (Before MySQL 5.0.3, account resource limits were counted separately for each host from which a user connected rather than per account row in the `user` table.) See Section 6.3.4, "Setting Account Resource Limits".

- `--one-thread`

Command-Line Format	`--one-thread`

Only use one thread (for debugging under Linux). This option is available only if the server is built with debugging enabled. See Section 22.4, "Debugging and Porting MySQL".

As of MySQL 5.1.17, this option is deprecated and is removed in MySQL 5.6. Use `--thread_handling=no-threads` instead.

- `--open-files-limit=count`

Command-Line Format	`--open-files-limit=#`	
System Variable	Name	`open_files_limit`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	0
	Min Value	0
	Max Value	`platform dependent`

Changes the number of file descriptors available to `mysqld`. You should try increasing the value of this option if `mysqld` gives you the error `Too many open files`. `mysqld` uses the option value to reserve descriptors with `setrlimit()`. Internally, the maximum value for this option is the maximum unsigned integer value, but the actual maximum is platform dependent. If the requested number of file descriptors cannot be allocated, `mysqld` writes a warning to the error log.

`mysqld` may attempt to allocate more than the requested number of descriptors (if they are available), using the values of `max_connections` and `table_open_cache` to estimate whether more descriptors will be needed.

On Unix, the value cannot be set less than `ulimit -n`.

- `--partition[=value]`

Command-Line Format	`--partition`	
Disabled by	`skip-partition`	
Permitted Values	Type	`boolean`
	Default	`ON`

Enables or disables user-defined partitioning support in the MySQL Server.

- `--pid-file=file_name`

Command-Line Format	`--pid-file=file_name`	
System Variable	**Name**	`pid_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The path name of the process ID file. The server creates the file in the data directory unless an absolute path name is given to specify a different directory. This file is used by other programs such as `mysqld_safe` to determine the server's process ID.

- `--plugin-`*xxx*

  Specifies an option that pertains to a server plugin. For example, many storage engines can be built as plugins, and for such engines, options for them can be specified with a `--plugin` prefix. Thus, the `--innodb_file_per_table` option for `InnoDB` can be specified as `--plugin-innodb_file_per_table`.

  For boolean options that can be enabled or disabled, the `--skip` prefix and other alternative formats are supported as well (see Section 4.2.5, "Program Option Modifiers"). For example, `--skip-plugin-innodb_file_per_table` disables `innodb_file_per_table`.

  The rationale for the `--plugin` prefix is that it enables plugin options to be specified unambiguously if there is a name conflict with a built-in server option. For example, were a plugin writer to name a plugin "sql" and implement a "mode" option, the option name might be `--sql-mode`, which would conflict with the built-in option of the same name. In such cases, references to the conflicting name are resolved in favor of the built-in option. To avoid the ambiguity, users can specify the plugin option as `--plugin-sql-mode`. Use of the `--plugin` prefix for plugin options is recommended to avoid any question of ambiguity.

- `--plugin-load=`*plugin_list*

Introduced	5.1.18	
Command-Line Format	`--plugin-load=plugin_list`	
Permitted Values	**Type**	`string`

This option tells the server to load the named plugins at startup. All plugins to load must be named in the same `--plugin-load` option. If multiple `--plugin-load` options are given, only the last one is used.

The option value is a semicolon-separated list of *name=plugin_library* and *plugin_library* values. Each *name* is the name of a plugin to load, and *plugin_library* is the name of the library object file that contains the plugin code. If a plugin library is named without any preceding plugin name, the server loads all plugins in the library. The server looks for plugin library files in the directory named by the `plugin_dir` system variable.

For example, if plugins named `myplug1` and `myplug2` have library files `myplug1.so` and `myplug2.so`, use this option to perform an early plugin load:

```
shell> mysqld --plugin-load="myplug1=myplug1.so;myplug2=myplug2.so"
```

Quotes are used around the argument value here because otherwise semicolon (`;`) is interpreted as a special character by some command interpreters. (Unix shells treat it as a command terminator, for example.)

Each named plugin is loaded for a single invocation of `mysqld` only. After a restart, the plugin is not loaded unless `--plugin-load` is used again. This is in contrast to `INSTALL PLUGIN`, which adds an entry to the `mysql.plugins` table to cause the plugin to be loaded for every normal server startup.

Under normal startup, the server determines which plugins to load by reading the `mysql.plugins` system table. If the server is started with the `--skip-grant-tables` option, it does not consult the `mysql.plugins` table and does not load plugins listed there. `--plugin-load` enables plugins to be loaded even when `--skip-grant-tables` is given. `--plugin-load` also enables plugins to be loaded at startup under configurations when plugins cannot be loaded at runtime.

For additional information about plugin loading, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

This option was added in MySQL 5.1.18.

- `--port=port_num`, `-P port_num`

Command-Line Format	`--port=#`	
System Variable	Name	`port`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	`3306`
	Min Value	`0`
	Max Value	`65535`

The port number to use when listening for TCP/IP connections. On Unix and Unix-like systems, the port number must be 1024 or higher unless the server is started by the `root` system user.

- `--port-open-timeout=num`

Introduced	5.1.5	
Command-Line Format	`--port-open-timeout=#`	
Permitted Values	Type	`integer`
	Default	`0`

On some systems, when the server is stopped, the TCP/IP port might not become available immediately. If the server is restarted quickly afterward, its attempt to reopen the port can fail. This option indicates how many seconds the server should wait for the TCP/IP port to become free if it cannot be opened. The default is not to wait. This option was added in MySQL 5.1.5.

- `--print-defaults`

Print the program name and all options that it gets from option files.

- `--remove [service_name]`

Command-Line Format	`--remove [service_name]`
Platform Specific	Windows

(Windows only) Remove a MySQL Windows service. The default service name is `MySQL` if no `service_name` value is given. For more information, see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

- `--safe-mode`

Command-Line Format	`--safe-mode`

Skip some optimization stages. This option is deprecated and is removed in MySQL 5.6.

- `--safe-show-database`

Deprecated	4.0.2	
Command-Line Format	`--safe-show-database`	
Permitted Values	**Type**	`boolean`

This option is deprecated and does not do anything because there is a `SHOW DATABASES` privilege that can be used to control access to database names on a per-account basis. See Section 6.2.1, "Privileges Provided by MySQL". `--safe-show-database` is removed in MySQL 5.5.

- `--safe-user-create`

Command-Line Format	`--safe-user-create`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

If this option is enabled, a user cannot create new MySQL users by using the `GRANT` statement unless the user has the `INSERT` privilege for the `mysql.user` table or any column in the table. If you want a user to have the ability to create new users that have those privileges that the user has the right to grant, you should grant the user the following privilege:

```
GRANT INSERT(user) ON mysql.user TO 'user_name'@'host_name';
```

This ensures that the user cannot change any privilege columns directly, but has to use the `GRANT` statement to give privileges to other users.

- `--secure-auth`

Command-Line Format	`--secure-auth`	
System Variable	**Name**	`secure_auth`
	Variable Scope	Global
	Dynamic	Yes
	Variable	499
Permitted Values	**Type**	`boolean`

	Default	OFF

This option causes the server to block connections by clients that attempt to use accounts that have passwords stored in the old (pre-4.1) format. Use it to prevent all use of passwords employing the old format (and hence insecure communication over the network).

Server startup fails with an error if this option is enabled and the privilege tables are in pre-4.1 format. See Section B.5.2.4, "Client does not support authentication protocol".

The `mysql` client also has a `--secure-auth` option, which prevents connections to a server if the server requires a password in old format for the client account.

- `--secure-file-priv=dir_name`

Introduced	5.1.17	
Command-Line Format	`--secure-file-priv=dir_name`	
System Variable	**Name**	`secure_file_priv`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`empty`
	Valid Values	`empty`
		`dirname`

This option limits the effect of the `LOAD DATA` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function to work only with files in the specified directory.

This option was added in MySQL 5.1.17.

- `--shared-memory`

Command-Line Format	`--shared_memory[={0,1}]`	
System Variable	**Name**	`shared_memory`
	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Windows	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Enable shared-memory connections by local clients. This option is available only on Windows.

- `--shared-memory-base-name=name`

Command-Line Format	`--shared_memory_base_name=name`	
System Variable	**Name**	`shared_memory_base_name`

	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Windows	
Permitted Values	Type	`string`
	Default	`MYSQL`

The name of shared memory to use for shared-memory connections. This option is available only on Windows. The default name is `MYSQL`. The name is case sensitive.

- `--skip-concurrent-insert`

Turn off the ability to select and insert at the same time on `MyISAM` tables. (This is to be used only if you think you have found a bug in this feature.) See Section 8.11.3, "Concurrent Inserts".

- `--skip-event-scheduler`

Command-Line Format	`--skip-event-scheduler`
	`--disable-event-scheduler`

Turns the Event Scheduler `OFF`. This is not the same as disabling the Event Scheduler, which requires setting `--event-scheduler=DISABLED`; see The `--event-scheduler` Option, for more information.

- `--skip-grant-tables`

This option causes the server to start without using the privilege system at all, which gives anyone with access to the server *unrestricted access to all databases*. You can cause a running server to start using the grant tables again by executing `mysqladmin flush-privileges` or `mysqladmin reload` command from a system shell, or by issuing a MySQL `FLUSH PRIVILEGES` statement after connecting to the server. This option also suppresses loading of user-defined functions (UDFs) and plugins that were installed with the `INSTALL PLUGIN` statement. Beginning with MySQL 5.1.17, it also suppresses scheduled events. To cause plugins to be loaded anyway, use the `--plugin-load` option.

`FLUSH PRIVILEGES` might be executed implicitly by other actions performed after startup. For example, `mysql_upgrade` flushes the privileges during the upgrade procedure.

`--skip-grant-tables` is unavailable if MySQL was configured with the `--disable-grant-options` option. See Section 2.11.4, "MySQL Source-Configuration Options".

- `--skip-host-cache`

Disable use of the internal host cache for faster name-to-IP resolution. In this case, the server performs a DNS lookup every time a client connects. See Section 8.12.6.2, "DNS Lookup Optimization and the Host Cache".

- `--skip-innodb`

Disable the `InnoDB` storage engine. In this case, the server will not start if the default storage engine is set to `InnoDB`. Use `--default-storage-engine` to set the default to some other engine if necessary.

- `--skip-merge`

Disable the `MERGE` storage engine. This option was added in MySQL 5.1.12 and removed in 5.1.14.

- `--skip-name-resolve`

Do not resolve host names when checking client connections. Use only IP addresses. If you use this option, all `Host` column values in the grant tables must be IP addresses or `localhost`. See Section 8.12.6.2, "DNS Lookup Optimization and the Host Cache".

Depending on the network configuration of your system and the `Host` values for your accounts, clients may need to connect using an explicit `--host` option, such as `--host=localhost` or `--host=127.0.0.1`.

- `--skip-networking`

Do not listen for TCP/IP connections at all. All interaction with `mysqld` must be made using named pipes or shared memory (on Windows) or Unix socket files (on Unix). This option is highly recommended for systems where only local clients are permitted. See Section 8.12.6.2, "DNS Lookup Optimization and the Host Cache".

- `--skip-partition`

Command-Line Format	`--skip-partition`
	`--disable-partition`

Disables user-defined partitioning. Partitioned tables can be seen using `SHOW TABLES` or by querying the `INFORMATION_SCHEMA.TABLES` table, but cannot be created or modified, nor can data in such tables be accessed. All partition-specific columns in the `INFORMATION_SCHEMA.PARTITIONS` table display `NULL`.

Since `DROP TABLE` removes table definition (`.frm`) files, this statement works on partitioned tables even when partitioning is disabled using the option. The statement, however, does not remove `.par` files associated with partitioned tables in such cases. For this reason, you should avoid dropping partitioned tables with partitioning disabled, or take action to remove the orphaned `.par` files manually.

- `--ssl*`

Options that begin with `--ssl` specify whether to permit clients to connect using SSL and indicate where to find SSL keys and certificates. See Section 6.4.5, "Command Options for Secure Connections".

- `--standalone`

Command-Line Format	`--standalone`
Platform Specific	Windows

Available on Windows only; instructs the MySQL server not to run as a service.

An attempt to connect to the host `127.0.0.1` normally resolves to the `localhost` account. However, this fails if the server is run with the `--skip-name-resolve` option, so make sure that an account exists that can accept a connection. For example, to be able to connect as `root` using `--host=127.0.0.1` or `--host=::1`, create these accounts:

```
CREATE USER 'root'@'127.0.0.1' IDENTIFIED BY 'root-password';
CREATE USER 'root'@'::1' IDENTIFIED BY 'root-password';
```

- `--symbolic-links`, `--skip-symbolic-links`

Command-Line Format	`--symbolic-links`

Enable or disable symbolic link support. This option has different effects on Windows and Unix:

- On Windows, enabling symbolic links enables you to establish a symbolic link to a database directory by creating a `db_name.sym` file that contains the path to the real directory. See Section 8.12.4.3, "Using Symbolic Links for Databases on Windows".

- On Unix, enabling symbolic links means that you can link a `MyISAM` index file or data file to another directory with the `INDEX DIRECTORY` or `DATA DIRECTORY` options of the `CREATE TABLE` statement. If you delete or rename the table, the files that its symbolic links point to also are deleted or renamed. See Section 8.12.4.2, "Using Symbolic Links for MyISAM Tables on Unix".

- `--skip-safemalloc`

Command-Line Format	`--skip-safemalloc`

If MySQL is configured with `--with-debug=full`, all MySQL programs check for memory overruns during each memory allocation and memory freeing operation. This checking is very slow, so for the server you can avoid it when you do not need it by using the `--skip-safemalloc` option.

- `--skip-show-database`

Command-Line Format	`--skip-show-database`	
System Variable	Name	`skip_show_database`
	Variable Scope	Global
	Dynamic Variable	No

This option sets the `skip_show_database` system variable that controls who is permitted to use the `SHOW DATABASES` statement. See Section 5.1.4, "Server System Variables".

- `--skip-stack-trace`

Command-Line Format	`--skip-stack-trace`

Do not write stack traces. This option is useful when you are running `mysqld` under a debugger. On some systems, you also must use this option to get a core file. See Section 22.4, "Debugging and Porting MySQL".

- `--skip-thread-priority`

Deprecated	5.1.29
Command-Line Format	`--skip-thread-priority`

Disable using thread priorities for faster response time. This option is deprecated as of MySQL 5.1.29 and is removed in MySQL 5.6.

Prior to MySQL 5.1.29, `mysqld` makes a large number of invalid calls to thread scheduling routines on Linux. These calls do not affect performance noticeably but may be a source of "noise" for debugging tools. For example, they can overwhelm other information of more interest in kernel logs. To avoid these calls, start the server with the `--skip-thread-priority` option.

- `--slow-query-log[={0|1}]`

Introduced	5.1.12	
Command-Line Format	`--slow-query-log` (>= 5.1.29)	
System Variable	**Name**	`slow_query_log`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Specify the initial slow query log state. With no argument or an argument of 1, the `--slow-query-log` option enables the log. If omitted or given with an argument of 0, the option disables the log. This option was added in MySQL 5.1.12.

- `--socket=path`

Command-Line Format	`--socket={file_name|pipe_name}`	
System Variable	**Name**	`socket`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`/tmp/mysql.sock`

On Unix, this option specifies the Unix socket file to use when listening for local connections. The default value is `/tmp/mysql.sock`. If this option is given, the server creates the file in the data directory unless an absolute path name is given to specify a different directory. On Windows, the option specifies the pipe name to use when listening for local connections that use a named pipe. The default value is `MySQL` (not case sensitive).

- `--sql-mode=value[,value[,value...]]`

Command-Line Format	`--sql-mode=name`	
System Variable	**Name**	`sql_mode`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`set`
	Default	`''`
	Valid Values	`ALLOW_INVALID_DATES`
		`ANSI_QUOTES`
		`ERROR_FOR_DIVISION_BY_ZERO`

	HIGH_NOT_PRECEDENCE
	IGNORE_SPACE
	NO_AUTO_CREATE_USER
	NO_AUTO_VALUE_ON_ZERO
	NO_BACKSLASH_ESCAPES
	NO_DIR_IN_CREATE
	NO_ENGINE_SUBSTITUTION
	NO_FIELD_OPTIONS
	NO_KEY_OPTIONS
	NO_TABLE_OPTIONS
	NO_UNSIGNED_SUBTRACTION
	NO_ZERO_DATE
	NO_ZERO_IN_DATE
	ONLY_FULL_GROUP_BY
	PAD_CHAR_TO_FULL_LENGTH
	PIPES_AS_CONCAT
	REAL_AS_FLOAT
	STRICT_ALL_TABLES
	STRICT_TRANS_TABLES

Set the SQL mode. See Section 5.1.7, "Server SQL Modes".

Note

MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

- `--sysdate-is-now`

Introduced	5.1.8	
Command-Line Format	`--sysdate-is-now`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

`SYSDATE()` by default returns the time at which it executes, not the time at which the statement in which it occurs begins executing. This differs from the behavior of `NOW()`. This option causes `SYSDATE()` to be an alias for `NOW()`. For information about the implications for binary logging and replication, see the description for `SYSDATE()` in Section 12.7, "Date and Time Functions" and for `SET TIMESTAMP` in Section 5.1.4, "Server System Variables".

This option was added in MySQL 5.1.8.

- `--tc-heuristic-recover={COMMIT|ROLLBACK}`

Command-Line Format	`--tc-heuristic-recover=name`

Permitted Values	Type	enumeration
	Default	COMMIT
	Valid Values	COMMIT
		ROLLBACK

The type of decision to use in the heuristic recovery process. This option is unused.

- `--temp-pool`

Command-Line Format	--temp-pool	
Permitted Values	Type	boolean
	Default	TRUE

This option causes most temporary files created by the server to use a small set of names, rather than a unique name for each new file. This works around a problem in the Linux kernel dealing with creating many new files with different names. With the old behavior, Linux seems to "leak" memory, because it is being allocated to the directory entry cache rather than to the disk cache. As of MySQL 5.1.31, this option is ignored except on Linux.

- `--transaction-isolation=level`

Command-Line Format	--transaction-isolation=name	
Permitted Values	Type	enumeration
	Default	REPEATABLE-READ
	Valid Values	READ-UNCOMMITTED
		READ-COMMITTED
		REPEATABLE-READ
		SERIALIZABLE

Sets the default transaction isolation level. The `level` value can be `READ-UNCOMMITTED`, `READ-COMMITTED`, `REPEATABLE-READ`, or `SERIALIZABLE`. See Section 13.3.6, "SET TRANSACTION Syntax".

The default transaction isolation level can also be set at runtime using the `SET TRANSACTION` statement or by setting the `tx_isolation` system variable.

- `--tmpdir=dir_name`, `-t dir_name`

Command-Line Format	--tmpdir=dir_name	
System Variable	Name	tmpdir
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	directory name

The path of the directory to use for creating temporary files. It might be useful if your default `/tmp` directory resides on a partition that is too small to hold temporary tables. This option accepts several paths that are used in round-robin fashion. Paths should be separated by colon characters (":") on Unix

and semicolon characters ("`;`") on Windows, NetWare, and OS/2. If the MySQL server is acting as a replication slave, you should not set `--tmpdir` to point to a directory on a memory-based file system or to a directory that is cleared when the server host restarts. For more information about the storage location of temporary files, see Section B.5.3.5, "Where MySQL Stores Temporary Files". A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA INFILE` operations. If files in the temporary file directory are lost when the server restarts, replication fails.

- `--user={user_name|user_id}`, `-u {user_name|user_id}`

Command-Line Format	`--user=name`	
Permitted Values	**Type**	`string`

Run the `mysqld` server as the user having the name *user_name* or the numeric user ID *user_id*. ("User" in this context refers to a system login account, not a MySQL user listed in the grant tables.)

This option is *mandatory* when starting `mysqld` as `root`. The server changes its user ID during its startup sequence, causing it to run as that particular user rather than as `root`. See Section 6.1.1, "Security Guidelines".

To avoid a possible security hole where a user adds a `--user=root` option to a `my.cnf` file (thus causing the server to run as `root`), `mysqld` uses only the first `--user` option specified and produces a warning if there are multiple `--user` options. Options in `/etc/my.cnf` and `$MYSQL_HOME/my.cnf` are processed before command-line options, so it is recommended that you put a `--user` option in `/etc/my.cnf` and specify a value other than `root`. The option in `/etc/my.cnf` is found before any other `--user` options, which ensures that the server runs as a user other than `root`, and that a warning results if any other `--user` option is found.

- `--verbose`, `-v`

Use this option with the `--help` option for detailed help.

- `--version`, `-V`

Display version information and exit.

5.1.4 Server System Variables

The MySQL server maintains many system variables that indicate how it is configured. Each system variable has a default value. System variables can be set at server startup using options on the command line or in an option file. Most of them can be changed dynamically while the server is running by means of the `SET` statement, which enables you to modify operation of the server without having to stop and restart it. You can refer to system variable values in expressions.

There are several ways to see the names and values of system variables:

- To see the values that a server will use based on its compiled-in defaults and any option files that it reads, use this command:

```
mysqld --verbose --help
```

- To see the values that a server will use based on its compiled-in defaults, ignoring the settings in any option files, use this command:

```
mysqld --no-defaults --verbose --help
```

- To see the current values used by a running server, use the `SHOW VARIABLES` statement.

This section provides a description of each system variable. Variables with no version indicated are present in all MySQL 5.1 releases.

The following table lists all available system variables.

Table 5.2 System Variable Summary

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
auto_increment_increment			Yes	Both	Yes
auto_increment_offset			Yes	Both	Yes
autocommit			Yes	Session	Yes
automatic_sp_privileges			Yes	Global	Yes
back_log			Yes	Global	No
basedir	Yes	Yes	Yes	Global	No
big-tables	Yes	Yes			Yes
- *Variable*: big_tables			Yes	Session	Yes
binlog_cache_size	Yes	Yes	Yes	Global	Yes
binlog_direct_non_transactional_updates	Yes	Yes	Yes	Both	Yes
binlog-format	Yes	Yes			Yes
- *Variable*: binlog_format			Yes	Both	Yes
bulk_insert_buffer_size	Yes	Yes	Yes	Both	Yes
character_set_client			Yes	Both	Yes
character_set_connection			Yes	Both	Yes
character_set_database[a]			Yes	Both	Yes
character-set-filesystem	Yes	Yes			Yes
- *Variable*: character_set_filesystem			Yes	Both	Yes
character_set_results			Yes	Both	Yes
character-set-server	Yes	Yes			Yes
- *Variable*: character_set_server			Yes	Both	Yes
character_set_system			Yes	Global	No
character-sets-dir	Yes	Yes			No
- *Variable*: character_sets_dir			Yes	Global	No
collation_connection			Yes	Both	Yes
collation_database[b]			Yes	Both	Yes
collation-server	Yes	Yes			Yes
- *Variable*: collation_server			Yes	Both	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
completion_type	Yes	Yes	Yes	Both	Yes
concurrent_insert	Yes	Yes	Yes	Global	Yes
connect_timeout	Yes	Yes	Yes	Global	Yes
datadir	Yes	Yes	Yes	Global	No
date_format			Yes	Both	No
datetime_format			Yes	Both	No
debug	Yes	Yes	Yes	Both	Yes
debug_sync			Yes	Both	Yes
default-storage-engine	Yes	Yes	Yes	Both	Yes
default_week_format	Yes	Yes	Yes	Both	Yes
delay-key-write	Yes	Yes			Yes
- *Variable*: delay_key_write			Yes	Global	Yes
delayed_insert_limit	Yes	Yes	Yes	Global	Yes
delayed_insert_timeout	Yes	Yes	Yes	Global	Yes
delayed_queue_size	Yes	Yes	Yes	Global	Yes
div_precision_increment	Yes	Yes	Yes	Both	Yes
engine-condition-pushdown	Yes	Yes			Yes
- *Variable*: engine_condition_pushdown			Yes	Both	Yes
error_count			Yes	Session	No
event-scheduler	Yes	Yes			Yes
- *Variable*: event_scheduler			Yes	Global	Yes
expire_logs_days	Yes	Yes	Yes	Global	Yes
flush	Yes	Yes	Yes	Global	Yes
flush_time	Yes	Yes	Yes	Global	Yes
foreign_key_checks			Yes	Session	Yes
ft_boolean_syntax	Yes	Yes	Yes	Global	Yes
ft_max_word_len	Yes	Yes	Yes	Global	No
ft_min_word_len	Yes	Yes	Yes	Global	No
ft_query_expansion_limit	Yes	Yes	Yes	Global	No
ft_stopword_file	Yes	Yes	Yes	Global	No
general-log	Yes	Yes			Yes
- *Variable*: general_log			Yes	Global	Yes
general_log_file	Yes	Yes	Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
group_concat_max_len	Yes	Yes	Yes	Both	Yes
have_archive			Yes	Global	No
have_blackhole_engine			Yes	Global	No
have_community_features			Yes	Global	No
have_compress			Yes	Global	No
have_crypt			Yes	Global	No
have_csv			Yes	Global	No
have_dynamic_loading			Yes	Global	No
have_example_engine			Yes	Global	No
have_federated_engine			Yes	Global	No
have_geometry			Yes	Global	No
have_innodb			Yes	Global	No
have_isam			Yes	Global	No
have_merge_engine			Yes	Global	No
have_ndbcluster			Yes	Global	No
have_openssl			Yes	Global	No
have_partition_engine			Yes	Global	No
have_partitioning			Yes	Global	No
have_query_cache			Yes	Global	No
have_raid			Yes	Global	No
have_row_based_replication			Yes	Global	No
have_rtree_keys			Yes	Global	No
have_ssl			Yes	Global	No
have_symlink			Yes	Global	No
hostname			Yes	Global	No
identity			Yes	Session	Yes
ignore-builtin-innodb	Yes	Yes			No
- *Variable*: ignore_builtin_innodb			Yes	Global	No
init_connect	Yes	Yes	Yes	Global	Yes
init-file	Yes	Yes			No
- *Variable*: init_file			Yes	Global	No
init_slave	Yes	Yes	Yes	Global	Yes
innodb_adaptive_flushing	Yes	Yes	Yes	Global	Yes
innodb_adaptive_hash_index	Yes	Yes	Yes	Global	No
innodb_additional_mem_pool_size	Yes	Yes	Yes	Global	No
innodb_autoextend_increment	Yes	Yes	Yes	Global	Yes
innodb_autoinc_lock_mode	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
innodb_buffer_pool_awe_mem_mb	Yes	Yes	Yes	Global	No
innodb_buffer_pool_size	Yes	Yes	Yes	Global	No
innodb_change_buffering	Yes	Yes	Yes	Global	Yes
innodb_change_buffering_debug	Yes	Yes	Yes	Global	Yes
innodb_checksums	Yes	Yes	Yes	Global	No
innodb_commit_concurrency	Yes	Yes	Yes	Global	Yes
innodb_concurrency_tickets	Yes	Yes	Yes	Global	Yes
innodb_data_file_path	Yes	Yes	Yes	Global	No
innodb_data_home_dir	Yes	Yes	Yes	Global	No
innodb_doublewrite	Yes	Yes	Yes	Global	No
innodb_fast_shutdown	Yes	Yes	Yes	Global	Yes
innodb_file_format	Yes	Yes	Yes	Global	Yes
innodb_file_format_check	Yes	Yes	Yes	Global	Yes
innodb_file_io_threads	Yes	Yes	Yes	Global	No
innodb_file_per_table	Yes	Yes	Yes	Global	No
innodb_flush_log_at_trx_commit	Yes	Yes	Yes	Global	Yes
innodb_flush_method	Yes	Yes	Yes	Global	No
innodb_force_recovery	Yes	Yes	Yes	Global	No
innodb_io_capacity	Yes	Yes	Yes	Global	No
innodb_limit_optimistic_insert_debug	Yes	Yes	Yes	Global	Yes
innodb_lock_wait_timeout	Yes	Yes	Yes	Varies	No
innodb_locks_unsafe_for_binlog	Yes	Yes	Yes	Global	No
innodb_log_arch_dir	Yes	Yes	Yes	Global	No
innodb_log_archive	Yes	Yes	Yes	Global	No
innodb_log_buffer_size	Yes	Yes	Yes	Global	No
innodb_log_file_size	Yes	Yes	Yes	Global	No
innodb_log_files_in_group	Yes	Yes	Yes	Global	No
innodb_log_group_home_dir	Yes	Yes	Yes	Global	No
innodb_max_dirty_pages_pct	Yes	Yes	Yes	Global	Yes
innodb_max_purge_lag	Yes	Yes	Yes	Global	Yes
innodb_mirrored_log_groups	Yes	Yes	Yes	Global	No
innodb_old_blocks_pct	Yes	Yes	Yes	Global	Yes
innodb_old_blocks_time	Yes	Yes	Yes	Global	Yes
innodb_open_files	Yes	Yes	Yes	Global	No
innodb_random_read_ahead	Yes	Yes	Yes	Global	Yes
innodb_read_ahead_threshold	Yes	Yes	Yes	Global	Yes
innodb_read_io_threads	Yes	Yes	Yes	Global	No
innodb_replication_delay	Yes	Yes	Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
innodb_rollback_on_timeout	Yes	Yes	Yes	Global	No
innodb_spin_wait_delay	Yes	Yes	Yes	Global	Yes
innodb_stats_method	Yes	Yes	Yes	Global	Yes
innodb_stats_on_metadata	Yes	Yes	Yes	Global	Varies
innodb_stats_sample_pages	Yes	Yes	Yes	Global	Yes
innodb_strict_mode	Yes	Yes	Yes	Both	Yes
innodb_support_xa	Yes	Yes	Yes	Both	Yes
innodb_sync_spin_loops	Yes	Yes	Yes	Global	Yes
innodb_table_locks	Yes	Yes	Yes	Both	Yes
innodb_thread_concurrency	Yes	Yes	Yes	Global	Yes
innodb_thread_sleep_delay	Yes	Yes	Yes	Global	Yes
innodb_trx_purge_view_update_only_debug	Yes	Yes	Yes	Global	Yes
innodb_trx_rseg_n_slots_debug	Yes	Yes	Yes	Global	Yes
innodb_use_legacy_cardinality_algorithm	Yes	Yes	Yes	Global	Yes
innodb_use_sys_malloc	Yes	Yes	Yes	Global	No
innodb_version			Yes	Global	No
innodb_write_io_threads	Yes	Yes	Yes	Global	No
insert_id			Yes	Session	Yes
interactive_timeout	Yes	Yes	Yes	Both	Yes
join_buffer_size	Yes	Yes	Yes	Both	Yes
keep_files_on_create	Yes	Yes	Yes	Both	Yes
key_buffer_size	Yes	Yes	Yes	Global	Yes
key_cache_age_threshold	Yes	Yes	Yes	Global	Yes
key_cache_block_size	Yes	Yes	Yes	Global	Yes
key_cache_division_limit	Yes	Yes	Yes	Global	Yes
language	Yes	Yes	Yes	Global	No
large_files_support			Yes	Global	No
large_page_size			Yes	Global	No
large-pages	Yes	Yes			No
- *Variable*: large_pages			Yes	Global	No
last_insert_id			Yes	Session	Yes
lc_time_names			Yes	Both	Yes
license			Yes	Global	No
local_infile			Yes	Global	Yes
locked_in_memory			Yes	Global	No
log	Yes	Yes	Yes	Global	Varies
log-bin	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
log_bin			Yes	Global	No
log-bin-trust-function-creators	Yes	Yes			Yes
- *Variable*: log_bin_trust_function_creators			Yes	Global	Yes
log-bin-trust-routine-creators	Yes	Yes			Yes
- *Variable*: log_bin_trust_routine_creators			Yes	Global	Yes
log-bin-use-v1-row-events	Yes	Yes			No
- *Variable*: log_bin_use_v1_row_events			Yes	Global	No
log_bin_use_v1_row_events	Yes	Yes	Yes	Global	No
log-error	Yes	Yes			No
- *Variable*: log_error			Yes	Global	No
log-output	Yes	Yes			Yes
- *Variable*: log_output			Yes	Global	Yes
log-queries-not-using-indexes	Yes	Yes			Yes
- *Variable*: log_queries_not_using_indexes			Yes	Global	Yes
log-slave-updates	Yes	Yes			No
- *Variable*: log_slave_updates			Yes	Global	No
log_slave_updates	Yes	Yes	Yes	Global	No
log-slow-queries	Yes	Yes			Varies
- *Variable*: log_slow_queries			Yes	Global	Varies
log-warnings	Yes	Yes			Yes
- *Variable*: log_warnings			Yes	Both	Yes
long_query_time	Yes	Yes	Yes	Both	Yes
low-priority-updates	Yes	Yes			Yes
- *Variable*: low_priority_updates			Yes	Both	Yes
lower_case_file_system			Yes	Global	No
lower_case_table_names	Yes	Yes	Yes	Global	No
max_allowed_packet	Yes	Yes	Yes	Both	Yes
max_binlog_cache_size	Yes	Yes	Yes	Global	Yes
max_binlog_size	Yes	Yes	Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
max_connect_errors	Yes	Yes	Yes	Global	Yes
max_connections	Yes	Yes	Yes	Global	Yes
max_delayed_threads	Yes	Yes	Yes	Both	Yes
max_error_count	Yes	Yes	Yes	Both	Yes
max_heap_table_size	Yes	Yes	Yes	Both	Yes
max_insert_delayed_threads			Yes	Both	Yes
max_join_size	Yes	Yes	Yes	Both	Yes
max_length_for_sort_data	Yes	Yes	Yes	Both	Yes
max_long_data_size	Yes	Yes	Yes	Global	No
max_prepared_stmt_count	Yes	Yes	Yes	Global	Yes
max_relay_log_size	Yes	Yes	Yes	Global	Yes
max_seeks_for_key	Yes	Yes	Yes	Both	Yes
max_sort_length	Yes	Yes	Yes	Both	Yes
max_sp_recursion_depth	Yes	Yes	Yes	Both	Yes
max_tmp_tables			Yes	Both	Yes
max_user_connections	Yes	Yes	Yes	Both	Yes
max_write_lock_count	Yes	Yes	Yes	Global	Yes
min-examined-row-limit	Yes	Yes	Yes	Both	Yes
multi_range_count	Yes	Yes	Yes	Both	Yes
myisam_data_pointer_size	Yes	Yes	Yes	Global	Yes
myisam_max_sort_file_size	Yes	Yes	Yes	Global	Yes
myisam_mmap_size	Yes	Yes	Yes	Global	No
myisam_recover_options			Yes	Global	No
myisam_repair_threads	Yes	Yes	Yes	Both	Yes
myisam_sort_buffer_size	Yes	Yes	Yes	Both	Yes
myisam_stats_method	Yes	Yes	Yes	Both	Yes
myisam_use_mmap	Yes	Yes	Yes	Global	Yes
named_pipe			Yes	Global	No
ndb_autoincrement_prefetch_sz	Yes	Yes	Yes	Both	Yes
ndb-batch-size	Yes	Yes	Yes	Global	No
ndb-blob-read-batch-bytes	Yes	Yes	Yes	Both	Yes
ndb-blob-write-batch-bytes	Yes	Yes	Yes	Both	Yes
ndb_cache_check_time	Yes	Yes	Yes	Global	Yes
ndb-cluster-connection-pool	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
ndb-deferred-constraints	Yes	Yes			Yes
- *Variable*: ndb_deferred_constraints			Yes	Both	Yes
ndb_deferred_constraints	Yes	Yes	Yes	Both	Yes
ndb-distribution	Yes	Yes			Yes
- *Variable*: ndb_distribution			Yes	Global	Yes
ndb_distribution	Yes	Yes	Yes	Global	Yes
ndb_eventbuffer_max_alloc	Yes	Yes	Yes	Global	Yes
ndb_extra_logging	Yes	Yes	Yes	Global	Yes
ndb_force_send	Yes	Yes	Yes	Both	Yes
ndb_index_stat_cache_entries	Yes	Yes	Yes	Both	Yes
ndb_index_stat_enable	Yes	Yes	Yes	Both	Yes
ndb_index_stat_option	Yes	Yes	Yes	Both	Yes
ndb_index_stat_update_freq	Yes	Yes	Yes	Both	Yes
ndb_join_pushdown			Yes	Both	Yes
ndb-log-apply-status	Yes	Yes			No
- *Variable*: ndb_log_apply_status			Yes	Global	No
ndb_log_apply_status	Yes	Yes	Yes	Global	No
ndb_log_bin	Yes		Yes	Both	Yes
ndb_log_binlog_index	Yes		Yes	Global	Yes
ndb-log-empty-epochs	Yes	Yes	Yes	Global	Yes
ndb_log_empty_epochs	Yes	Yes	Yes	Global	Yes
ndb-log-orig	Yes	Yes			No
- *Variable*: ndb_log_orig			Yes	Global	No
ndb_log_orig	Yes	Yes	Yes	Global	No
ndb-log-transaction-id	Yes	Yes			No
- *Variable*: ndb_log_transaction_id			Yes	Global	No
ndb_log_transaction_id			Yes	Global	No
ndb-log-update-as-write	Yes	Yes	Yes	Global	Yes
ndb_log_updated_only	Yes	Yes	Yes	Global	Yes
ndb_optimization_delay			Yes	Global	Yes
ndb_optimized_node_selection	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
ndb_report_thresh_binlog_epoch_slip	Yes	Yes	Yes	Global	Yes
ndb_report_thresh_binlog_mem_usage	Yes	Yes	Yes	Global	Yes
ndb_table_no_logging			Yes	Session	Yes
ndb_table_temporary			Yes	Session	Yes
ndb_use_copying_alter_table			Yes	Both	No
ndb_use_exact_count			Yes	Both	Yes
ndb_use_transactions	Yes	Yes	Yes	Both	Yes
ndb_version			Yes	Global	No
ndb_version_string			Yes	Global	No
ndb-wait-connected	Yes	Yes	Yes	Global	No
ndb-wait-setup	Yes	Yes	Yes	Global	No
ndbinfo_database			Yes	Global	No
ndbinfo_max_bytes	Yes		Yes	Both	Yes
ndbinfo_max_rows	Yes		Yes	Both	Yes
ndbinfo_offline			Yes	Global	Yes
ndbinfo_show_hidden	Yes		Yes	Both	Yes
ndbinfo_table_prefix	Yes		Yes	Both	Yes
ndbinfo_version			Yes	Global	No
net_buffer_length	Yes	Yes	Yes	Both	Yes
net_read_timeout	Yes	Yes	Yes	Both	Yes
net_retry_count	Yes	Yes	Yes	Both	Yes
net_write_timeout	Yes	Yes	Yes	Both	Yes
new	Yes	Yes	Yes	Both	Yes
old	Yes	Yes	Yes	Global	No
old-alter-table	Yes	Yes			Yes
- *Variable*: old_alter_table			Yes	Both	Yes
old_passwords			Yes	Both	Yes
open-files-limit	Yes	Yes			No
- *Variable*: open_files_limit			Yes	Global	No
optimizer_prune_level	Yes	Yes	Yes	Both	Yes
optimizer_search_depth	Yes	Yes	Yes	Both	Yes
optimizer_switch	Yes	Yes	Yes	Both	Yes
pid-file	Yes	Yes			No
- *Variable*: pid_file			Yes	Global	No
plugin_dir	Yes	Yes	Yes	Global	No
port	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
preload_buffer_size	Yes	Yes	Yes	Both	Yes
prepared_stmt_count			Yes	Global	No
profiling			Yes	Session	Yes
profiling_history_size	Yes	Yes	Yes	Both	Yes
protocol_version			Yes	Global	No
pseudo_thread_id			Yes	Session	Yes
query_alloc_block_size	Yes	Yes	Yes	Both	Yes
query_cache_limit	Yes	Yes	Yes	Global	Yes
query_cache_min_res_unit	Yes	Yes	Yes	Global	Yes
query_cache_size	Yes	Yes	Yes	Global	Yes
query_cache_type	Yes	Yes	Yes	Both	Yes
query_cache_wlock_invalidate	Yes	Yes	Yes	Both	Yes
query_prealloc_size	Yes	Yes	Yes	Both	Yes
rand_seed1			Yes	Session	Yes
rand_seed2			Yes	Session	Yes
range_alloc_block_size	Yes	Yes	Yes	Both	Yes
read_buffer_size	Yes	Yes	Yes	Both	Yes
read_only	Yes	Yes	Yes	Global	Yes
read_rnd_buffer_size	Yes	Yes	Yes	Both	Yes
relay-log	Yes	Yes			No
- *Variable*: relay_log			Yes	Global	No
relay-log-index	Yes	Yes			No
- *Variable*: relay_log_index			Yes	Global	No
relay_log_index	Yes	Yes	Yes	Global	No
relay_log_info_file	Yes	Yes	Yes	Global	No
relay_log_purge	Yes	Yes	Yes	Global	Yes
relay_log_space_limit	Yes	Yes	Yes	Global	No
report-host	Yes	Yes			No
- *Variable*: report_host			Yes	Global	No
report-password	Yes	Yes			No
- *Variable*: report_password			Yes	Global	No
report-port	Yes	Yes			No
- *Variable*: report_port			Yes	Global	No
report-user	Yes	Yes			No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
- *Variable*: report_user			Yes	Global	No
rpl_recovery_rank			Yes	Global	Yes
secure-auth	Yes	Yes			Yes
- *Variable*: secure_auth			Yes	Global	Yes
secure-file-priv	Yes	Yes			No
- *Variable*: secure_file_priv			Yes	Global	No
server-id	Yes	Yes			Yes
- *Variable*: server_id			Yes	Global	Yes
server-id-bits	Yes	Yes			No
- *Variable*: server_id_bits			Yes	Global	No
server_id_bits	Yes	Yes	Yes	Global	No
shared_memory	Yes	Yes	Yes	Global	No
shared_memory_base_name	Yes	Yes	Yes	Global	No
skip_external_locking	Yes	Yes	Yes	Global	No
skip-name-resolve	Yes	Yes			No
- *Variable*: skip_name_resolve			Yes	Global	No
skip-networking	Yes	Yes			No
- *Variable*: skip_networking			Yes	Global	No
skip-show-database	Yes	Yes			No
- *Variable*: skip_show_database			Yes	Global	No
slave_allow_batching	Yes	Yes	Yes	Global	Yes
slave_compressed_protocol	Yes	Yes	Yes	Global	Yes
slave_exec_mode	Yes	Yes	Yes	Global	Yes
slave-load-tmpdir	Yes	Yes			No
- *Variable*: slave_load_tmpdir			Yes	Global	No
slave_max_allowed_packet			Yes	Global	Yes
slave-net-timeout	Yes	Yes			Yes
- *Variable*: slave_net_timeout			Yes	Global	Yes
slave-skip-errors	Yes	Yes			No
- *Variable*: slave_skip_errors			Yes	Global	No
slave_transaction_retries	Yes	Yes	Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
slave_type_conversions	Yes	Yes	Yes	Global	No
slow_launch_time	Yes	Yes	Yes	Global	Yes
slow-query-log	Yes	Yes			Yes
- *Variable*: slow_query_log			Yes	Global	Yes
slow_query_log_file	Yes	Yes	Yes	Global	Yes
socket	Yes	Yes	Yes	Global	No
sort_buffer_size	Yes	Yes	Yes	Both	Yes
sql_auto_is_null			Yes	Session	Yes
sql_big_selects			Yes	Session	Yes
sql_big_tables			Yes	Session	Yes
sql_buffer_result			Yes	Session	Yes
sql_log_bin			Yes	Session	Yes
sql_log_off			Yes	Session	Yes
sql_log_update			Yes	Session	Yes
sql_low_priority_updates			Yes	Both	Yes
sql_max_join_size			Yes	Both	Yes
sql-mode	Yes	Yes			Yes
- *Variable*: sql_mode			Yes	Both	Yes
sql_notes			Yes	Session	Yes
sql_quote_show_create			Yes	Session	Yes
sql_safe_updates			Yes	Session	Yes
sql_select_limit			Yes	Both	Yes
sql_slave_skip_counter			Yes	Global	Yes
sql_warnings			Yes	Session	Yes
ssl-ca	Yes	Yes			No
- *Variable*: ssl_ca			Yes	Global	No
ssl-capath	Yes	Yes			No
- *Variable*: ssl_capath			Yes	Global	No
ssl-cert	Yes	Yes			No
- *Variable*: ssl_cert			Yes	Global	No
ssl-cipher	Yes	Yes			No
- *Variable*: ssl_cipher			Yes	Global	No
ssl-key	Yes	Yes			No
- *Variable*: ssl_key			Yes	Global	No
storage_engine			Yes	Both	Yes
sync_binlog	Yes	Yes	Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
sync_frm	Yes	Yes	Yes	Global	Yes
system_time_zone			Yes	Global	No
table_cache	Yes	Yes	Yes	Global	Yes
table_definition_cache			Yes	Global	Yes
table_lock_wait_timeout	Yes	Yes	Yes	Global	Yes
table_open_cache			Yes	Global	Yes
table_type			Yes	Both	Yes
thread_cache_size	Yes	Yes	Yes	Global	Yes
thread_concurrency	Yes	Yes	Yes	Global	No
thread_handling	Yes	Yes	Yes	Global	No
thread_stack	Yes	Yes	Yes	Global	No
time_format			Yes	Both	No
time_zone			Yes	Both	Yes
timed_mutexes	Yes	Yes	Yes	Global	Yes
timestamp			Yes	Session	Yes
tmp_table_size	Yes	Yes	Yes	Both	Yes
tmpdir	Yes	Yes	Yes	Global	No
transaction_alloc_block_size	Yes	Yes	Yes	Both	Yes
transaction_allow_batching			Yes	Session	Yes
transaction_prealloc_size	Yes	Yes	Yes	Both	Yes
tx_isolation			Yes	Both	Yes
unique_checks			Yes	Session	Yes
updatable_views_with_limit	Yes	Yes	Yes	Both	Yes
version			Yes	Global	No
version_comment			Yes	Global	No
version_compile_machine			Yes	Global	No
version_compile_os			Yes	Global	No
wait_timeout	Yes	Yes	Yes	Both	Yes
warning_count			Yes	Session	No

[a]This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

[b]This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

For additional system variable information, see these sections:

- Section 5.1.5, "Using System Variables", discusses the syntax for setting and displaying system variable values.

- Section 5.1.5.2, "Dynamic System Variables", lists the variables that can be set at runtime.

- Information on tuning system variables can be found in Section 8.12.2, "Tuning Server Parameters".

- Section 14.6.8, "InnoDB Startup Options and System Variables", lists `InnoDB` system variables.

- MySQL Cluster System Variables, lists system variables which are specific to MySQL Cluster.

- For information on server system variables specific to replication, see Section 16.1.3, "Replication and Binary Logging Options and Variables".

> **Note**
>
> Some of the following variable descriptions refer to "enabling" or "disabling" a variable. These variables can be enabled with the `SET` statement by setting them to `ON` or `1`, or disabled by setting them to `OFF` or `0`. However, to set such a variable on the command line or in an option file, you must set it to `1` or `0`; setting it to `ON` or `OFF` will not work. For example, on the command line, `--delay_key_write=1` works but `--delay_key_write=ON` does not.

Some system variables control the size of buffers or caches. For a given buffer, the server might need to allocate internal data structures. These structures typically are allocated from the total memory allocated to the buffer, and the amount of space required might be platform dependent. This means that when you assign a value to a system variable that controls a buffer size, the amount of space actually available might differ from the value assigned. In some cases, the amount might be less than the value assigned. It is also possible that the server will adjust a value upward. For example, if you assign a value of 0 to a variable for which the minimal value is 1024, the server will set the value to 1024.

Values for buffer sizes, lengths, and stack sizes are given in bytes unless otherwise specified.

Some system variables take file name values. Unless otherwise specified, the default file location is the data directory if the value is a relative path name. To specify the location explicitly, use an absolute path name. Suppose that the data directory is `/var/mysql/data`. If a file-valued variable is given as a relative path name, it will be located under `/var/mysql/data`. If the value is an absolute path name, its location is as given by the path name.

- `autocommit`

System Variable	Name	autocommit
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	**Type**	boolean
	Default	ON

The autocommit mode. If set to 1, all changes to a table take effect immediately. If set to 0, you must use `COMMIT` to accept a transaction or `ROLLBACK` to cancel it. If `autocommit` is 0 and you change it to 1, MySQL performs an automatic `COMMIT` of any open transaction. Another way to begin a transaction is to use a `START TRANSACTION` or `BEGIN` statement. See Section 13.3.1, "START TRANSACTION, COMMIT, and ROLLBACK Syntax".

By default, client connections begin with `autocommit` set to 1. To cause clients to begin with a default of 0, set the server's `init_connect` system variable:

```
SET GLOBAL init_connect='SET autocommit=0';
```

The `init_connect` variable can also be set on the command line or in an option file. To set the variable as just shown using an option file, include these lines:

```
[mysqld]
init_connect='SET autocommit=0'
```

The content of `init_connect` is not executed for users that have the `SUPER` privilege.

- `automatic_sp_privileges`

System Variable	Name	`automatic_sp_privileges`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`TRUE`

When this variable has a value of 1 (the default), the server automatically grants the `EXECUTE` and `ALTER ROUTINE` privileges to the creator of a stored routine, if the user cannot already execute and alter or drop the routine. (The `ALTER ROUTINE` privilege is required to drop the routine.) The server also automatically drops those privileges from the creator when the routine is dropped. If `automatic_sp_privileges` is 0, the server does not automatically add or drop these privileges.

The creator of a routine is the account used to execute the `CREATE` statement for it. This might not be the same as the account named as the `DEFINER` in the routine definition.

See also Section 19.2.2, "Stored Routines and MySQL Privileges".

- `back_log`

System Variable	Name	`back_log`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	`50`
	Min Value	`1`
	Max Value	`65535`

The number of outstanding connection requests MySQL can have. This comes into play when the main MySQL thread gets very many connection requests in a very short time. It then takes some time (although very little) for the main thread to check the connection and start a new thread. The `back_log` value indicates how many requests can be stacked during this short time before MySQL momentarily stops answering new requests. You need to increase this only if you expect a large number of connections in a short period of time.

In other words, this value is the size of the listen queue for incoming TCP/IP connections. Your operating system has its own limit on the size of this queue. The manual page for the Unix `listen()` system

call should have more details. Check your OS documentation for the maximum value for this variable. `back_log` cannot be set higher than your operating system limit.

- `basedir`

Command-Line Format	`--basedir=dir_name`	
System Variable	**Name**	`basedir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`

The MySQL installation base directory. This variable can be set with the `--basedir` option. Relative path names for other variables usually are resolved relative to the base directory.

- `big_tables`

If set to 1, all temporary tables are stored on disk rather than in memory. This is a little slower, but the error `The table tbl_name is full` does not occur for `SELECT` operations that require a large temporary table. The default value for a new connection is 0 (use in-memory temporary tables). Normally, you should never need to set this variable, because in-memory tables are automatically converted to disk-based tables as required.

> **Note**
>
> This variable was formerly named `sql_big_tables`.

- `bulk_insert_buffer_size`

Command-Line Format	`--bulk_insert_buffer_size=#`	
System Variable	**Name**	`bulk_insert_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`8388608`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`8388608`
	Min Value	`0`
	Max Value	`18446744073709547520`

`MyISAM` uses a special tree-like cache to make bulk inserts faster for `INSERT ... SELECT`, `INSERT ... VALUES (...), (...), ...`, and `LOAD DATA INFILE` when adding data to nonempty tables. This variable limits the size of the cache tree in bytes per thread. Setting it to 0 disables this optimization. The default value is 8MB.

- `character_set_client`

System Variable	Name	`character_set_client`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

The character set for statements that arrive from the client. The session value of this variable is set using the character set requested by the client when the client connects to the server. (Many clients support a `--default-character-set` option to enable this character set to be specified explicitly. See also Section 10.1.4, "Connection Character Sets and Collations".) The global value of the variable is used to set the session value in cases when the client-requested value is unknown or not available, or the server is configured to ignore client requests:

- The client is from a version of MySQL older than MySQL 4.1, and thus does not request a character set.

- The client requests a character set not known to the server. For example, a Japanese-enabled client requests `sjis` when connecting to a server not configured with `sjis` support.

- `mysqld` was started with the `--skip-character-set-client-handshake` option, which causes it to ignore client character set configuration. This reproduces MySQL 4.0 behavior and is useful should you wish to upgrade the server without upgrading all the clients.

`ucs2` cannot be used as a client character set, which means that it also does not work for `SET NAMES` or `SET CHARACTER SET`.

- `character_set_connection`

System Variable	Name	`character_set_connection`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

The character set for the current connection. Used for literals that do not have an explicit character set specification and for number-to-string conversion.

- `character_set_database`

System Variable	Name	`character_set_database`
	Variable Scope	Global, Session

	Dynamic Variable	Yes
Footnote	This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.	
Permitted Values	**Type**	`string`

The character set used by the default database. The server sets this variable whenever the default database changes. If there is no default database, the variable has the same value as `character_set_server`.

- `character_set_filesystem`

Introduced	5.1.6	
Command-Line Format	`--character-set-filesystem=name`	
System Variable	**Name**	`character_set_filesystem`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`
	Default	`binary`

The file system character set. This variable is used to interpret string literals that refer to file names, such as in the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. Such file names are converted from `character_set_client` to `character_set_filesystem` before the file opening attempt occurs. The default value is `binary`, which means that no conversion occurs. For systems on which multibyte file names are permitted, a different value may be more appropriate. For example, if the system represents file names using UTF-8, set `character_set_filesystem` to `'utf8'`. This variable was added in MySQL 5.1.6.

- `character_set_results`

System Variable	**Name**	`character_set_results`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

The character set used for returning query results such as result sets or error messages to the client.

- `character_set_server`

Command-Line Format	`--character-set-server`	
System Variable	**Name**	`character_set_server`
	Variable Scope	Global, Session
	Dynamic Variable	Yes

Permitted Values	Type	`string`
	Default	`latin1`

The server's default character set.

- `character_set_system`

System Variable	Name	`character_set_system`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`string`
	Default	`utf8`

The character set used by the server for storing identifiers. The value is always `utf8`.

- `character_sets_dir`

Command-Line Format	`--character-sets-dir=dir_name`	
System Variable	Name	`character_sets_dir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`directory name`

The directory where character sets are installed.

- `collation_connection`

System Variable	Name	`collation_connection`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`string`

The collation of the connection character set.

- `collation_database`

System Variable	Name	`collation_database`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Footnote	This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.	

Permitted Values	Type	string

The collation used by the default database. The server sets this variable whenever the default database changes. If there is no default database, the variable has the same value as `collation_server`.

- `collation_server`

Command-Line Format	`--collation-server`	
System Variable	**Name**	`collation_server`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	string
	Default	`latin1_swedish_ci`

The server's default collation.

- `completion_type`

Command-Line Format	`--completion_type=#`	
System Variable	**Name**	`completion_type`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	0
	Valid Values	0
		1
		2

The transaction completion type. This variable can take the values shown in the following table.

Value	Description
0	`COMMIT` and `ROLLBACK` are unaffected. This is the default value.
1	`COMMIT` and `ROLLBACK` are equivalent to `COMMIT AND CHAIN` and `ROLLBACK AND CHAIN`, respectively. (A new transaction starts immediately with the same isolation level as the just-terminated transaction.)
2	`COMMIT` and `ROLLBACK` are equivalent to `COMMIT RELEASE` and `ROLLBACK RELEASE`, respectively. (The server disconnects after terminating the transaction.)

`completion_type` affects transactions that begin with `START TRANSACTION` or `BEGIN` and end with `COMMIT` or `ROLLBACK`. It does not apply to implicit commits resulting from execution of the statements listed in Section 13.3.3, "Statements That Cause an Implicit Commit". It also does not apply for `XA COMMIT`, `XA ROLLBACK`, or when `autocommit=1`.

- `concurrent_insert`   527

Command-Line Format	--concurrent_insert[=#]		
System Variable	**Name**	`concurrent_insert`	
	Variable Scope	Global	
	Dynamic Variable	Yes	
Permitted Values	**Type**	`integer`	
	Default	1	
	Valid Values	0	
		1	
		2	

If 1 (the default), MySQL permits `INSERT` and `SELECT` statements to run concurrently for `MyISAM` tables that have no free blocks in the middle of the data file. If you start `mysqld` with `--skip-new`, this variable is set to 0.

This variable can take three integer values.

Value	Description
0	Disables concurrent inserts
1	(Default) Enables concurrent insert for `MyISAM` tables that do not have holes
2	Enables concurrent inserts for all `MyISAM` tables, even those that have holes. For a table with a hole, new rows are inserted at the end of the table if it is in use by another thread. Otherwise, MySQL acquires a normal write lock and inserts the row into the hole.

See also Section 8.11.3, "Concurrent Inserts".

- `connect_timeout`

Command-Line Format	--connect_timeout=#		
System Variable	**Name**	`connect_timeout`	
	Variable Scope	Global	
	Dynamic Variable	Yes	
Permitted Values (<= 5.1.22)	**Type**	`integer`	
	Default	5	
	Min Value	2	
	Max Value	31536000	
Permitted Values (>= 5.1.23)	**Type**	`integer`	
	Default	10	
	Min Value	2	

	Max Value	31536000

The number of seconds that the `mysqld` server waits for a connect packet before responding with `Bad handshake`. The default value is 10 seconds as of MySQL 5.1.23 and 5 seconds before that.

Increasing the `connect_timeout` value might help if clients frequently encounter errors of the form `Lost connection to MySQL server at 'XXX', system error: errno`.

- `datadir`

Command-Line Format	`--datadir=dir_name`	
System Variable	Name	`datadir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`directory name`

The MySQL data directory. This variable can be set with the `--datadir` option.

- `date_format`

This variable is unused.

- `datetime_format`

This variable is unused.

- `debug`

Command-Line Format	`--debug[=debug_options]`	
System Variable	Name	`debug`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (Unix)	Type	`string`
	Default	`d:t:i:o,/tmp/mysqld.trace`
Permitted Values (Windows)	Type	`string`
	Default	`d:t:i:O,\mysqld.trace`

This variable indicates the current debugging settings. It is available only for servers built with debugging support. The initial value comes from the value of instances of the `--debug` option given at server startup. The global and session values may be set at runtime; the `SUPER` privilege is required, even for the session value.

Assigning a value that begins with `+` or `-` cause the value to added to or subtracted from the current value:

```
mysql> SET debug = 'T';
```

```
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| T       |
+---------+

mysql> SET debug = '+P';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| P:T     |
+---------+

mysql> SET debug = '-P';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| T       |
+---------+
```

This variable was added in MySQL 5.1.7.

- debug_sync

Introduced	5.1.41	
System Variable	**Name**	debug_sync
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	string

This variable is the user interface to the Debug Sync facility. Use of Debug Sync requires that MySQL be configured with the --enable-debug-sync option (see Section 2.11.4, "MySQL Source-Configuration Options"). If Debug Sync is not compiled in, this system variable is not available.

The global variable value is read only and indicates whether the facility is enabled. By default, Debug Sync is disabled and the value of debug_sync is OFF. If the server is started with --debug-sync-timeout=N, where N is a timeout value greater than 0, Debug Sync is enabled and the value of debug_sync is ON - current signal followed by the signal name. Also, N becomes the default timeout for individual synchronization points.

The session value can be read by any user and will have the same value as the global variable. The session value can be set by users that have the SUPER privilege to control synchronization points.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

This variable was added in MySQL 5.1.41.

- default_week_format

Command-Line Format	--default_week_format=#	
System Variable	**Name**	default_week_format

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	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`7`

The default mode value to use for the `WEEK()` function. See Section 12.7, "Date and Time Functions".

- `delay_key_write`

Command-Line Format	`--delay-key-write[=name]`	
System Variable	Name	`delay_key_write`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`enumeration`
	Default	`ON`
	Valid Values	`ON`
		`OFF`
		`ALL`

This option applies only to `MyISAM` tables. It can have one of the following values to affect handling of the `DELAY_KEY_WRITE` table option that can be used in `CREATE TABLE` statements.

Option	Description
`OFF`	`DELAY_KEY_WRITE` is ignored.
`ON`	MySQL honors any `DELAY_KEY_WRITE` option specified in `CREATE TABLE` statements. This is the default value.
`ALL`	All new opened tables are treated as if they were created with the `DELAY_KEY_WRITE` option enabled.

If `DELAY_KEY_WRITE` is enabled for a table, the key buffer is not flushed for the table on every index update, but only when the table is closed. This speeds up writes on keys a lot, but if you use this feature, you should add automatic checking of all `MyISAM` tables by starting the server with the `--myisam-recover` option (for example, `--myisam-recover=BACKUP,FORCE`). See Section 5.1.3, "Server Command Options", and Section 14.5.1, "MyISAM Startup Options".

> **Warning**
>
> If you enable external locking with `--external-locking`, there is no protection against index corruption for tables that use delayed key writes.

- `delayed_insert_limit`

Command-Line Format	`--delayed_insert_limit=#`	
System Variable	**Name**	`delayed_insert_limit`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`100`
	Min Value	`1`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`100`
	Min Value	`1`
	Max Value	`18446744073709547520`

After inserting `delayed_insert_limit` delayed rows, the `INSERT DELAYED` handler thread checks whether there are any `SELECT` statements pending. If so, it permits them to execute before continuing to insert delayed rows.

- `delayed_insert_timeout`

Command-Line Format	`--delayed_insert_timeout=#`	
System Variable	**Name**	`delayed_insert_timeout`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`300`

How many seconds an `INSERT DELAYED` handler thread should wait for `INSERT` statements before terminating.

- `delayed_queue_size`

Command-Line Format	`--delayed_queue_size=#`	
System Variable	**Name**	`delayed_queue_size`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values (32-bit platforms)	Type	`integer`
	Default	`1000`
	Min Value	`1`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`1000`
	Min Value	`1`
	Max Value	`18446744073709547520`

This is a per-table limit on the number of rows to queue when handling `INSERT DELAYED` statements. If the queue becomes full, any client that issues an `INSERT DELAYED` statement waits until there is room in the queue again.

- `div_precision_increment`

Command-Line Format	`--div_precision_increment=#`	
System Variable	Name	`div_precision_increment`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`4`
	Min Value	`0`
	Max Value	`30`

This variable indicates the number of digits by which to increase the scale of the result of division operations performed with the `/` operator. The default value is 4. The minimum and maximum values are 0 and 30, respectively. The following example illustrates the effect of increasing the default value.

```
mysql> SELECT 1/7;
+--------+
| 1/7    |
+--------+
| 0.1429 |
+--------+
mysql> SET div_precision_increment = 12;
mysql> SELECT 1/7;
+----------------+
| 1/7            |
+----------------+
| 0.142857142857 |
+----------------+
```

For more information, see Section 22.4.3, "The DBUG Package".

- `engine_condition_pushdown`

Command-Line Format	`--engine-condition-pushdown`	
System Variable	**Name**	`engine_condition_pushdown`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`ON`

The engine condition pushdown optimization enables processing for certain comparisons to be "pushed down" to the storage engine level for more efficient execution. For more information, see Section 8.2.1.5, "Engine Condition Pushdown Optimization".

Engine condition pushdown is used only by the `NDBCLUSTER` storage engine. Enabling this optimization on a MySQL Server acting as a MySQL Cluster SQL node causes `WHERE` conditions on unindexed columns to be evaluated on the cluster's data nodes and only the rows that match to be sent back to the SQL node that issued the query. This greatly reduces the amount of cluster data that must be sent over the network, increasing the efficiency with which results are returned.

The `engine_condition_pushdown` variable controls whether engine condition pushdown is enabled. By default, this variable is `ON` (1). Setting it to `OFF` (0) disables pushdown.

- `error_count`

The number of errors that resulted from the last statement that generated messages. This variable is read only. See Section 13.7.5.18, "SHOW ERRORS Syntax".

- `event_scheduler`

Introduced	5.1.6	
Command-Line Format	`--event-scheduler[=value]`	
System Variable	**Name**	`event_scheduler`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`ON`
		`OFF`
		`DISABLED`

This variable indicates the status of the Event Scheduler; as of MySQL 5.1.12, possible values are `ON`, `OFF`, and `DISABLED`, with the default being `OFF`. This variable and its effects on the Event Scheduler's operation are discussed in greater detail in the Overview section of the Events chapter.

This variable was added in MySQL 5.1.6.

- `expire_logs_days`

Command-Line Format	`--expire_logs_days=#`	
System Variable	**Name**	`expire_logs_days`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`99`

The number of days for automatic binary log file removal. The default is 0, which means "no automatic removal." Possible removals happen at startup and when the binary log is flushed. Log flushing occurs as indicated in Section 5.4, "MySQL Server Logs".

To remove binary log files manually, use the `PURGE BINARY LOGS` statement. See Section 13.4.1.1, "PURGE BINARY LOGS Syntax".

- `flush`

Command-Line Format	`--flush`	
System Variable	**Name**	`flush`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

If `ON`, the server flushes (synchronizes) all changes to disk after each SQL statement. Normally, MySQL does a write of all changes to disk only after each SQL statement and lets the operating system handle the synchronizing to disk. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing". This variable is set to `ON` if you start `mysqld` with the `--flush` option.

- `flush_time`

Command-Line Format	`--flush_time=#`	
System Variable	**Name**	`flush_time`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values	Type	integer
	Default	0
	Min Value	0
Permitted Values (Windows)	Type	integer
	Default	1800
	Min Value	0

If this is set to a nonzero value, all tables are closed every `flush_time` seconds to free up resources and synchronize unflushed data to disk. This option is best used only on systems with minimal resources.

- `foreign_key_checks`

If set to 1 (the default), foreign key constraints for `InnoDB` tables are checked. If set to 0, foreign key constraints are ignored, with a couple of exceptions. When re-creating a table that was dropped, an error is returned if the table definition does not conform to the foreign key constraints referencing the table. Likewise, an `ALTER TABLE` operation returns an error if a foreign key definition is incorrectly formed. For more information, see Section 13.1.17.3, "Using FOREIGN KEY Constraints".

Disabling foreign key checking can be useful for reloading `InnoDB` tables in an order different from that required by their parent/child relationships. See Section 14.6.6.6, "InnoDB and FOREIGN KEY Constraints".

Setting `foreign_key_checks` to 0 also affects data definition statements: `DROP SCHEMA` drops a schema even if it contains tables that have foreign keys that are referred to by tables outside the schema, and `DROP TABLE` drops tables that have foreign keys that are referred to by other tables.

> **Note**
>
> Setting `foreign_key_checks` to 1 does not trigger a scan of the existing table data. Therefore, rows added to the table while `foreign_key_checks = 0` will not be verified for consistency.

- `ft_boolean_syntax`

Command-Line Format	--ft_boolean_syntax=name	
System Variable	Name	ft_boolean_syntax
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	string
	Default	+ -><()~*:""&|

The list of operators supported by boolean full-text searches performed using `IN BOOLEAN MODE`. See Section 12.9.2, "Boolean Full-Text Searches".

The default variable value is `'+ -><()~*:""&|'`. The rules for changing the value are as follows:

- Operator function is determined by position within the string.

- The replacement value must be 14 characters.

- Each character must be an ASCII nonalphanumeric character.

- Either the first or second character must be a space.

- No duplicates are permitted except the phrase quoting operators in positions 11 and 12. These two characters are not required to be the same, but they are the only two that may be.

- Positions 10, 13, and 14 (which by default are set to "`:`", "`&`", and "`|`") are reserved for future extensions.

- `ft_max_word_len`

Command-Line Format	`--ft_max_word_len=#`	
System Variable	Name	`ft_max_word_len`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Min Value	`10`

The maximum length of the word to be included in a `FULLTEXT` index.

> **Note**
>
> `FULLTEXT` indexes must be rebuilt after changing this variable. Use `REPAIR TABLE` *`tbl_name`* `QUICK`.

- `ft_min_word_len`

Command-Line Format	`--ft_min_word_len=#`	
System Variable	Name	`ft_min_word_len`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	`4`
	Min Value	`1`

The minimum length of the word to be included in a `FULLTEXT` index.

> **Note**
>
> `FULLTEXT` indexes must be rebuilt after changing this variable. Use `REPAIR TABLE` *tbl_name* `QUICK`.

- `ft_query_expansion_limit`

Command-Line Format	`--ft_query_expansion_limit=#`	
System Variable	**Name**	`ft_query_expansion_limit`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`20`
	Min Value	`0`
	Max Value	`1000`

The number of top matches to use for full-text searches performed using `WITH QUERY EXPANSION`.

- `ft_stopword_file`

Command-Line Format	`--ft_stopword_file=file_name`	
System Variable	**Name**	`ft_stopword_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The file from which to read the list of stopwords for full-text searches. The server looks for the file in the data directory unless an absolute path name is given to specify a different directory. All the words from the file are used; comments are *not* honored. By default, a built-in list of stopwords is used (as defined in the `storage/myisam/ft_static.c` file). Setting this variable to the empty string (`''`) disables stopword filtering. See also Section 12.9.4, "Full-Text Stopwords".

> **Note**
>
> `FULLTEXT` indexes must be rebuilt after changing this variable or the contents of the stopword file. Use `REPAIR TABLE` *tbl_name* `QUICK`.

- `general_log`

Introduced	5.1.12	
Command-Line Format	`--general-log`	
System Variable	**Name**	`general_log`

	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

Whether the general query log is enabled. The value can be 0 (or `OFF`) to disable the log or 1 (or `ON`) to enable the log. The default value depends on whether the `--general_log` option is given (`--log` before MySQL 5.1.29). The destination for log output is controlled by the `log_output` system variable; if that value is `NONE`, no log entries are written even if the log is enabled. The `general_log` variable was added in MySQL 5.1.12.

- `general_log_file`

Introduced	5.1.12	
Command-Line Format	`--general-log-file=file_name` (>= 5.1.29)	
System Variable	Name	`general_log_file`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`file name`
	Default	`host_name.log`

The name of the general query log file. The default value is *host_name*.`log`, but the initial value can be changed with the `--general_log_file` option (`--log` before MySQL 5.1.29). This variable was added in MySQL 5.1.12.

- `group_concat_max_len`

Command-Line Format	`--group_concat_max_len=#`	
System Variable	Name	`group_concat_max_len`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`1024`
	Min Value	`4`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`1024`
	Min Value	`4`

	Max Value	18446744073709547520

The maximum permitted result length in bytes for the `GROUP_CONCAT()` function. The default is 1024.

- `have_archive`

  `YES` if `mysqld` supports `ARCHIVE` tables, `NO` if not. This variable was removed in MySQL 5.1.14.

- `have_blackhole_engine`

  `YES` if `mysqld` supports `BLACKHOLE` tables, `NO` if not. This variable was removed in MySQL 5.1.14.

- `have_compress`

  `YES` if the `zlib` compression library is available to the server, `NO` if not. If not, the `COMPRESS()` and `UNCOMPRESS()` functions cannot be used.

- `have_community_features`

  `YES` if statement profiling capability is present, `NO` if not. If present, the `profiling` system variable controls whether this capability is enabled or disabled. See Section 13.7.5.33, "SHOW PROFILES Syntax".

  This variable was added in MySQL 5.1.24. It is renamed to `have_profiling` in MySQL 5.5.

- `have_crypt`

  `YES` if the `crypt()` system call is available to the server, `NO` if not. If not, the `ENCRYPT()` function cannot be used.

- `have_csv`

  `YES` if `mysqld` supports `CSV` tables, `NO` if not.

  This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `have_dynamic_loading`

  `YES` if `mysqld` supports dynamic loading of plugins, `NO` if not. This variable was added in MySQL 5.1.10.

- `have_example_engine`

  `YES` if `mysqld` supports `EXAMPLE` tables, `NO` if not. This variable was removed in MySQL 5.1.14.

- `have_federated_engine`

  `YES` if `mysqld` supports `FEDERATED` tables, `NO` if not. This variable was removed in MySQL 5.1.14.

- `have_geometry`

  `YES` if the server supports spatial data types, `NO` if not.

- `have_innodb`

  `YES` if `mysqld` supports `InnoDB` tables. `DISABLED` if `--skip-innodb` is used.

  This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `have_isam`

  This variable appears only for reasons of backward compatibility. It is always `NO` because `ISAM` tables are no longer supported. This variable was removed in MySQL 5.1.7.

- `have_merge_engine`

  `YES` if `mysqld` supports `MERGE` tables. `DISABLED` if `--skip-merge` is used. This variable was removed in MySQL 5.1.3.

- `have_openssl`

  `YES` if `mysqld` supports SSL connections, `NO` if not. As of MySQL 5.1.17, this variable is an alias for `have_ssl`.

- `have_partitioning`

  `YES` if `mysqld` supports partitioning. Added in MySQL 5.1.1 as `have_partition_engine` and renamed to `have_partioning` in 5.1.6.

  This variable is deprecated and is removed in MySQL 5.6. Use `SHOW PLUGINS` instead. For more information, see Chapter 18, *Partitioning*.

- `have_query_cache`

  `YES` if `mysqld` supports the query cache, `NO` if not.

- `have_row_based_replication`

Introduced	5.1.5	
Removed	5.1.15	
System Variable	Name	`have_row_based_replication`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`boolean`

  `YES` if the server can perform replication using row-based binary logging. If the value is `NO`, the server can use only statement-based logging. See Section 16.1.2, "Replication Formats". This variable was added in MySQL 5.1.5 and removed in 5.1.15.

- `have_raid`

  This variable appears only for reasons of backward compatibility. It is always `NO` because `RAID` tables are no longer supported. This variable was removed in MySQL 5.1.7.

- `have_rtree_keys`

  `YES` if `RTREE` indexes are available, `NO` if not. (These are used for spatial indexes in `MyISAM` tables.)

- `have_ssl`

  `YES` if `mysqld` supports SSL connections, `NO` if not. `DISABLED` indicates that the server was compiled with SSL support, but was not started with the appropriate `--ssl-xxx` options. For more information, see Section 6.4.2, "Building MySQL with Support for Secure Connections".

This variable was added in MySQL 5.1.17. Before that, use `have_openssl`.

- `have_symlink`

  `YES` if symbolic link support is enabled, `NO` if not. This is required on Unix for support of the `DATA DIRECTORY` and `INDEX DIRECTORY` table options, and on Windows for support of data directory symlinks. If the server is started with the `--skip-symbolic-links` option, the value is `DISABLED`.

- `hostname`

Introduced	5.1.17	
System Variable	Name	`hostname`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`string`

  The server sets this variable to the server host name at startup. This variable was added in MySQL 5.1.17.

- `identity`

  This variable is a synonym for the `last_insert_id` variable. It exists for compatibility with other database systems. You can read its value with `SELECT @@identity`, and set it using `SET identity`.

- `init_connect`

Command-Line Format	`--init-connect=name`	
System Variable	Name	`init_connect`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`string`

  A string to be executed by the server for each client that connects. The string consists of one or more SQL statements, separated by semicolon characters. For example, each client session begins by default with autocommit mode enabled. There is no global `autocommit` system variable to specify that autocommit should be disabled by default, but `init_connect` can be used to achieve the same effect:

```
SET GLOBAL init_connect='SET autocommit=0';
```

  The `init_connect` variable can also be set on the command line or in an option file. To set the variable as just shown using an option file, include these lines:

```
[mysqld]
init_connect='SET autocommit=0'
```

  The content of `init_connect` is not executed for users that have the `SUPER` privilege. This is done so that an erroneous value for `init_connect` does not prevent all clients from connecting. For example,

the value might contain a statement that has a syntax error, thus causing client connections to fail. Not executing `init_connect` for users that have the `SUPER` privilege enables them to open a connection and fix the `init_connect` value.

The server discards any result sets produced by statements in the value of of `init_connect`.

- `init_file`

Command-Line Format	`--init-file=file_name`	
System Variable	Name	`init_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`file name`

The name of the file specified with the `--init-file` option when you start the server. This should be a file containing SQL statements that you want the server to execute when it starts. Each statement must be on a single line and should not include comments. For more information, see the description of `--init-file`.

Note that the `--init-file` option is unavailable if MySQL was configured with the `--disable-grant-options` option. See Section 2.11.4, "MySQL Source-Configuration Options".

- `innodb_xxx`

`InnoDB` system variables are listed in Section 14.6.8, "InnoDB Startup Options and System Variables". These variables control many aspects of storage, memory use, and I/O patterns for `InnoDB` tables, and are especially important in MySQL 5.5 and higher, where InnoDB is the default storage engine.

- `insert_id`

The value to be used by the following `INSERT` or `ALTER TABLE` statement when inserting an `AUTO_INCREMENT` value. This is mainly used with the binary log.

- `interactive_timeout`

Command-Line Format	`--interactive_timeout=#`	
System Variable	Name	`interactive_timeout`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`28800`
	Min Value	`1`

The number of seconds the server waits for activity on an interactive connection before closing it. An interactive client is defined as a client that uses the `CLIENT_INTERACTIVE` option to `mysql_real_connect()`. See also `wait_timeout`.

- `join_buffer_size`

Command-Line Format	`--join_buffer_size=#`	
System Variable	**Name**	`join_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (<= 5.1.22)	**Type**	`integer`
	Default	`131072`
	Min Value	`8200`
	Max Value	`4294967295`
Permitted Values (Windows, 32-bit platforms, >= 5.1.23)	**Type**	`integer`
	Default	`131072`
	Min Value	`8200`
	Max Value	`4294967295`
Permitted Values (Windows, 64-bit platforms, >= 5.1.23)	**Type**	`integer`
	Default	`131072`
	Min Value	`8228`
	Max Value	`4294967295`
Permitted Values (Other, 32-bit platforms, >= 5.1.23)	**Type**	`integer`
	Default	`131072`
	Min Value	`8200`
	Max Value	`4294967295`
Permitted Values (Other, 64-bit platforms, >= 5.1.23)	**Type**	`integer`
	Default	`131072`
	Min Value	`8228`
	Max Value	`18446744073709547520`

The minimum size of the buffer that is used for plain index scans, range index scans, and joins that do not use indexes and thus perform full table scans. Normally, the best way to get fast joins is to add indexes. Increase the value of `join_buffer_size` to get a faster full join when adding indexes is not possible. One join buffer is allocated for each full join between two tables. For a complex join between several tables for which indexes are not used, multiple join buffers might be necessary.

There is no gain from setting the buffer larger than required to hold each matching row, and all joins allocate at least the minimum size, so use caution in setting this variable to a large value globally. It is better to keep the global setting small and change to a larger setting only in sessions that are doing large joins. Memory allocation time can cause substantial performance drops if the global size is larger than needed by most queries that use it.

The maximum permissible setting for `join_buffer_size` is 4GB−1. As of MySQL 5.1.23, larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB−1 with a warning).

For additional information about join buffering, see Section 8.2.1.8, "Nested-Loop Join Algorithms".

- `keep_files_on_create`

Introduced	5.1.21	
Command-Line Format	`--keep_files_on_create=#`	
System Variable	**Name**	`keep_files_on_create`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

If a `MyISAM` table is created with no `DATA DIRECTORY` option, the `.MYD` file is created in the database directory. By default, if `MyISAM` finds an existing `.MYD` file in this case, it overwrites it. The same applies to `.MYI` files for tables created with no `INDEX DIRECTORY` option. To suppress this behavior, set the `keep_files_on_create` variable to `ON` (1), in which case `MyISAM` will not overwrite existing files and returns an error instead. The default value is `OFF` (0).

If a `MyISAM` table is created with a `DATA DIRECTORY` or `INDEX DIRECTORY` option and an existing `.MYD` or `.MYI` file is found, MyISAM always returns an error. It will not overwrite a file in the specified directory.

This variable was added in MySQL 5.1.23.

- `key_buffer_size`

Command-Line Format	`--key_buffer_size=#`	
System Variable	**Name**	`key_buffer_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.1.22)	**Type**	`integer`
	Default	`8388608`
	Min Value	`8`

	Max Value	4294967295
Permitted Values (32-bit platforms, >= 5.1.23)	Type	`integer`
	Default	`8388608`
	Min Value	`8`
	Max Value	`4294967295`
Permitted Values (64-bit platforms, >= 5.1.23)	Type	`integer`
	Default	`8388608`
	Min Value	`8`
	Max Value	`OS_PER_PROCESS_LIMIT`

Index blocks for `MyISAM` tables are buffered and are shared by all threads. `key_buffer_size` is the size of the buffer used for index blocks. The key buffer is also known as the key cache.

The maximum permissible setting for `key_buffer_size` is 4GB−1 on 32-bit platforms. As of MySQL 5.1.23, larger values are permitted for 64-bit platforms, except 64-bit Windows prior to MySQL 5.1.31, for which large values are truncated to 4GB−1 with a warning. As of MySQL 5.1.31, larger values are also permitted for 64-bit Windows. The effective maximum size might be less, depending on your available physical RAM and per-process RAM limits imposed by your operating system or hardware platform. The value of this variable indicates the amount of memory requested. Internally, the server allocates as much memory as possible up to this amount, but the actual allocation might be less.

You can increase the value to get better index handling for all reads and multiple writes; on a system whose primary function is to run MySQL using the `MyISAM` storage engine, 25% of the machine's total memory is an acceptable value for this variable. However, you should be aware that, if you make the value too large (for example, more than 50% of the machine's total memory), your system might start to page and become extremely slow. This is because MySQL relies on the operating system to perform file system caching for data reads, so you must leave some room for the file system cache. You should also consider the memory requirements of any other storage engines that you may be using in addition to `MyISAM`.

For even more speed when writing many rows at the same time, use `LOCK TABLES`. See Section 8.2.2.1, "Speed of INSERT Statements".

You can check the performance of the key buffer by issuing a `SHOW STATUS` statement and examining the `Key_read_requests`, `Key_reads`, `Key_write_requests`, and `Key_writes` status variables. (See Section 13.7.5, "SHOW Syntax".) The `Key_reads/Key_read_requests` ratio should normally be less than 0.01. The `Key_writes/Key_write_requests` ratio is usually near 1 if you are using mostly updates and deletes, but might be much smaller if you tend to do updates that affect many rows at the same time or if you are using the `DELAY_KEY_WRITE` table option.

The fraction of the key buffer in use can be determined using `key_buffer_size` in conjunction with the `Key_blocks_unused` status variable and the buffer block size, which is available from the `key_cache_block_size` system variable:

```
1 - ((Key_blocks_unused * key_cache_block_size) / key_buffer_size)
```

This value is an approximation because some space in the key buffer is allocated internally for administrative structures. Factors that influence the amount of overhead for these structures include block size and pointer size. As block size increases, the percentage of the key buffer lost to overhead tends to decrease. Larger blocks results in a smaller number of read operations (because more keys are obtained per read), but conversely an increase in reads of keys that are not examined (if not all keys in a block are relevant to a query).

It is possible to create multiple `MyISAM` key caches. The size limit of 4GB applies to each cache individually, not as a group. See Section 8.10.1, "The MyISAM Key Cache".

- `key_cache_age_threshold`

Command-Line Format	`--key_cache_age_threshold=#`	
System Variable	**Name**	`key_cache_age_threshold`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`300`
	Min Value	`100`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`300`
	Min Value	`100`
	Max Value	`18446744073709547520`

This value controls the demotion of buffers from the hot sublist of a key cache to the warm sublist. Lower values cause demotion to happen more quickly. The minimum value is 100. The default value is 300. See Section 8.10.1, "The MyISAM Key Cache".

- `key_cache_block_size`

Command-Line Format	`--key_cache_block_size=#`	
System Variable	**Name**	`key_cache_block_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1024`
	Min Value	`512`

	Max Value	16384

The size in bytes of blocks in the key cache. The default value is 1024. See Section 8.10.1, "The MyISAM Key Cache".

- `key_cache_division_limit`

Command-Line Format	`--key_cache_division_limit=#`	
System Variable	**Name**	`key_cache_division_limit`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`100`
	Min Value	`1`
	Max Value	`100`

The division point between the hot and warm sublists of the key cache buffer list. The value is the percentage of the buffer list to use for the warm sublist. Permissible values range from 1 to 100. The default value is 100. See Section 8.10.1, "The MyISAM Key Cache".

- `language`

Command-Line Format	`--language=name`	
System Variable	**Name**	`language`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`
	Default	`/usr/local/mysql/share/mysql/english/`

The directory where error messages are located. See Section 10.2, "Setting the Error Message Language".

- `large_files_support`

System Variable	**Name**	`large_files_support`
	Variable Scope	Global
	Dynamic Variable	No

Whether `mysqld` was compiled with options for large file support.

- `large_pages`

Command-Line Format	`--large-pages`	
System Variable	**Name**	`large_pages`
	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Linux	
Permitted Values (Linux)	**Type**	`boolean`
	Default	`FALSE`

Whether large page support is enabled (via the `--large-pages` option). See Section 8.12.5.2, "Enabling Large Page Support".

- `large_page_size`

System Variable	**Name**	`large_page_size`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (Linux)	**Type**	`integer`
	Default	0

If large page support is enabled, this shows the size of memory pages. Large memory pages are supported only on Linux; on other platforms, the value of this variable is always 0. See Section 8.12.5.2, "Enabling Large Page Support".

- `last_insert_id`

The value to be returned from `LAST_INSERT_ID()`. This is stored in the binary log when you use `LAST_INSERT_ID()` in a statement that updates a table. Setting this variable does not update the value returned by the `mysql_insert_id()` C API function.

- `lc_time_names`

Introduced	5.1.12	
System Variable	**Name**	`lc_time_names`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

This variable specifies the locale that controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()` and `MONTHNAME()` functions. Locale names are POSIX-style values such as `'ja_JP'` or `'pt_BR'`.

The default value is `'en_US'` regardless of your system's locale setting. For further information, see Section 10.7, "MySQL Server Locale Support". This variable was added in MySQL 5.1.12.

- `license`

System Variable	Name	`license`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`GPL`

The type of license the server has.

- `local_infile`

System Variable	Name	`local_infile`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`true`

Whether `LOCAL` is supported for `LOAD DATA INFILE` statements. If this variable is disabled, clients cannot use `LOCAL` in `LOAD DATA` statements. While the default for this variable is `true`, whether `LOAD DATA INFILE LOCAL` is actually permitted depends on how MySQL was compiled, as well as a number of settings on both the server and the client; see Section 6.1.6, "Security Issues with LOAD DATA LOCAL", for details.

- `locked_in_memory`

System Variable	Name	`locked_in_memory`
	Variable Scope	Global
	Dynamic Variable	No

Whether `mysqld` was locked in memory with `--memlock`.

- `log`

Deprecated	5.1.29, by general-log	
Command-Line Format	`--log[=file_name]`	
System Variable (<= 5.1.22)	**Name**	`log`
	Variable Scope	Global

	Dynamic Variable	No
System Variable (>= 5.1.23)	**Name**	`log`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`file name`

Whether logging of all statements to the general query log is enabled. See Section 5.4.3, "The General Query Log".

This variable is deprecated as of MySQL 5.1.29 and is removed in MySQL 5.6. Use `general_log` instead.

- `log_bin_trust_function_creators`

Command-Line Format	`--log-bin-trust-function-creators`	
System Variable	**Name**	`log_bin_trust_function_creators`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This variable applies when binary logging is enabled. It controls whether stored function creators can be trusted not to create stored functions that will cause unsafe events to be written to the binary log. If set to 0 (the default), users are not permitted to create or alter stored functions unless they have the `SUPER` privilege in addition to the `CREATE ROUTINE` or `ALTER ROUTINE` privilege. A setting of 0 also enforces the restriction that a function must be declared with the `DETERMINISTIC` characteristic, or with the `READS SQL DATA` or `NO SQL` characteristic. If the variable is set to 1, MySQL does not enforce these restrictions on stored function creation. This variable also applies to trigger creation. See Section 19.7, "Binary Logging of Stored Programs".

- `log_bin_trust_routine_creators`

This is the old name for `log_bin_trust_function_creators`. This variable is deprecated and is removed in MySQL 5.5.

- `log_error`

Command-Line Format	`--log-error[=file_name]`	
System Variable	**Name**	`log_error`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The location of the error log, or empty if the server is writing error message to the standard error output. See Section 5.4.2, "The Error Log".

- `log_output`

Introduced	5.1.6	
Command-Line Format	`--log-output=name`	
System Variable	**Name**	`log_output`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`set`
	Default	`FILE`
	Valid Values	`TABLE`
		`FILE`
		`NONE`

The destination for general query log and slow query log output. The value can be a comma-separated list of one or more of the words `TABLE` (log to tables), `FILE` (log to files), or `NONE` (do not log to tables or files). The default value is `FILE`. `NONE`, if present, takes precedence over any other specifiers. If the value is `NONE` log entries are not written even if the logs are enabled. If the logs are not enabled, no logging occurs even if the value of `log_output` is not `NONE`. For more information, see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations". This variable was added in MySQL 5.1.6.

- `log_queries_not_using_indexes`

Command-Line Format	`--log-queries-not-using-indexes`	
System Variable (>= 5.1.11)	**Name**	`log_queries_not_using_indexes`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Whether queries that do not use indexes are logged to the slow query log. See Section 5.4.5, "The Slow Query Log". This variable was added in MySQL 5.1.11.

- `log_slow_queries`

Deprecated	5.1.29, by slow-query-log	
Command-Line Format	`--log-slow-queries[=name]`	
System Variable (<= 5.1.22)	**Name**	`log_slow_queries`
	Variable Scope	Global

	Dynamic Variable	No
System Variable (>= 5.1.23)	**Name**	`log_slow_queries`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`

Whether slow queries should be logged. "Slow" is determined by the value of the `long_query_time` variable. See Section 5.4.5, "The Slow Query Log".

This variable is deprecated as of MySQL 5.1.29 and is removed in MySQL 5.6. Use `slow_query_log` instead.

- `log_warnings`

Command-Line Format	`--log-warnings[=#]`	
System Variable	**Name**	`log_warnings`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`18446744073709547520`

Whether to produce additional warning messages to the error log. This variable is enabled (1) by default and can be disabled by setting it to 0. As of MySQL 5.1.38, the server logs messages about statements that are unsafe for statement-based logging if the value is greater than 0. Aborted connections and access-denied errors for new connection attempts are logged if the value is greater than 1.

- `long_query_time`

Command-Line Format	`--long_query_time=#`	
System Variable	**Name**	`long_query_time`
	Variable Scope	Global, Session

	Dynamic Variable	Yes
Permitted Values	**Type**	`numeric`
	Default	`10`
	Min Value	`0`

If a query takes longer than this many seconds, the server increments the `Slow_queries` status variable. If the slow query log is enabled, the query is logged to the slow query log file. This value is measured in real time, not CPU time, so a query that is under the threshold on a lightly loaded system might be above the threshold on a heavily loaded one. The default value of `long_query_time` is 10. Beginning with MySQL 5.1.21, the minimum is 0, and the value can be specified to a resolution of microseconds. For logging to a file, times are written including the microseconds part. For logging to tables, only integer times are written; the microseconds part is ignored. Prior to MySQL 5.1.21, the minimum value is 1, and the value for this variable must be an integer. See Section 5.4.5, "The Slow Query Log".

- `low_priority_updates`

Command-Line Format	`--low-priority-updates`	
System Variable	**Name**	`low_priority_updates`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

If set to `1`, all `INSERT`, `UPDATE`, `DELETE`, and `LOCK TABLE WRITE` statements wait until there is no pending `SELECT` or `LOCK TABLE READ` on the affected table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`). This variable previously was named `sql_low_priority_updates`.

- `lower_case_file_system`

System Variable	**Name**	`lower_case_file_system`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`

This variable describes the case sensitivity of file names on the file system where the data directory is located. `OFF` means file names are case sensitive, `ON` means they are not case sensitive. This variable is read only because it reflects a file system attribute and setting it would have no effect on the file system.

- `lower_case_table_names`

Command-Line Format	`--lower_case_table_names[=#]`	
System Variable	**Name**	`lower_case_table_names`

	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`2`

If set to 0, table names are stored as specified and comparisons are case sensitive. If set to 1, table names are stored in lowercase on disk and comparisons are not case sensitive. If set to 2, table names are stored as given but compared in lowercase. This option also applies to database names and table aliases. For additional information, see Section 9.2.2, "Identifier Case Sensitivity".

On Windows the default value is 1. On OS X, the default value is 2.

You should *not* set `lower_case_table_names` to 0 if you are running MySQL on a system where the data directory resides on a case-insensitive file system (such as on Windows or OS X). It is an unsupported combination that could result in a hang condition when running an `INSERT INTO ... SELECT ... FROM tbl_name` operation with the wrong `tbl_name` letter case. With `MyISAM`, accessing table names using different letter cases could cause index corruption.

If you are using `InnoDB` tables, you should set this variable to 1 on all platforms to force names to be converted to lowercase. Prior to MySQL Cluster NDB 6.3.35, MySQL Cluster NDB 7.0.15, and MySQL Cluster NDB 7.1.4, this is also true for tables using the `NDB` storage engine.

The setting of this variable has no effect on replication filtering options. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules", for more information.

You should not use different settings for `lower_case_table_names` on replication masters and slaves. In particular, you should not do this when the slave uses a case-sensitive file system, as this can cause replication to fail. For more information, see Section 16.4.1.38, "Replication and Variables".

* `max_allowed_packet`

Command-Line Format	`--max_allowed_packet=#`	
System Variable	Name	`max_allowed_packet`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`1048576`
	Min Value	`1024`
	Max Value	`1073741824`

The maximum size of one packet or any generated/intermediate string.

The packet message buffer is initialized to `net_buffer_length` bytes, but can grow up to `max_allowed_packet` bytes when needed. This value by default is small, to catch large (possibly incorrect) packets.

You must increase this value if you are using large `BLOB` columns or long strings. It should be as big as the largest `BLOB` you want to use. The protocol limit for `max_allowed_packet` is 1GB. The value should be a multiple of 1024; nonmultiples are rounded down to the nearest multiple.

When you change the message buffer size by changing the value of the `max_allowed_packet` variable, you should also change the buffer size on the client side if your client program permits it. The default `max_allowed_packet` value built in to the client library is 1GB, but individual client programs might override this. For example, `mysql` and `mysqldump` have defaults of 16MB and 24MB, respectively. They also enable you to change the client-side value by setting `max_allowed_packet` on the command line or in an option file.

As of MySQL 5.1.31, the session value of this variable is read only. Before 5.1.31, setting the session value is permitted but has no effect. The client can receive up to as many bytes as the session value. However, the server will not send to the client more bytes than the current global `max_allowed_packet` value. (The global value could be less than the session value if the global value is changed after the client connects.)

- `max_connect_errors`

Command-Line Format	`--max_connect_errors=#`	
System Variable	**Name**	`max_connect_errors`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10`
	Min Value	`1`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`10`
	Min Value	`1`
	Max Value	`18446744073709547520`

If more than this many successive connection requests from a host are interrupted without a successful connection, the server blocks that host from further connections. You can unblock blocked hosts by flushing the host cache. To do so, issue a `FLUSH HOSTS` statement or execute a `mysqladmin flush-hosts` command. If a connection is established successfully within fewer than `max_connect_errors` attempts after a previous connection was interrupted, the error count for the host is cleared to zero. However, once a host is blocked, flushing the host cache is the only way to unblock it.

- `max_connections`

Command-Line Format	`--max_connections=#`	
System Variable	**Name**	`max_connections`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.1.14)	**Type**	`integer`
	Default	`100`
	Min Value	`1`
	Max Value	`16384`
Permitted Values (>= 5.1.15, <= 5.1.16)	**Type**	`integer`
	Default	`151`
	Min Value	`1`
	Max Value	`16384`
Permitted Values (>= 5.1.17)	**Type**	`integer`
	Default	`151`
	Min Value	`1`
	Max Value	`100000`

The maximum permitted number of simultaneous client connections. By default, this is 151, beginning with MySQL 5.1.15. (Previously, the default was 100.) See Section B.5.2.7, "Too many connections", for more information.

Increasing this value increases the number of file descriptors that `mysqld` requires. See Section 8.4.3.1, "How MySQL Opens and Closes Tables", for comments on file descriptor limits.

- `max_delayed_threads`

Command-Line Format	`--max_delayed_threads=#`	
System Variable	**Name**	`max_delayed_threads`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`20`
	Min Value	`0`

	Max Value	16384

Do not start more than this number of threads to handle `INSERT DELAYED` statements. If you try to insert data into a new table after all `INSERT DELAYED` threads are in use, the row is inserted as if the `DELAYED` attribute was not specified. If you set this to 0, MySQL never creates a thread to handle `DELAYED` rows; in effect, this disables `DELAYED` entirely.

For the `SESSION` value of this variable, the only valid values are 0 or the `GLOBAL` value.

- `max_error_count`

Command-Line Format	`--max_error_count=#`	
System Variable	**Name**	`max_error_count`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`64`
	Min Value	`0`
	Max Value	`65535`

The maximum number of error, warning, and note messages to be stored for display by the `SHOW ERRORS` and `SHOW WARNINGS` statements.

- `max_heap_table_size`

Command-Line Format	`--max_heap_table_size=#`	
System Variable	**Name**	`max_heap_table_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`16777216`
	Min Value	`16384`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`16777216`
	Min Value	`16384`

	Max Value	`1844674407370954752`

This variable sets the maximum size to which user-created `MEMORY` tables are permitted to grow. The value of the variable is used to calculate `MEMORY` table `MAX_ROWS` values. Setting this variable has no effect on any existing `MEMORY` table, unless the table is re-created with a statement such as `CREATE TABLE` or altered with `ALTER TABLE` or `TRUNCATE TABLE`. A server restart also sets the maximum size of existing `MEMORY` tables to the global `max_heap_table_size` value.

This variable is also used in conjunction with `tmp_table_size` to limit the size of internal in-memory tables. See Section 8.4.4, "Internal Temporary Table Use in MySQL".

`max_heap_table_size` is not replicated. See Section 16.4.1.22, "Replication and MEMORY Tables", and Section 16.4.1.38, "Replication and Variables", for more information.

- `max_insert_delayed_threads`

System Variable	**Name**	`max_insert_delayed_threads`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`

This variable is a synonym for `max_delayed_threads`.

- `max_join_size`

Command-Line Format	`--max_join_size=#`	
System Variable	**Name**	`max_join_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`4294967295`
	Min Value	`1`
	Max Value	`4294967295`

Do not permit statements that probably need to examine more than `max_join_size` rows (for single-table statements) or row combinations (for multiple-table statements) or that are likely to do more than `max_join_size` disk seeks. By setting this value, you can catch statements where keys are not used properly and that would probably take a long time. Set it if your users tend to perform joins that lack a `WHERE` clause, that take a long time, or that return millions of rows.

Setting this variable to a value other than `DEFAULT` resets the value of `sql_big_selects` to `0`. If you set the `sql_big_selects` value again, the `max_join_size` variable is ignored.

If a query result is in the query cache, no result size check is performed, because the result has previously been computed and it does not burden the server to send it to the client.

This variable previously was named `sql_max_join_size`.

- `max_length_for_sort_data`

Command-Line Format	`--max_length_for_sort_data=#`	
System Variable	**Name**	`max_length_for_sort_data`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1024`
	Min Value	`4`
	Max Value	`8388608`

The cutoff on the size of index values that determines which `filesort` algorithm to use. See Section 8.2.1.11, "ORDER BY Optimization".

- `max_long_data_size`

Introduced	5.1.57	
Deprecated	5.1.57	
Command-Line Format	`--max_long_data_size=#`	
System Variable	**Name**	`max_long_data_size`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`1048576`
	Min Value	`1024`
	Max Value	`4294967295`

The maximum size of parameter values that can be sent with the `mysql_stmt_send_long_data()` C API function. If not set at server startup, the default is the value of the `max_allowed_packet` system variable. This variable is deprecated. In MySQL 5.6, it is removed and the maximum parameter size is controlled by `max_allowed_packet`.

- `max_prepared_stmt_count`

Introduced	5.1.10

Command-Line Format	`--max_prepared_stmt_count=#`	
System Variable	**Name**	`max_prepared_stmt_count`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`16382`
	Min Value	`0`
	Max Value	`1048576`

This variable limits the total number of prepared statements in the server. (The sum of the number of prepared statements across all sessions.) It can be used in environments where there is the potential for denial-of-service attacks based on running the server out of memory by preparing huge numbers of statements. If the value is set lower than the current number of prepared statements, existing statements are not affected and can be used, but no new statements can be prepared until the current number drops below the limit. The default value is 16,382. The permissible range of values is from 0 to 1 million. Setting the value to 0 disables prepared statements. This variable was added in MySQL 5.1.10.

- `max_relay_log_size`

Command-Line Format	`--max_relay_log_size=#`	
System Variable	**Name**	`max_relay_log_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`1073741824`

If a write by a replication slave to its relay log causes the current log file size to exceed the value of this variable, the slave rotates the relay logs (closes the current file and opens the next one). If `max_relay_log_size` is 0, the server uses `max_binlog_size` for both the binary log and the relay log. If `max_relay_log_size` is greater than 0, it constrains the size of the relay log, which enables you to have different sizes for the two logs. You must set `max_relay_log_size` to between 4096 bytes and 1GB (inclusive), or to 0. The default value is 0. See Section 16.2.1, "Replication Implementation Details".

- `max_seeks_for_key`

Command-Line Format	`--max_seeks_for_key=#`	
System Variable	**Name**	`max_seeks_for_key`

	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`4294967295`
	Min Value	`1`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`18446744073709547520`
	Min Value	`1`
	Max Value	`18446744073709547520`

Limit the assumed maximum number of seeks when looking up rows based on a key. The MySQL optimizer assumes that no more than this number of key seeks are required when searching for matching rows in a table by scanning an index, regardless of the actual cardinality of the index (see Section 13.7.5.23, "SHOW INDEX Syntax"). By setting this to a low value (say, 100), you can force MySQL to prefer indexes instead of table scans.

- `max_sort_length`

Command-Line Format	`--max_sort_length=#`	
System Variable	**Name**	`max_sort_length`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1024`
	Min Value	`4`
	Max Value	`8388608`

The number of bytes to use when sorting data values. The server uses only the first `max_sort_length` bytes of each value and ignores the rest. Consequently, values that differ only after the first `max_sort_length` bytes compare as equal for `GROUP BY`, `ORDER BY`, and `DISTINCT` operations.

- `max_sp_recursion_depth`

Command-Line Format	`--max_sp_recursion_depth[=#]`	
System Variable	**Name**	`max_sp_recursion_depth`

	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Max Value	`255`

The number of times that any given stored procedure may be called recursively. The default value for this option is 0, which completely disables recursion in stored procedures. The maximum value is 255.

Stored procedure recursion increases the demand on thread stack space. If you increase the value of `max_sp_recursion_depth`, it may be necessary to increase thread stack size by increasing the value of `thread_stack` at server startup.

- `max_tmp_tables`

This variable is unused.

- `max_user_connections`

Command-Line Format	`--max_user_connections=#`	
System Variable	**Name**	`max_user_connections`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`

The maximum number of simultaneous connections permitted to any given MySQL user account. A value of 0 (the default) means "no limit."

This variable has a global value that can be set at server startup or runtime. It also has a read-only session value that indicates the effective simultaneous-connection limit that applies to the account associated with the current session. The session value is initialized as follows:

- If the user account has a nonzero `MAX_USER_CONNECTIONS` resource limit, the session `max_user_connections` value is set to that limit.

- Otherwise, the session `max_user_connections` value is set to the global value.

Account resource limits are specified using the `GRANT` statement. See Section 6.3.4, "Setting Account Resource Limits", and Section 13.7.1.3, "GRANT Syntax".

- `max_write_lock_count`

Command-Line Format	--max_write_lock_count=#	
System Variable	Name	max_write_lock_count
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	4294967295
	Min Value	1
	Max Value	4294967295
Permitted Values (64-bit platforms)	Type	integer
	Default	18446744073709547520
	Min Value	1
	Max Value	18446744073709547520

After this many write locks, permit some pending read lock requests to be processed in between.

- min_examined_row_limit

Introduced	5.1.21	
Command-Line Format	--min-examined-row-limit=#	
System Variable	Name	min_examined_row_limit
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	0
	Min Value	0
	Max Value	4294967295
Permitted Values (64-bit platforms)	Type	integer
	Default	0
	Min Value	0
	Max Value	18446744073709547520

Queries that examine fewer than this number of rows are not logged to the slow query log. This variable was added in MySQL 5.1.21.

- `multi_range_count`

Command-Line Format	`--multi_range_count=#`	
System Variable	**Name**	`multi_range_count`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`256`
	Min Value	`1`
	Max Value	`4294967295`

The maximum number of ranges to send to a table handler at once during range selects. The default value is 256. Sending multiple ranges to a handler at once can improve the performance of certain selects dramatically. This is especially true for the `NDBCLUSTER` table handler, which needs to send the range requests to all nodes. Sending a batch of those requests at once reduces communication costs significantly.

This variable is deprecated in MySQL 5.1, and is no longer supported in MySQL 5.5, in which arbitrarily long lists of ranges can be processed.

- `myisam_data_pointer_size`

Command-Line Format	`--myisam_data_pointer_size=#`	
System Variable	**Name**	`myisam_data_pointer_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`6`
	Min Value	`2`
	Max Value	`7`

The default pointer size in bytes, to be used by `CREATE TABLE` for `MyISAM` tables when no `MAX_ROWS` option is specified. This variable cannot be less than 2 or larger than 7. The default value is 6. See Section B.5.2.12, "The table is full".

- `myisam_max_sort_file_size`

Command-Line Format	`--myisam_max_sort_file_size=#`	
System Variable	**Name**	`myisam_max_sort_file_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`2147483648`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`9223372036854775807`

The maximum size of the temporary file that MySQL is permitted to use while re-creating a `MyISAM` index (during `REPAIR TABLE`, `ALTER TABLE`, or `LOAD DATA INFILE`). If the file size would be larger than this value, the index is created using the key cache instead, which is slower. The value is given in bytes.

If `MyISAM` index files exceed this size and disk space is available, increasing the value may help performance. The space must be available in the file system containing the directory where the original index file is located.

- `myisam_mmap_size`

Introduced	5.1.43	
Command-Line Format	`--myisam_mmap_size=#`	
System Variable	**Name**	`myisam_mmap_size`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`4294967295`
	Min Value	`7`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`18446744073709547520`
	Min Value	`7`
	Max Value	`18446744073709547520`

The maximum amount of memory to use for memory mapping compressed `MyISAM` files. If many compressed `MyISAM` tables are used, the value can be decreased to reduce the likelihood of memory-swapping problems. This variable was added in MySQL 5.1.43.

- `myisam_recover_options`

System Variable	Name	`myisam_recover_options`
	Variable Scope	Global
	Dynamic Variable	No

The value of the `--myisam-recover` option. See Section 5.1.3, "Server Command Options".

- `myisam_repair_threads`

Command-Line Format	`--myisam_repair_threads=#`	
System Variable	Name	`myisam_repair_threads`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`1`
	Min Value	`1`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`1`
	Min Value	`1`
	Max Value	`18446744073709547520`

If this value is greater than 1, `MyISAM` table indexes are created in parallel (each index in its own thread) during the `Repair by sorting` process. The default value is 1.

Note

Multi-threaded repair is still *beta-quality* code.

- `myisam_sort_buffer_size`

Command-Line Format	`--myisam_sort_buffer_size=#`	
System Variable	Name	`myisam_sort_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes

Permitted Values (Windows)	Type	`integer`
	Default	`8388608`
	Min Value	`4096`
	Max Value	`4294967295`
Permitted Values (Other, 32-bit platforms)	Type	`integer`
	Default	`8388608`
	Min Value	`4096`
	Max Value	`4294967295`
Permitted Values (Other, 64-bit platforms)	Type	`integer`
	Default	`8388608`
	Min Value	`4096`
	Max Value	`18446744073709547520`

The size of the buffer that is allocated when sorting `MyISAM` indexes during a `REPAIR TABLE` or when creating indexes with `CREATE INDEX` or `ALTER TABLE`.

The maximum permissible setting for `myisam_sort_buffer_size` is 4GB−1. As of MySQL 5.1.23, larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB−1 with a warning).

- `myisam_stats_method`

Command-Line Format	`--myisam_stats_method=name`	
System Variable	Name	`myisam_stats_method`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`enumeration`
	Default	`nulls_unequal`
	Valid Values	`nulls_equal`
		`nulls_unequal`
		`nulls_ignored`

How the server treats `NULL` values when collecting statistics about the distribution of index values for `MyISAM` tables. This variable has three possible values, `nulls_equal`, `nulls_unequal`, and `nulls_ignored`. For `nulls_equal`, all `NULL` index values are considered equal and form a single value group that has a size equal to the number of `NULL` values. For `nulls_unequal`, `NULL` values are considered unequal, and each `NULL` forms a distinct value group of size 1. For `nulls_ignored`, `NULL` values are ignored.

The method that is used for generating table statistics influences how the optimizer chooses indexes for query execution, as described in Section 8.3.7, "InnoDB and MyISAM Index Statistics Collection".

Any unique prefix of a valid value may be used to set the value of this variable.

- `myisam_use_mmap`

Introduced	5.1.4	
Command-Line Format	`--myisam_use_mmap`	
System Variable	**Name**	`myisam_use_mmap`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Use memory mapping for reading and writing `MyISAM` tables. This variable was added in MySQL 5.1.4.

- `named_pipe`

System Variable	**Name**	`named_pipe`
	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Windows	
Permitted Values (Windows)	**Type**	`boolean`
	Default	`OFF`

(Windows only.) Indicates whether the server supports connections over named pipes.

- `net_buffer_length`

Command-Line Format	`--net_buffer_length=#`	
System Variable	**Name**	`net_buffer_length`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`16384`
	Min Value	`1024`
	Max Value	`1048576`

Each client thread is associated with a connection buffer and result buffer. Both begin with a size given by `net_buffer_length` but are dynamically enlarged up to `max_allowed_packet` bytes as needed. The result buffer shrinks to `net_buffer_length` after each SQL statement.

This variable should not normally be changed, but if you have very little memory, you can set it to the expected length of statements sent by clients. If statements exceed this length, the connection buffer is automatically enlarged. The maximum value to which `net_buffer_length` can be set is 1MB.

As of MySQL 5.1.31, the session value of this variable is read only. Before 5.1.31, setting the session value is permitted but has no effect.

- `net_read_timeout`

Command-Line Format	`--net_read_timeout=#`	
System Variable	**Name**	`net_read_timeout`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`30`
	Min Value	`1`

The number of seconds to wait for more data from a connection before aborting the read. Before MySQL 5.1.41, this timeout applies only to TCP/IP connections, not to connections made through Unix socket files, named pipes, or shared memory. When the server is reading from the client, `net_read_timeout` is the timeout value controlling when to abort. When the server is writing to the client, `net_write_timeout` is the timeout value controlling when to abort. See also `slave_net_timeout`.

On Linux, the `NO_ALARM` build flag affects timeout behavior as indicated in the description of the `net_retry_count` system variable.

- `net_retry_count`

Command-Line Format	`--net_retry_count=#`	
System Variable	**Name**	`net_retry_count`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10`
	Min Value	`1`
	Max Value	`4294967295`

Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`10`
	Min Value	`1`
	Max Value	`18446744073709547520`

If a read or write on a communication port is interrupted, retry this many times before giving up. This value should be set quite high on FreeBSD because internal interrupts are sent to all threads.

On Linux, the `NO_ALARM` build flag (`-DNO_ALARM`) modifies how the binary treats both `net_read_timeout` and `net_write_timeout`. With this flag enabled, neither timer cancels the current statement until after the failing connection has been waited on an additional `net_retry_count` times. This means that the effective timeout value becomes `(timeout setting)` `× (net_retry_count+1)`.

- `net_write_timeout`

Command-Line Format	`--net_write_timeout=#`	
System Variable	**Name**	`net_write_timeout`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`60`
	Min Value	`1`

The number of seconds to wait for a block to be written to a connection before aborting the write. Before MySQL 5.1.41, this timeout applies only to TCP/IP connections, not to connections made using Unix socket files, named pipes, or shared memory. See also `net_read_timeout`.

On Linux, the `NO_ALARM` build flag affects timeout behavior as indicated in the description of the `net_retry_count` system variable.

- `new`

Command-Line Format	`--new`	
System Variable	**Name**	`new`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Disabled by	`skip-new`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This variable was used in MySQL 4.0 to turn on some 4.1 behaviors, and is retained for backward compatibility. Its value is always `OFF`.

In MySQL Cluster 5.1.12 and later, setting this variable to `ON` makes it possible to employ partitioning types other than `KEY` or `LINEAR KEY` with `NDB` tables. *This feature is experimental only, and not supported in production.* For additional information, see User-defined partitioning and the NDB storage engine (MySQL Cluster).

- `old`

Introduced	5.1.18	
Command-Line Format	`--old`	
System Variable	**Name**	`old`
	Variable Scope	Global
	Dynamic Variable	No

`old` is a compatibility variable. It is disabled by default, but can be enabled at startup to revert the server to behaviors present in older versions.

When `old` is enabled, it changes the default scope of index hints to that used prior to MySQL 5.1.17. That is, index hints with no `FOR` clause apply only to how indexes are used for row retrieval and not to resolution of `ORDER BY` or `GROUP BY` clauses. (See Section 8.9.3, "Index Hints".) Take care about enabling this in a replication setup. With statement-based binary logging, having different modes for the master and slaves might lead to replication errors.

This variable was added as `old_mode` in MySQL 5.1.17 and renamed to `old` in MySQL 5.1.18.

- `old_alter_table`

Command-Line Format	`--old-alter-table`	
System Variable	**Name**	`old_alter_table`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

When this variable is enabled, the server does not use the optimized method of processing an `ALTER TABLE` operation. It reverts to using a temporary table, copying over the data, and then renaming the temporary table to the original, as used by MySQL 5.0 and earlier. For more information on the operation of `ALTER TABLE`, see Section 13.1.7, "ALTER TABLE Syntax".

- `old_passwords`

System Variable	**Name**	`old_passwords`
	Variable Scope	Global, Session

	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`0`

This variable controls the password hashing method used by the `PASSWORD()` function. It also influences password hashing performed by `CREATE USER` and `GRANT` statements that specify a password using an `IDENTIFIED BY` clause.

The value determines whether or not to use "old" native MySQL password hashing. A value of 0 (or `OFF`) causes passwords to be encrypted using the format available from MySQL 4.1 on. A value of 1 (or `ON`) causes password encryption to use the older pre-4.1 format.

If `old_passwords=1`, `PASSWORD(str)` returns the same value as `OLD_PASSWORD(str)`. The latter function is not affected by the value of `old_passwords`.

For information about hashing formats, see Section 6.1.2.4, "Password Hashing in MySQL".

- `one_shot`

  This is not a variable, but it can be used when setting some variables. It is described in Section 13.7.4.1, "SET Syntax for Variable Assignment".

- `open_files_limit`

Command-Line Format	`--open-files-limit=#`	
System Variable	**Name**	`open_files_limit`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`platform dependent`

The number of files that the operating system permits `mysqld` to open. This is the real value permitted by the system and might be different from the value you gave using the `--open-files-limit` option to `mysqld` or `mysqld_safe`. The value is 0 on systems where MySQL cannot change the number of open files.

- `optimizer_prune_level`

Command-Line Format	`--optimizer_prune_level[=#]`	
System Variable	**Name**	`optimizer_prune_level`
	Variable Scope	Global, Session

		Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`	
	Default	`1`	

Controls the heuristics applied during query optimization to prune less-promising partial plans from the optimizer search space. A value of 0 disables heuristics so that the optimizer performs an exhaustive search. A value of 1 causes the optimizer to prune plans based on the number of rows retrieved by intermediate plans.

- `optimizer_search_depth`

Command-Line Format	`--optimizer_search_depth[=#]`	
System Variable	**Name**	`optimizer_search_depth`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`62`
	Min Value	`0`
	Max Value	`63`

The maximum depth of search performed by the query optimizer. Values larger than the number of relations in a query result in better query plans, but take longer to generate an execution plan for a query. Values smaller than the number of relations in a query return an execution plan quicker, but the resulting plan may be far from being optimal. If set to 0, the system automatically picks a reasonable value. If set to 63, the optimizer switches to the algorithm used in MySQL 5.0.0 (and previous versions) for performing searches. The value of 63 is deprecated and will be treated as invalid in a future MySQL release.

- `optimizer_switch`

Introduced	5.1.34	
Command-Line Format	`--optimizer_switch=value`	
System Variable	**Name**	`optimizer_switch`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`set`
	Valid Values	`index_merge={on|off}`
		`index_merge_intersection={on|off}`
		`index_merge_sort_union={on|off}`
		`index_merge_union={on|off}`

The `optimizer_switch` system variable enables control over optimizer behaviors. The value of this variable is a set of flags, each of which has a value of `on` or `off` to indicate whether the corresponding optimizer behavior is enabled or disabled. This variable has global and session values and can be changed at runtime. The global default can be set at server startup.

To see the current set of optimizer flags, select the variable value:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                    index_merge_sort_union=on,index_merge_intersection=on
```

For more information about the syntax of this variable and the optimizer behaviors that it controls, see Section 8.9.2, "Controlling Switchable Optimizations".

- `pid_file`

Command-Line Format	`--pid-file=file_name`	
System Variable	**Name**	`pid_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The path name of the process ID (PID) file. This variable can be set with the `--pid-file` option.

- `plugin_dir`

Introduced	5.1.2	
Command-Line Format	`--plugin_dir=dir_name`	
System Variable	**Name**	`plugin_dir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (<= 5.1.1)	**Type**	`directory name`
	Default	
Permitted Values (Windows, >= 5.1.2)	**Type**	`directory name`
	Default	`BASEDIR/lib/plugin`
Permitted Values (Other, >= 5.1.2)	**Type**	`directory name`
	Default	`BASEDIR/lib/mysql/plugin`

The path name of the plugin directory. This variable was added in MySQL 5.1.2.

If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `--secure-file-priv` to a directory where `SELECT` writes can be made safely.

- `port`

Command-Line Format	`--port=#`	
System Variable	**Name**	`port`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`3306`
	Min Value	`0`
	Max Value	`65535`

The number of the port on which the server listens for TCP/IP connections. This variable can be set with the `--port` option.

- `preload_buffer_size`

Command-Line Format	`--preload_buffer_size=#`	
System Variable	**Name**	`preload_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`32768`
	Min Value	`1024`
	Max Value	`1073741824`

The size of the buffer that is allocated when preloading indexes.

- `prepared_stmt_count`

Introduced	5.1.10	
Removed	5.1.13	
System Variable (>= 5.1.10, <= 5.1.13)	**Name**	`prepared_stmt_count`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`

The current number of prepared statements. (The maximum number of statements is given by the `max_prepared_stmt_count` system variable.) This variable was added in MySQL 5.1.10. In MySQL 5.1.14, it was converted to the global `Prepared_stmt_count` status variable.

- `profiling`

  If set to 0 or `OFF` (the default), statement profiling is disabled. If set to 1 or `ON`, statement profiling is enabled and the `SHOW PROFILE` and `SHOW PROFILES` statements provide access to profiling information. See Section 13.7.5.33, "SHOW PROFILES Syntax". This variable was added in MySQL 5.1.24.

- `profiling_history_size`

  The number of statements for which to maintain profiling information if `profiling` is enabled. The default value is 15. The maximum value is 100. Setting the value to 0 effectively disables profiling. See Section 13.7.5.33, "SHOW PROFILES Syntax". This variable was added in MySQL 5.1.24.

- `protocol_version`

System Variable	Name	`protocol_version`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`

The version of the client/server protocol used by the MySQL server.

- `pseudo_thread_id`

System Variable	Name	`pseudo_thread_id`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`integer`

This variable is for internal server use.

- `query_alloc_block_size`

Command-Line Format	`--query_alloc_block_size=#`	
System Variable	Name	`query_alloc_block_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`8192`

	Min Value	1024
	Max Value	4294967295
	Block Size	1024
Permitted Values (64-bit platforms)	Type	integer
	Default	8192
	Min Value	1024
	Max Value	18446744073709547520
	Block Size	1024

The allocation size of memory blocks that are allocated for objects created during statement parsing and execution. If you have problems with memory fragmentation, it might help to increase this parameter.

- `query_cache_limit`

Command-Line Format	`--query_cache_limit=#`	
System Variable	**Name**	`query_cache_limit`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`1048576`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`1048576`
	Min Value	`0`
	Max Value	`18446744073709547520`

Do not cache results that are larger than this number of bytes. The default value is 1MB.

- `query_cache_min_res_unit`

Command-Line Format	`--query_cache_min_res_unit=#`	
System Variable	**Name**	`query_cache_min_res_unit`

	Variable Scope	Global	
	Dynamic Variable	Yes	
Permitted Values (32-bit platforms)	Type	`integer`	
	Default	`4096`	
	Min Value	`512`	
	Max Value	`4294967295`	
Permitted Values (64-bit platforms)	Type	`integer`	
	Default	`4096`	
	Min Value	`512`	
	Max Value	`18446744073709547520`	

The minimum size (in bytes) for blocks allocated by the query cache. The default value is 4096 (4KB). Tuning information for this variable is given in Section 8.10.3.3, "Query Cache Configuration".

- `query_cache_size`

Command-Line Format	`--query_cache_size=#`		
System Variable	Name	`query_cache_size`	
	Variable Scope	Global	
	Dynamic Variable	Yes	
Permitted Values (32-bit platforms)	Type	`integer`	
	Default	`0`	
	Min Value	`0`	
	Max Value	`4294967295`	
Permitted Values (64-bit platforms)	Type	`integer`	
	Default	`0`	
	Min Value	`0`	
	Max Value	`18446744073709547520`	

The amount of memory allocated for caching query results. The default value is 0, which disables the query cache. The permissible values are multiples of 1024; other values are rounded down to the nearest multiple. `query_cache_size` bytes of memory are allocated even if `query_cache_type` is set to 0. See Section 8.10.3.3, "Query Cache Configuration", for more information.

The query cache needs a minimum size of about 40KB to allocate its structures. (The exact size depends on system architecture.) If you set the value of `query_cache_size` too small, a warning will occur, as described in Section 8.10.3.3, "Query Cache Configuration".

- `query_cache_type`

Command-Line Format	`--query_cache_type=#`	
System Variable	**Name**	`query_cache_type`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`1`
	Valid Values	`0`
		`1`
		`2`

Set the query cache type. Setting the `GLOBAL` value sets the type for all clients that connect thereafter. Individual clients can set the `SESSION` value to affect their own use of the query cache. Possible values are shown in the following table.

Option	Description
`0` or `OFF`	Do not cache results in or retrieve results from the query cache. Note that this does not deallocate the query cache buffer. To do that, you should set `query_cache_size` to 0.
`1` or `ON`	Cache all cacheable query results except for those that begin with `SELECT SQL_NO_CACHE`.
`2` or `DEMAND`	Cache results only for cacheable queries that begin with `SELECT SQL_CACHE`.

This variable defaults to `ON`.

Any unique prefix of a valid value may be used to set the value of this variable.

- `query_cache_wlock_invalidate`

Command-Line Format	`--query_cache_wlock_invalidate`	
System Variable	**Name**	`query_cache_wlock_invalidate`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Normally, when one client acquires a `WRITE` lock on a `MyISAM` table, other clients are not blocked from issuing statements that read from the table if the query results are present in the query cache. Setting

this variable to 1 causes acquisition of a `WRITE` lock for a table to invalidate any queries in the query cache that refer to the table. This forces other clients that attempt to access the table to wait while the lock is in effect.

- `query_prealloc_size`

Command-Line Format	`--query_prealloc_size=#`	
System Variable	**Name**	`query_prealloc_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`8192`
	Min Value	`8192`
	Max Value	`4294967295`
	Block Size	`1024`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`8192`
	Min Value	`8192`
	Max Value	`18446744073709547520`
	Block Size	`1024`

The size of the persistent buffer used for statement parsing and execution. This buffer is not freed between statements. If you are running complex queries, a larger `query_prealloc_size` value might be helpful in improving performance, because it can reduce the need for the server to perform memory allocation during query execution operations.

- `rand_seed1`

The `rand_seed1` and `rand_seed2` variables exist as session variables only, and can be set but not read. Beginning with MySQL 5.1.18, the variables—but not their values—are shown in the output of `SHOW VARIABLES`.

The purpose of these variables is to support replication of the `RAND()` function. For statements that invoke `RAND()`, the master passes two values to the slave, where they are used to seed the random number generator. The slave uses these values to set the session variables `rand_seed1` and `rand_seed2` so that `RAND()` on the slave generates the same value as on the master.

- `rand_seed2`

See the description for `rand_seed1`.

- `range_alloc_block_size`

Command-Line Format	`--range_alloc_block_size=#`		
System Variable	**Name**	`range_alloc_block_size`	
	Variable Scope	Global, Session	
	Dynamic Variable	Yes	
Permitted Values (32-bit platforms)	**Type**	`integer`	
	Default	`4096`	
	Min Value	`4096`	
	Max Value	`4294967295`	
	Block Size	`1024`	

The size of blocks that are allocated when doing range optimization.

- `read_buffer_size`

Command-Line Format	`--read_buffer_size=#`		
System Variable	**Name**	`read_buffer_size`	
	Variable Scope	Global, Session	
	Dynamic Variable	Yes	
Permitted Values	**Type**	`integer`	
	Default	`131072`	
	Min Value	`8200`	
	Max Value	`2147479552`	

Each thread that does a sequential scan for a `MyISAM` table allocates a buffer of this size (in bytes) for each table it scans. If you do many sequential scans, you might want to increase this value, which defaults to 131072. The value of this variable should be a multiple of 4KB. If it is set to a value that is not a multiple of 4KB, its value will be rounded down to the nearest multiple of 4KB.

This option is also used in the following context for all storage engines:

- For caching the indexes in a temporary file (not a temporary table), when sorting rows for `ORDER BY`.

- For bulk insert into partitions.

- For caching results of nested queries.

and in one other storage engine-specific way: to determine the memory block size for `MEMORY` tables.

The maximum permissible setting for `read_buffer_size` is 2GB.

For more information about memory use during different operations, see Section 8.12.5.1, "How MySQL Uses Memory".

- `read_only`

Command-Line Format	`--read_only`	
System Variable	**Name**	`read_only`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

When the `read_only` system variable is enabled, the server permits no client updates except from users who have the `SUPER` privilege. This variable is disabled by default.

Even with `read_only` enabled, the server permits these operations:

- Updates performed by slave threads, if the server is a replication slave. In replication setups, it can be useful to enable `read_only` on slave servers to ensure that slaves accept updates only from the master server and not from clients.

- Use of `ANALYZE TABLE` or `OPTIMIZE TABLE` statements. The purpose of read-only mode is to prevent changes to table structure or contents. Analysis and optimization do not qualify as such changes. This means, for example, that consistency checks on read-only replication slaves can be performed with `mysqlcheck --all-databases --analyze`.

- Operations on `TEMPORARY` tables.

- Inserts into the log tables (`mysql.general_log` and `mysql.slow_log`; see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations").

`read_only` exists only as a `GLOBAL` variable, so changes to its value require the `SUPER` privilege. Changes to `read_only` on a master server are not replicated to slave servers. The value can be set on a slave server independent of the setting on the master.

> **Important**
>
> As of MySQL 5.1, enabling `read_only` prevents users not having the `SUPER` privilege from using account-management statements such as `CREATE USER` or `SET PASSWORD`. This is not the case for MySQL 5.0. When replicating from a MySQL 5.0 master to a MySQL 5.1 or later slave, check whether this will have an impact on your applications.

As of MySQL 5.1.15, the following conditions apply to attempts to enable `read_only`:

- The attempt fails and an error occurs if you have any explicit locks (acquired with `LOCK TABLES`) or have a pending transaction.

- The attempt blocks while other clients hold explicit table locks or have pending transactions, until the locks are released and the transactions end. While the attempt to enable `read_only` is pending,

requests by other clients for table locks or to begin transactions also block until `read_only` has been set.

- `read_only` can be enabled while you hold a global read lock (acquired with `FLUSH TABLES WITH READ LOCK`) because that does not involve table locks.

- `read_rnd_buffer_size`

Command-Line Format	`--read_rnd_buffer_size=#`	
System Variable	**Name**	`read_rnd_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`262144`
	Min Value	`8200`
	Max Value	`2147483647`

When reading rows from a `MyISAM` table in sorted order following a key-sorting operation, the rows are read through this buffer to avoid disk seeks. See Section 8.2.1.11, "ORDER BY Optimization". Setting the variable to a large value can improve `ORDER BY` performance by a lot. However, this is a buffer allocated for each client, so you should not set the global variable to a large value. Instead, change the session variable only from within those clients that need to run large queries.

The maximum permissible setting for `read_rnd_buffer_size` is 2GB.

For more information about memory use during different operations, see Section 8.12.5.1, "How MySQL Uses Memory".

- `relay_log_purge`

Command-Line Format	`--relay_log_purge`	
System Variable	**Name**	`relay_log_purge`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

Disables or enables automatic purging of relay log files as soon as they are not needed any more. The default value is 1 (`ON`).

- `relay_log_space_limit`

Command-Line Format	`--relay_log_space_limit=#`	
System Variable	**Name**	`relay_log_space_limit`

	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`18446744073709547520`

The maximum amount of space to use for all relay logs.

- `report_host`

Command-Line Format	`--report-host=host_name`	
System Variable (>= 5.1.24)	**Name**	`report_host`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

The value of the `--report-host` option. This variable was added in MySQL 5.1.24.

- `report_password`

Command-Line Format	`--report-password=name`	
System Variable (>= 5.1.24)	**Name**	`report_password`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

The value of the `--report-password` option. Not the same as the password for the MySQL replication user account. This variable was added in MySQL 5.1.24.

- `report_port`

Command-Line Format	`--report-port=#`

System Variable (>= 5.1.24)	Name	report_port
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	integer
	Default	3306
	Min Value	0
	Max Value	65535

The value of the `--report-port` option. This variable was added in MySQL 5.1.24.

- `report_user`

Command-Line Format	--report-user=name
System Variable (>= 5.1.24)	Name	report_user
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	string

The value of the `--report-user` option. This variable was added in MySQL 5.1.24.

- `secure_auth`

Command-Line Format	--secure-auth
System Variable	Name	secure_auth
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	boolean
	Default	OFF

If this variable is enabled, the server blocks connections by clients that attempt to use accounts that have passwords stored in the old (pre-4.1) format.

Enable this variable to prevent all use of passwords employing the old format (and hence insecure communication over the network).

Server startup fails with an error if this variable is enabled and the privilege tables are in pre-4.1 format. See Section B.5.2.4, "Client does not support authentication protocol".

- `secure_file_priv`

Introduced	5.1.17

Command-Line Format	`--secure-file-priv=dir_name`	
System Variable	**Name**	`secure_file_priv`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`empty`
	Valid Values	`empty`
		`dirname`

This variable is used to limit the effect of data import and export operations, such as those performed by the `LOAD DATA` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. By default, this variable is empty. If set to the name of a directory, it limits import and export operations to work only with files in that directory.

This variable was added in MySQL 5.1.17.

- `server_id`

Command-Line Format	`--server-id=#`	
System Variable	**Name**	`server_id`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`

The server ID, used in replication to give each master and slave a unique identity. This variable is set by the `--server-id` option. For each server participating in replication, you should pick a positive integer in the range from 1 to $2^{32} - 1$ to act as that server's ID.

- `shared_memory`

Command-Line Format	`--shared_memory[={0,1}]`	
System Variable	**Name**	`shared_memory`
	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Windows	
Permitted Values	**Type**	`boolean`

	Default	FALSE

(Windows only.) Whether the server permits shared-memory connections.

- `shared_memory_base_name`

Command-Line Format	`--shared_memory_base_name=name`	
System Variable	**Name**	`shared_memory_base_name`
	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Windows	
Permitted Values	**Type**	`string`
	Default	`MYSQL`

(Windows only.) The name of shared memory to use for shared-memory connections. This is useful when running multiple MySQL instances on a single physical machine. The default name is `MYSQL`. The name is case sensitive.

- `skip_external_locking`

Command-Line Format	`--skip-external-locking`	
System Variable	**Name**	`skip_external_locking`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`ON`

This is `OFF` if `mysqld` uses external locking (system locking), `ON` if external locking is disabled. This affects only `MyISAM` table access.

This variable is set by the `--external-locking` or `--skip-external-locking` option. External locking is disabled by default.

External locking affects only `MyISAM` table access. For more information, including conditions under which it can and cannot be used, see Section 8.11.4, "External Locking".

- `skip_name_resolve`

Command-Line Format	`--skip-name-resolve`	
System Variable (>= 5.1.46)	**Name**	`skip_name_resolve`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`

	Default	OFF

This variable is set from the value of the `--skip-name-resolve` option. If it is `OFF`, `mysqld` resolves host names when checking client connections. If it is `ON`, `mysqld` uses only IP numbers; in this case, all `Host` column values in the grant tables must be IP addresses or `localhost`. See Section 8.12.6.2, "DNS Lookup Optimization and the Host Cache".

This variable was added in MySQL 5.1.46.

- `skip_networking`

Command-Line Format	`--skip-networking`	
System Variable	**Name**	`skip_networking`
	Variable Scope	Global
	Dynamic Variable	No

This is `ON` if the server permits only local (non-TCP/IP) connections. On Unix, local connections use a Unix socket file. On Windows, local connections use a named pipe or shared memory. On NetWare, only TCP/IP connections are supported, so do not set this variable to `ON`. This variable can be set to `ON` with the `--skip-networking` option.

- `skip_show_database`

Command-Line Format	`--skip-show-database`	
System Variable	**Name**	`skip_show_database`
	Variable Scope	Global
	Dynamic Variable	No

This prevents people from using the `SHOW DATABASES` statement if they do not have the `SHOW DATABASES` privilege. This can improve security if you have concerns about users being able to see databases belonging to other users. Its effect depends on the `SHOW DATABASES` privilege: If the variable value is `ON`, the `SHOW DATABASES` statement is permitted only to users who have the `SHOW DATABASES` privilege, and the statement displays all database names. If the value is `OFF`, `SHOW DATABASES` is permitted to all users, but displays the names of only those databases for which the user has the `SHOW DATABASES` or other privilege. (Note that *any* global privilege is considered a privilege for the database.)

- `slow_launch_time`

Command-Line Format	`--slow_launch_time=#`	
System Variable	**Name**	`slow_launch_time`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer

	Default	2

If creating a thread takes longer than this many seconds, the server increments the `Slow_launch_threads` status variable.

- `slow_query_log`

Introduced	5.1.12	
Command-Line Format	`--slow-query-log` (>= 5.1.29)	
System Variable	Name	`slow_query_log`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

Whether the slow query log is enabled. The value can be 0 (or `OFF`) to disable the log or 1 (or `ON`) to enable the log. The default value depends on whether the `--slow_query_log` option is given (`--log-slow-queries` before MySQL 5.1.29). The destination for log output is controlled by the `log_output` system variable; if that value is `NONE`, no log entries are written even if the log is enabled. The `slow_query_log` variable was added in MySQL 5.1.12.

"Slow" is determined by the value of the `long_query_time` variable. See Section 5.4.5, "The Slow Query Log".

- `slow_query_log_file`

Introduced	5.1.12	
Command-Line Format	`--slow-query-log-file=file_name`	
System Variable	Name	`slow_query_log_file`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`file name`
	Default	`host_name-slow.log`

The name of the slow query log file. The default value is *host_name*`-slow.log`, but the initial value can be changed with the `--slow_query_log_file` option (`--log-slow-queries` before MySQL 5.1.29). This variable was added in MySQL 5.1.12.

- `socket`

Command-Line Format	`--socket={file_name|pipe_name}`	
System Variable	Name	`socket`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`/tmp/mysql.sock`

On Unix platforms, this variable is the name of the socket file that is used for local client connections. The default is `/tmp/mysql.sock`. (For some distribution formats, the directory might be different, such as `/var/lib/mysql` for RPMs.)

On Windows, this variable is the name of the named pipe that is used for local client connections. The default value is `MySQL` (not case sensitive).

- `sort_buffer_size`

Command-Line Format	`--sort_buffer_size=#`	
System Variable	**Name**	`sort_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (<= 5.1.22)	**Type**	`integer`
	Default	`2097144`
	Min Value	`32768`
	Max Value	`4294967295`
Permitted Values (Windows, >= 5.1.23)	**Type**	`integer`
	Default	`2097144`
	Min Value	`32768`
	Max Value	`4294967295`
Permitted Values (Other, 32-bit platforms, >= 5.1.23)	**Type**	`integer`
	Default	`2097144`
	Min Value	`32768`
	Max Value	`4294967295`
Permitted Values (Other, 64-bit platforms, >= 5.1.23)	**Type**	`integer`
	Default	`2097144`
	Min Value	`32768`
	Max Value	`18446744073709551615`

Each session that needs to do a sort allocates a buffer of this size. `sort_buffer_size` is not specific to any storage engine and applies in a general manner for optimization. See Section 8.2.1.11, "ORDER BY Optimization", for example.

If you see many `Sort_merge_passes` per second in `SHOW GLOBAL STATUS` output, you can consider increasing the `sort_buffer_size` value to speed up `ORDER BY` or `GROUP BY` operations that cannot be improved with query optimization or improved indexing. The entire buffer is allocated even if it is not all needed, so setting it larger than required globally will slow down most queries that sort. It is best to increase it as a session setting, and only for the sessions that need a larger size. On Linux, there are thresholds of 256KB and 2MB where larger values may significantly slow down memory allocation, so you should consider staying below one of those values. Experiment to find the best value for your workload. See Section B.5.3.5, "Where MySQL Stores Temporary Files".

The maximum permissible setting for `sort_buffer_size` is 4GB−1. As of MySQL 5.1.23, larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB−1 with a warning).

- `sql_auto_is_null`

System Variable	Name	`sql_auto_is_null`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`1`

If this variable is set to 1 (the default), then after a statement that successfully inserts an automatically generated `AUTO_INCREMENT` value, you can find that value by issuing a statement of the following form:

```
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

If the statement returns a row, the value returned is the same as if you invoked the `LAST_INSERT_ID()` function. For details, including the return value after a multiple-row insert, see Section 12.14, "Information Functions". If no `AUTO_INCREMENT` value was successfully inserted, the `SELECT` statement returns no row.

The behavior of retrieving an `AUTO_INCREMENT` value by using an `IS NULL` comparison is used by some ODBC programs, such as Access. See Obtaining Auto-Increment Values. This behavior can be disabled by setting `sql_auto_is_null` to 0.

- `sql_big_selects`

System Variable	Name	`sql_big_selects`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`1`

If set to 0, MySQL aborts `SELECT` statements that are likely to take a very long time to execute (that is, statements for which the optimizer estimates that the number of examined rows exceeds the value of `max_join_size`). This is useful when an inadvisable `WHERE` statement has been issued. The default value for a new connection is 1, which permits all `SELECT` statements.

If you set the `max_join_size` system variable to a value other than `DEFAULT`, `sql_big_selects` is set to 0.

- `sql_buffer_result`

System Variable	Name	`sql_buffer_result`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`0`

If set to 1, `sql_buffer_result` forces results from `SELECT` statements to be put into temporary tables. This helps MySQL free the table locks early and can be beneficial in cases where it takes a long time to send results to the client. The default value is 0.

- `sql_log_bin`

System Variable	Name	`sql_log_bin`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`

If set to 0, no logging is done to the binary log for the client. The client must have the `SUPER` privilege to set this option. The default value is 1.

- `sql_log_off`

System Variable	Name	`sql_log_off`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`0`

If set to 1, no logging is done to the general query log for this client. The client must have the `SUPER` privilege to set this option. The default value is 0.

- `sql_log_update`

Deprecated	5.0.0, by sql_log_bin

System Variable	Name	sql_log_update
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	boolean

This variable is deprecated, and is mapped to `sql_log_bin`. It is removed in MySQL 5.5.

- sql_mode

Command-Line Format	--sql-mode=name	
System Variable	Name	sql_mode
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	set
	Default	''
	Valid Values	ALLOW_INVALID_DATES
		ANSI_QUOTES
		ERROR_FOR_DIVISION_BY_ZERO
		HIGH_NOT_PRECEDENCE
		IGNORE_SPACE
		NO_AUTO_CREATE_USER
		NO_AUTO_VALUE_ON_ZERO
		NO_BACKSLASH_ESCAPES
		NO_DIR_IN_CREATE
		NO_ENGINE_SUBSTITUTION
		NO_FIELD_OPTIONS
		NO_KEY_OPTIONS
		NO_TABLE_OPTIONS
		NO_UNSIGNED_SUBTRACTION
		NO_ZERO_DATE
		NO_ZERO_IN_DATE
		ONLY_FULL_GROUP_BY
		PAD_CHAR_TO_FULL_LENGTH
		PIPES_AS_CONCAT
		REAL_AS_FLOAT
		STRICT_ALL_TABLES
		STRICT_TRANS_TABLES

The current server SQL mode, which can be set dynamically. For details, see Section 5.1.7, "Server SQL Modes".

> **Note**
>
> MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

- `sql_notes`

  If set to 1 (the default), warnings of `Note` level increment `warning_count` and the server records them. If set to 0, `Note` warnings do not increment `warning_count` and the server does not record them. `mysqldump` includes output to set this variable to 0 so that reloading the dump file does not produce warnings for events that do not affect the integrity of the reload operation.

- `sql_quote_show_create`

  If set to 1 (the default), the server quotes identifiers for `SHOW CREATE TABLE` and `SHOW CREATE DATABASE` statements. If set to 0, quoting is disabled. This option is enabled by default so that replication works for identifiers that require quoting. See Section 13.7.5.12, "SHOW CREATE TABLE Syntax", and Section 13.7.5.8, "SHOW CREATE DATABASE Syntax".

- `sql_safe_updates`

  If set to 1, MySQL aborts `UPDATE` or `DELETE` statements that do not use a key in the `WHERE` clause or a `LIMIT` clause. (Specifically, `UPDATE` statements must have a `WHERE` clause that uses a key or a `LIMIT` clause, or both. `DELETE` statements must have both.) This makes it possible to catch `UPDATE` or `DELETE` statements where keys are not used properly and that would probably change or delete a large number of rows. The default value is 0.

- `sql_select_limit`

System Variable	Name	sql_select_limit
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	integer

The maximum number of rows to return from `SELECT` statements. The default value for a new connection is the maximum number of rows that the server permits per table, which depends on the server configuration and may be affected if the server build was configured with `--with-big-tables`. Typical default values are $(2^{32})-1$ or $(2^{64})-1$. If you have changed the limit, the default value can be restored by assigning a value of `DEFAULT`.

If a `SELECT` has a `LIMIT` clause, the `LIMIT` takes precedence over the value of `sql_select_limit`.

- `sql_warnings`

  This variable controls whether single-row `INSERT` statements produce an information string if warnings occur. The default is 0. Set the value to 1 to produce an information string.

- `ssl_ca`

Introduced	5.1.11	
Command-Line Format	`--ssl-ca=file_name`	
System Variable	**Name**	`ssl_ca`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The path to a file with a list of trusted SSL CAs. This variable was added in MySQL 5.1.11.

- `ssl_capath`

Introduced	5.1.11	
Command-Line Format	`--ssl-capath=dir_name`	
System Variable	**Name**	`ssl_capath`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`

The path to a directory that contains trusted SSL CA certificates in PEM format. This variable was added in MySQL 5.1.11.

- `ssl_cert`

Introduced	5.1.11	
Command-Line Format	`--ssl-cert=file_name`	
System Variable	**Name**	`ssl_cert`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The name of the SSL certificate file to use for establishing a secure connection. This variable was added in MySQL 5.1.11.

- `ssl_cipher`

Introduced	5.1.11	
Command-Line Format	`--ssl-cipher=name`	
System Variable	**Name**	`ssl_cipher`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`string`

A list of permissible ciphers to use for SSL encryption. This variable was added in MySQL 5.1.11.

- `ssl_key`

Introduced	5.1.11	
Command-Line Format	`--ssl-key=file_name`	
System Variable	**Name**	`ssl_key`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The name of the SSL key file to use for establishing a secure connection. This variable was added in MySQL 5.1.11.

- `storage_engine`

System Variable	**Name**	`storage_engine`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`MyISAM`

The default storage engine (table type). To set the storage engine at server startup, use the `--default-storage-engine` option. See Section 5.1.3, "Server Command Options".

To see which storage engines are available and enabled, use the `SHOW ENGINES` statement or query the `INFORMATION_SCHEMA ENGINES` table.

- `sync_frm`

Command-Line Format	`--sync-frm`	
System Variable	**Name**	`sync_frm`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

If this variable is set to 1, when any nontemporary table is created its `.frm` file is synchronized to disk (using `fdatasync()`). This is slower but safer in case of a crash. The default is 1.

- `system_time_zone`

System Variable	Name	`system_time_zone`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

The server system time zone. When the server begins executing, it inherits a time zone setting from the machine defaults, possibly modified by the environment of the account used for running the server or the startup script. The value is used to set `system_time_zone`. Typically the time zone is specified by the `TZ` environment variable. It also can be specified using the `--timezone` option of the `mysqld_safe` script.

The `system_time_zone` variable differs from `time_zone`. Although they might have the same value, the latter variable is used to initialize the time zone for each client that connects. See Section 10.6, "MySQL Server Time Zone Support".

- `table_cache`

Deprecated	5.1.3, by table_open_cache	
Removed	5.1.3	
Command-Line Format	`--table_cache=#`	
System Variable	**Name**	`table_cache`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`64`
	Min Value	`1`
	Max Value	`524288`

This is the old name of `table_open_cache` before MySQL 5.1.3. From 5.1.3 on, use `table_open_cache` instead.

- `table_definition_cache`

Introduced	5.1.3	
System Variable	**Name**	`table_definition_cache`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values (<= 5.1.24)	**Type**	`integer`
	Default	`128`
	Min Value	`1`
	Max Value	`524288`
Permitted Values (>= 5.1.25)	**Type**	`integer`
	Default	`256`
	Min Value	`256`
	Max Value	`524288`

The number of table definitions (from `.frm` files) that can be stored in the definition cache. If you use a large number of tables, you can create a large table definition cache to speed up opening of tables. The table definition cache takes less space and does not use file descriptors, unlike the normal table cache. This variable was added in MySQL 5.1.3. The minimum and default values are 1 and 128 before MySQL 5.1.25. The minimum and default are both 256 as of MySQL 5.1.25.

- `table_lock_wait_timeout`

Command-Line Format	`--table_lock_wait_timeout=#`	
System Variable	**Name**	`table_lock_wait_timeout`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`50`
	Min Value	`1`
	Max Value	`1073741824`

This variable is unused.

- `table_open_cache`

Introduced	5.1.3	
System Variable	**Name**	`table_open_cache`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`64`

Min Value	1
Max Value	524288

The number of open tables for all threads. Increasing this value increases the number of file descriptors that `mysqld` requires. You can check whether you need to increase the table cache by checking the `Opened_tables` status variable. See Section 5.1.6, "Server Status Variables". If the value of `Opened_tables` is large and you do not use `FLUSH TABLES` often (which just forces all tables to be closed and reopened), then you should increase the value of the `table_open_cache` variable. For more information about the table cache, see Section 8.4.3.1, "How MySQL Opens and Closes Tables". Before MySQL 5.1.3, this variable is called `table_cache`.

- `table_type`

System Variable	Name	`table_type`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`enumeration`

This variable is a synonym for `storage_engine`, which is the preferred name; `table_type` is deprecated and is removed in MySQL 5.5.

- `thread_cache_size`

Command-Line Format	`--thread_cache_size=#`	
System Variable	Name	`thread_cache_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	0
	Min Value	0
	Max Value	16384

How many threads the server should cache for reuse. When a client disconnects, the client's threads are put in the cache if there are fewer than `thread_cache_size` threads there. Requests for threads are satisfied by reusing threads taken from the cache if possible, and only when the cache is empty is a new thread created. This variable can be increased to improve performance if you have a lot of new connections. Normally, this does not provide a notable performance improvement if you have a good thread implementation. However, if your server sees hundreds of connections per second you should normally set `thread_cache_size` high enough so that most new connections use cached threads. By examining the difference between the `Connections` and `Threads_created` status variables, you can see how efficient the thread cache is. For details, see Section 5.1.6, "Server Status Variables".

- thread_concurrency

Command-Line Format	--thread_concurrency=#	
System Variable	Name	thread_concurrency
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	integer
	Default	10
	Min Value	1
	Max Value	512

This variable is specific to Solaris systems, for which mysqld invokes the thr_setconcurrency() with the variable value. This function enables applications to give the threads system a hint about the desired number of threads that should be run at the same time.

- thread_handling

Introduced	5.1.17	
Command-Line Format	--thread_handling=name	
System Variable (>= 5.1.17)	Name	thread_handling
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	enumeration
	Default	one-thread-per-connection
	Valid Values	no-threads
		one-thread-per-connection

The thread-handling model used by the server for connection threads. The permissible values are no-threads (the server uses a single thread to handle one connection) and one-thread-per-connection (the server uses one thread to handle each client connection). no-threads is useful for debugging under Linux; see Section 22.4, "Debugging and Porting MySQL". This variable was added in MySQL 5.1.17

- thread_stack

Command-Line Format	--thread_stack=#	
System Variable	Name	thread_stack
	Variable Scope	Global
	Dynamic Variable	No

Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`196608`
	Min Value	`131072`
	Max Value	`4294967295`
	Block Size	`1024`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`262144`
	Min Value	`131072`
	Max Value	`18446744073709547520`
	Block Size	`1024`

The stack size for each thread. Many of the limits detected by the `crash-me` test are dependent on this value. See Section 8.13.2, "The MySQL Benchmark Suite". The default of 192KB (256KB for 64-bit systems) is large enough for normal operation. If the thread stack size is too small, it limits the complexity of the SQL statements that the server can handle, the recursion depth of stored procedures, and other memory-consuming actions.

- `time_format`

  This variable is unused.

- `time_zone`

System Variable	**Name**	`time_zone`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

The current time zone. This variable is used to initialize the time zone for each client that connects. By default, the initial value of this is `'SYSTEM'` (which means, "use the value of `system_time_zone`"). The value can be specified explicitly at server startup with the `--default-time-zone` option. See Section 10.6, "MySQL Server Time Zone Support".

- `timed_mutexes`

Command-Line Format	`--timed_mutexes`
System Variable	**Name**	`timed_mutexes`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values	Type	`boolean`
	Default	`OFF`

This variable controls whether `InnoDB` mutexes are timed. If this variable is set to 0 or `OFF` (the default), mutex timing is disabled. If the variable is set to 1 or `ON`, mutex timing is enabled. With timing enabled, the `os_wait_times` value in the output from `SHOW ENGINE INNODB MUTEX` indicates the amount of time (in ms) spent in operating system waits. Otherwise, the value is 0.

* `timestamp`

System Variable	Name	`timestamp`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`numeric`

Set the time for this client. This is used to get the original timestamp if you use the binary log to restore rows. *`timestamp_value`* should be a Unix epoch timestamp (a value like that returned by `UNIX_TIMESTAMP()`, not a value in `'YYYY-MM-DD hh:mm:ss'` format) or `DEFAULT`.

Setting `timestamp` to a constant value causes it to retain that value until it is changed again. Setting `timestamp` to `DEFAULT` causes its value to be the current date and time as of the time it is accessed.

`SET timestamp` affects the value returned by `NOW()` but not by `SYSDATE()`. This means that timestamp settings in the binary log have no effect on invocations of `SYSDATE()`. The server can be started with the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`, in which case `SET timestamp` affects both functions.

* `tmp_table_size`

Command-Line Format	`--tmp_table_size=#`	
System Variable	Name	`tmp_table_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (<= 5.1.11)	Type	`integer`
	Default	`33554432`
	Min Value	`1024`
	Max Value	`4294967295`
Permitted Values (>= 5.1.12, <= 5.1.36)	Type	`integer`
	Default	`16777216`
	Min Value	`1024`

		Max Value	4294967295
Permitted Values (>= 5.1.37, <= 5.1.55)	**Type**		`integer`
	Default		`16777216`
	Min Value		`1024`
	Max Value		`9223372036854775807`
Permitted Values (>= 5.1.56)	**Type**		`integer`
	Default		`16777216`
	Min Value		`1024`
	Max Value		`18446744073709551615`

The maximum size of internal in-memory temporary tables. This variable does not apply to user-created `MEMORY` tables.

The actual limit is determined as the minimum of `tmp_table_size` and `max_heap_table_size`. If an in-memory temporary table exceeds the limit, MySQL automatically converts it to an on-disk `MyISAM` table. Increase the value of `tmp_table_size` (and `max_heap_table_size` if necessary) if you do many advanced `GROUP BY` queries and you have lots of memory.

You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

See also Section 8.4.4, "Internal Temporary Table Use in MySQL".

- `tmpdir`

Command-Line Format	`--tmpdir=dir_name`	
System Variable	**Name**	`tmpdir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`

The directory used for temporary files and temporary tables. This variable can be set to a list of several paths that are used in round-robin fashion. Paths should be separated by colon characters ("`:`") on Unix and semicolon characters ("`;`") on Windows, NetWare, and OS/2.

The multiple-directory feature can be used to spread the load between several physical disks. If the MySQL server is acting as a replication slave, you should not set `tmpdir` to point to a directory on a memory-based file system or to a directory that is cleared when the server host restarts. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA INFILE` operations. If files in the temporary file directory are lost when the server restarts, replication fails. You can set the slave's temporary directory using the `slave_load_tmpdir`

variable. In that case, the slave will not use the general `tmpdir` value and you can set `tmpdir` to a nonpermanent location.

- `transaction_alloc_block_size`

Command-Line Format	`--transaction_alloc_block_size=#`	
System Variable	**Name**	`transaction_alloc_block_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`8192`
	Min Value	`1024`
	Max Value	`4294967295`
	Block Size	`1024`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`8192`
	Min Value	`1024`
	Max Value	`18446744073709547520`
	Block Size	`1024`

The amount in bytes by which to increase a per-transaction memory pool which needs memory. See the description of `transaction_prealloc_size`.

- `transaction_prealloc_size`

Command-Line Format	`--transaction_prealloc_size=#`	
System Variable	**Name**	`transaction_prealloc_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`4096`
	Min Value	`1024`
	Max Value	`4294967295`

	Block Size	1024
Permitted Values (64-bit platforms)	**Type**	integer
	Default	4096
	Min Value	1024
	Max Value	18446744073709547520
	Block Size	1024

There is a per-transaction memory pool from which various transaction-related allocations take memory. The initial size of the pool in bytes is `transaction_prealloc_size`. For every allocation that cannot be satisfied from the pool because it has insufficient memory available, the pool is increased by `transaction_alloc_block_size` bytes. When the transaction ends, the pool is truncated to `transaction_prealloc_size` bytes.

By making `transaction_prealloc_size` sufficiently large to contain all statements within a single transaction, you can avoid many `malloc()` calls.

- `tx_isolation`

System Variable	**Name**	tx_isolation
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	enumeration
	Default	REPEATABLE-READ
	Valid Values	READ-UNCOMMITTED
		READ-COMMITTED
		REPEATABLE-READ
		SERIALIZABLE

The default transaction isolation level. Defaults to REPEATABLE-READ.

This variable can be set directly, or indirectly using the SET TRANSACTION statement. See Section 13.3.6, "SET TRANSACTION Syntax". If you set `tx_isolation` directly to an isolation level name that contains a space, the name should be enclosed within quotation marks, with the space replaced by a dash. For example:

```
SET tx_isolation = 'READ-COMMITTED';
```

Any unique prefix of a valid value may be used to set the value of this variable.

The default transaction isolation level can also be set at startup using the --transaction-isolation server option.

- `unique_checks`

System Variable	Name	`unique_checks`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`1`

If set to 1 (the default), uniqueness checks for secondary indexes in `InnoDB` tables are performed. If set to 0, storage engines are permitted to assume that duplicate keys are not present in input data. If you know for certain that your data does not contain uniqueness violations, you can set this to 0 to speed up large table imports to `InnoDB`.

Setting this variable to 0 does not *require* storage engines to ignore duplicate keys. An engine is still permitted to check for them and issue duplicate-key errors if it detects them.

- `updatable_views_with_limit`

Command-Line Format	`--updatable_views_with_limit=#`	
System Variable	Name	`updatable_views_with_limit`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`1`

This variable controls whether updates to a view can be made when the view does not contain all columns of the primary key defined in the underlying table, if the update statement contains a `LIMIT` clause. (Such updates often are generated by GUI tools.) An update is an `UPDATE` or `DELETE` statement. Primary key here means a `PRIMARY KEY`, or a `UNIQUE` index in which no column can contain `NULL`.

The variable can have two values:

- `1` or `YES`: Issue a warning only (not an error message). This is the default value.

- `0` or `NO`: Prohibit the update.

- `version`

The version number for the server. The value might also include a suffix indicating server build or configuration information. `-log` indicates that one or more of the general log, slow query log, or binary log are enabled. `-debug` indicates that the server was built with debugging support enabled.

- `version_comment`

System Variable	Name	`version_comment`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	string

The `configure` script has a `--with-comment` option that permits a comment to be specified when building MySQL. This variable contains the value of that comment.

- `version_compile_machine`

System Variable	**Name**	version_compile_machine
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	string

The type of machine or architecture on which MySQL was built.

- `version_compile_os`

System Variable	**Name**	version_compile_os
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	string

The type of operating system on which MySQL was built.

- `wait_timeout`

Command-Line Format		--wait_timeout=#
System Variable	**Name**	wait_timeout
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (Windows)	**Type**	integer
	Default	28800
	Min Value	1
	Max Value	2147483
Permitted Values (Other)	**Type**	integer
	Default	28800
	Min Value	1

	Max Value	31536000

The number of seconds the server waits for activity on a noninteractive connection before closing it. Before MySQL 5.1.41, this timeout applies only to TCP/IP connections, not to connections made through Unix socket files, named pipes, or shared memory.

On thread startup, the session `wait_timeout` value is initialized from the global `wait_timeout` value or from the global `interactive_timeout` value, depending on the type of client (as defined by the `CLIENT_INTERACTIVE` connect option to `mysql_real_connect()`). See also `interactive_timeout`.

* `warning_count`

  The number of errors, warnings, and notes that resulted from the last statement that generated messages. This variable is read only. See Section 13.7.5.42, "SHOW WARNINGS Syntax".

5.1.5 Using System Variables

The MySQL server maintains many system variables that indicate how it is configured. Section 5.1.4, "Server System Variables", describes the meaning of these variables. Each system variable has a default value. System variables can be set at server startup using options on the command line or in an option file. Most of them can be changed dynamically while the server is running by means of the `SET` statement, which enables you to modify operation of the server without having to stop and restart it. You can also use system variable values in expressions.

There are two scopes in which system variables exist. Global variables affect the overall operation of the server. Session variables affect its operation for individual client connections. A given system variable can have both a global and a session value. Global and session system variables are related as follows:

* When the server starts, it initializes each global variable to its default value. These defaults can be changed by options specified on the command line or in an option file. (See Section 4.2.3, "Specifying Program Options".)

* The server also maintains a set of session variables for each client that connects. The client's session variables are initialized at connect time using the current values of the corresponding global variables. For example, a client's SQL mode is controlled by the session `sql_mode` value, which is initialized when the client connects to the value of the global `sql_mode` value.

  For some system variables, the session value is not initialized from the corresponding global value; if so, that is indicated in the variable description.

System variable values can be set globally at server startup by using options on the command line or in an option file. When you use a startup option to set a variable that takes a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3; that is, units of kilobytes, megabytes, or gigabytes, respectively. Thus, the following command starts the server with a query cache size of 16 megabytes and a maximum packet size of one gigabyte:

```
mysqld --query_cache_size=16M --max_allowed_packet=1G
```

Within an option file, those variables are set like this:

```
[mysqld]
query_cache_size=16M
max_allowed_packet=1G
```

The lettercase of suffix letters does not matter; `16M` and `16m` are equivalent, as are `1G` and `1g`.

To restrict the maximum value to which a system variable can be set at runtime with the `SET` statement, specify this maximum by using an option of the form `--maximum-var_name=value` at server startup. For example, to prevent the value of `query_cache_size` from being increased to more than 32MB at runtime, use the option `--maximum-query_cache_size=32M`.

Many system variables are dynamic and can be changed at runtime by using the `SET` statement. For a list, see Section 5.1.5.2, "Dynamic System Variables". To change a system variable with `SET`, refer to it by name, optionally preceded by a modifier:

- To indicate that a variable is a global variable, precede its name by the `GLOBAL` keyword or the `@@global.` qualifier:

```
SET GLOBAL max_connections = 1000;
SET @@global.max_connections = 1000;
```

  The `SUPER` privilege is required to set global variables.

- To indicate that a variable is a session variable, precede its name by the `SESSION` keyword or either the `@@session.` or `@@` qualifier:

```
SET SESSION sql_mode = 'TRADITIONAL';
SET @@session.sql_mode = 'TRADITIONAL';
SET @@sql_mode = 'TRADITIONAL';
```

  Setting a session variable normally requires no special privilege, although there are exceptions that require the `SUPER` privilege (such as `sql_log_bin`). A client can change its own session variables, but not those of any other client.

- `LOCAL` and `@@local.` are synonyms for `SESSION` and `@@session.`.

- If no modifier is present, `SET` changes the session variable. If the variable has no session value, an error occurs.

```
mysql> SET max_connections = 1000;
ERROR 1229 (HY000): Variable 'max_connections' is a
GLOBAL variable and should be set with SET GLOBAL
```

- An error occurs if you:

  - Use `SET GLOBAL` (or `@@global.`) when setting a variable that has only a session value

  - Omit `GLOBAL` (or `@@global.`) or `PERSIST` (or `@@persist.`) when setting a variable that has only a global value

  - Use `SET SESSION` (or `@@SESSION.`) when setting a variable that has only a global value

The preceding modifiers apply only to system variables. It is not permitted to apply them to user-defined variables, stored procedure or function parameters, or stored program local variables. An error occurs for such attempts.

A `SET` statement can contain multiple variable assignments, separated by commas. This statement assigns values to a user-defined variable and a system variable:

```
SET @x = 1, SESSION sql_mode = '';
```

If you set multiple system variables, the most recent GLOBAL or SESSION modifier in the statement is used for following assignments that have no modifier specified.

Examples of multiple-variable assignment:

```
SET GLOBAL sort_buffer_size = 1000000, SESSION sort_buffer_size = 1000000;
SET @@global.sort_buffer_size = 1000000, @@local.sort_buffer_size = 1000000;
SET GLOBAL max_connections = 1000, sort_buffer_size = 1000000;
```

If any variable assignment in a SET statement fails, the entire statement fails and no variables are changed.

If you change a session system variable, the value remains in effect within your session until you change the variable to a different value or the session ends. The change has no effect on other sessions.

If you change a global system variable, the value is remembered and used for new connections until you change the variable to a different value or the server restarts. The change is visible to any client that accesses the global variable. However, the change affects the corresponding session variable only for clients that connect after the change. The global variable change does not affect the session variable for any client that is currently connected (not even the session within which the SET GLOBAL statement occurred).

To make a global system variable setting permanent so that it applies across server restarts, you should also set it in an option file.

To set a GLOBAL value to the compiled-in MySQL default value or a SESSION variable to the current corresponding GLOBAL value, set the variable to the value DEFAULT. For example, the following two statements are identical in setting the session value of max_join_size to the current global value:

```
SET @@session.max_join_size=DEFAULT;
SET @@session.max_join_size=@@global.max_join_size;
```

Not all system variables can be set to DEFAULT. In such cases, assigning DEFAULT results in an error.

It is not permitted to assign DEFAULT to user-defined variables, and not supported for stored procedure or function parameters or stored program local variables. This results in an error for user-defined variables, and the results are undefined for parameters or local variables.

To refer to the value of a system variable in expressions, use one of the @@-modifiers. For example, you can retrieve values in a SELECT statement like this:

```
SELECT @@global.sql_mode, @@session.sql_mode, @@sql_mode;
```

When you refer to a system variable in an expression as @@var_name (that is, when you do not specify @@global. or @@session.), MySQL returns the session value if it exists and the global value otherwise. This differs from SET @@var_name = value, which always refers to the session value.

Suffixes for specifying a value multiplier can be used when setting a variable at server startup, but not to set the value with SET at runtime. On the other hand, with SET you can assign a variable's value using an expression, which is not true when you set a variable at server startup. For example, the first of the following lines is legal at server startup, but the second is not:

```
shell> mysql --max_allowed_packet=16M
shell> mysql --max_allowed_packet=16*1024*1024
```

Conversely, the second of the following lines is legal at runtime, but the first is not:

```
mysql> SET GLOBAL max_allowed_packet=16M;
mysql> SET GLOBAL max_allowed_packet=16*1024*1024;
```

> **Note**
>
> Some system variables can be enabled with the SET statement by setting them to
> ON or 1, or disabled by setting them to OFF or 0. However, to set such a variable
> on the command line or in an option file, you must set it to 1 or 0; setting it to ON or
> OFF will not work. For example, on the command line, --delay_key_write=1
> works but --delay_key_write=ON does not.

To display system variable names and values, use the SHOW VARIABLES statement:

```
mysql> SHOW VARIABLES;
+--------------------------------+----------------------------------+
| Variable_name                  | Value                            |
+--------------------------------+----------------------------------+
| auto_increment_increment       | 1                                |
| auto_increment_offset          | 1                                |
| automatic_sp_privileges        | ON                               |
| back_log                       | 50                               |
| basedir                        | /home/mysql/                     |
| binlog_cache_size              | 32768                            |
| bulk_insert_buffer_size        | 8388608                          |
| character_set_client           | latin1                           |
| character_set_connection       | latin1                           |
| character_set_database         | latin1                           |
| character_set_results          | latin1                           |
| character_set_server           | latin1                           |
| character_set_system           | utf8                             |
| character_sets_dir             | /home/mysql/share/mysql/charsets/ |
| collation_connection           | latin1_swedish_ci                |
| collation_database             | latin1_swedish_ci                |
| collation_server               | latin1_swedish_ci                |
...
| innodb_additional_mem_pool_size | 1048576                         |
| innodb_autoextend_increment    | 8                                |
| innodb_buffer_pool_size        | 8388608                          |
| innodb_checksums               | ON                               |
| innodb_commit_concurrency      | 0                                |
| innodb_concurrency_tickets     | 500                              |
| innodb_data_file_path          | ibdata1:10M:autoextend           |
| innodb_data_home_dir           |                                  |
...
| version                        | 5.1.6-alpha-log                  |
| version_comment                | Source distribution              |
| version_compile_machine        | i686                             |
| version_compile_os             | suse-linux                       |
| wait_timeout                   | 28800                            |
+--------------------------------+----------------------------------+
```

With a LIKE clause, the statement displays only those variables that match the pattern. To obtain a
specific variable name, use a LIKE clause as shown:

```
SHOW VARIABLES LIKE 'max_join_size';
SHOW SESSION VARIABLES LIKE 'max_join_size';
```

To get a list of variables whose name match a pattern, use the "%" wildcard character in a LIKE clause:

```
SHOW VARIABLES LIKE '%size%';
SHOW GLOBAL VARIABLES LIKE '%size%';
```

Wildcard characters can be used in any position within the pattern to be matched. Strictly speaking, because "_" is a wildcard that matches any single character, you should escape it as "_" to match it literally. In practice, this is rarely necessary.

For `SHOW VARIABLES`, if you specify neither `GLOBAL` nor `SESSION`, MySQL returns `SESSION` values.

The reason for requiring the `GLOBAL` keyword when setting `GLOBAL`-only variables but not when retrieving them is to prevent problems in the future. If we were to remove a `SESSION` variable that has the same name as a `GLOBAL` variable, a client with the `SUPER` privilege might accidentally change the `GLOBAL` variable rather than just the `SESSION` variable for its own connection. If we add a `SESSION` variable with the same name as a `GLOBAL` variable, a client that intends to change the `GLOBAL` variable might find only its own `SESSION` variable changed.

5.1.5.1 Structured System Variables

A structured variable differs from a regular system variable in two respects:

- Its value is a structure with components that specify server parameters considered to be closely related.

- There might be several instances of a given type of structured variable. Each one has a different name and refers to a different resource maintained by the server.

MySQL supports one structured variable type, which specifies parameters governing the operation of key caches. A key cache structured variable has these components:

- `key_buffer_size`

- `key_cache_block_size`

- `key_cache_division_limit`

- `key_cache_age_threshold`

This section describes the syntax for referring to structured variables. Key cache variables are used for syntax examples, but specific details about how key caches operate are found elsewhere, in Section 8.10.1, "The MyISAM Key Cache".

To refer to a component of a structured variable instance, you can use a compound name in `instance_name.component_name` format. Examples:

```
hot_cache.key_buffer_size
hot_cache.key_cache_block_size
cold_cache.key_cache_block_size
```

For each structured system variable, an instance with the name of `default` is always predefined. If you refer to a component of a structured variable without any instance name, the `default` instance is used. Thus, `default.key_buffer_size` and `key_buffer_size` both refer to the same system variable.

Structured variable instances and components follow these naming rules:

- For a given type of structured variable, each instance must have a name that is unique *within* variables of that type. However, instance names need not be unique *across* structured variable types. For example, each structured variable has an instance named `default`, so `default` is not unique across variable types.

- The names of the components of each structured variable type must be unique across all system variable names. If this were not true (that is, if two different types of structured variables could share component member names), it would not be clear which default structured variable to use for references to member names that are not qualified by an instance name.

- If a structured variable instance name is not legal as an unquoted identifier, refer to it as a quoted identifier using backticks. For example, `hot-cache` is not legal, but `` `hot-cache` `` is.

- `global`, `session`, and `local` are not legal instance names. This avoids a conflict with notation such as `@@global.var_name` for referring to nonstructured system variables.

Currently, the first two rules have no possibility of being violated because the only structured variable type is the one for key caches. These rules will assume greater significance if some other type of structured variable is created in the future.

With one exception, you can refer to structured variable components using compound names in any context where simple variable names can occur. For example, you can assign a value to a structured variable using a command-line option:

```
shell> mysqld --hot_cache.key_buffer_size=64K
```

In an option file, use this syntax:

```
[mysqld]
hot_cache.key_buffer_size=64K
```

If you start the server with this option, it creates a key cache named `hot_cache` with a size of 64KB in addition to the default key cache that has a default size of 8MB.

Suppose that you start the server as follows:

```
shell> mysqld --key_buffer_size=256K \
         --extra_cache.key_buffer_size=128K \
         --extra_cache.key_cache_block_size=2048
```

In this case, the server sets the size of the default key cache to 256KB. (You could also have written `--default.key_buffer_size=256K`.) In addition, the server creates a second key cache named `extra_cache` that has a size of 128KB, with the size of block buffers for caching table index blocks set to 2048 bytes.

The following example starts the server with three different key caches having sizes in a 3:1:1 ratio:

```
shell> mysqld --key_buffer_size=6M \
         --hot_cache.key_buffer_size=2M \
         --cold_cache.key_buffer_size=2M
```

Structured variable values may be set and retrieved at runtime as well. For example, to set a key cache named `hot_cache` to a size of 10MB, use either of these statements:

```
mysql> SET GLOBAL hot_cache.key_buffer_size = 10*1024*1024;
mysql> SET @@global.hot_cache.key_buffer_size = 10*1024*1024;
```

To retrieve the cache size, do this:

```
mysql> SELECT @@global.hot_cache.key_buffer_size;
```

However, the following statement does not work. The variable is not interpreted as a compound name, but as a simple string for a `LIKE` pattern-matching operation:

```
mysql> SHOW GLOBAL VARIABLES LIKE 'hot_cache.key_buffer_size';
```

This is the exception to being able to use structured variable names anywhere a simple variable name may occur.

5.1.5.2 Dynamic System Variables

Many server system variables are dynamic and can be set at runtime using `SET GLOBAL` or `SET SESSION`. You can also obtain their values using `SELECT`. See Section 5.1.5, "Using System Variables".

The following table shows the full list of all dynamic system variables. The last column indicates for each variable whether `GLOBAL` or `SESSION` (or both) apply. The table also lists session options that can be set with the `SET` statement. Section 5.1.4, "Server System Variables", discusses these options.

Variables that have a type of "string" take a string value. Variables that have a type of "numeric" take a numeric value. Variables that have a type of "boolean" can be set to 0, 1, `ON` or `OFF`. (If you set them on the command line or in an option file, use the numeric values.) Variables that are marked as "enumeration" normally should be set to one of the available values for the variable, but can also be set to the number that corresponds to the desired enumeration value. For enumerated system variables, the first enumeration value corresponds to 0. This differs from `ENUM` columns, for which the first enumeration value corresponds to 1.

Table 5.3 Dynamic Variable Summary

Variable Name	Variable Type	Variable Scope
auto_increment_increment	integer	GLOBAL | SESSION
auto_increment_offset	integer	GLOBAL | SESSION
autocommit	boolean	SESSION
automatic_sp_privileges	boolean	GLOBAL
big_tables	boolean	SESSION
binlog_cache_size	integer	GLOBAL
binlog_direct_non_transactional_updates	boolean	GLOBAL | SESSION
binlog_format	enumeration	GLOBAL | SESSION
bulk_insert_buffer_size	integer	GLOBAL | SESSION
character_set_client	string	GLOBAL | SESSION
character_set_connection	string	GLOBAL | SESSION
character_set_database	string	GLOBAL | SESSION
character_set_filesystem	string	GLOBAL | SESSION
character_set_results	string	GLOBAL | SESSION
character_set_server	string	GLOBAL | SESSION
collation_connection	string	GLOBAL | SESSION
collation_database	string	GLOBAL | SESSION
collation_server	string	GLOBAL | SESSION
completion_type	integer	GLOBAL | SESSION
concurrent_insert	integer	GLOBAL
connect_timeout	integer	GLOBAL
debug	string	GLOBAL | SESSION
debug_sync	string	GLOBAL | SESSION
storage_engine	enumeration	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
default_week_format	integer	GLOBAL | SESSION
delay_key_write	enumeration	GLOBAL
delayed_insert_limit	integer	GLOBAL
delayed_insert_timeout	integer	GLOBAL
delayed_queue_size	integer	GLOBAL
div_precision_increment	integer	GLOBAL | SESSION
engine_condition_pushdown	boolean	GLOBAL | SESSION
event_scheduler	enumeration	GLOBAL
expire_logs_days	integer	GLOBAL
flush	boolean	GLOBAL
flush_time	integer	GLOBAL
foreign_key_checks	boolean	SESSION
ft_boolean_syntax	string	GLOBAL
general_log	boolean	GLOBAL
general_log_file	filename	GLOBAL
group_concat_max_len	integer	GLOBAL | SESSION
identity	integer	SESSION
init_connect	string	GLOBAL
init_slave	string	GLOBAL
innodb_adaptive_flushing	boolean	GLOBAL
innodb_autoextend_increment	integer	GLOBAL
innodb_change_buffering	enumeration	GLOBAL
innodb_change_buffering_debug	integer	GLOBAL
innodb_commit_concurrency	integer	GLOBAL
innodb_concurrency_tickets	integer	GLOBAL
innodb_fast_shutdown	integer	GLOBAL
innodb_file_format	string	GLOBAL
innodb_file_format_check	string	GLOBAL
innodb_flush_log_at_trx_commit	enumeration	GLOBAL
innodb_limit_optimistic_insert_debug	integer	GLOBAL
innodb_max_dirty_pages_pct	numeric	GLOBAL
innodb_max_purge_lag	integer	GLOBAL
innodb_old_blocks_pct	integer	GLOBAL
innodb_old_blocks_time	integer	GLOBAL
innodb_random_read_ahead	boolean	GLOBAL
innodb_read_ahead_threshold	integer	GLOBAL
innodb_replication_delay	integer	GLOBAL
innodb_spin_wait_delay	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
innodb_stats_method	enumeration	GLOBAL
innodb_stats_on_metadata	boolean	GLOBAL
innodb_stats_sample_pages	integer	GLOBAL
innodb_strict_mode	boolean	GLOBAL | SESSION
innodb_support_xa	boolean	GLOBAL | SESSION
innodb_sync_spin_loops	integer	GLOBAL
innodb_table_locks	boolean	GLOBAL | SESSION
innodb_thread_concurrency	integer	GLOBAL
innodb_thread_sleep_delay	integer	GLOBAL
innodb_trx_purge_view_update_only_debug	boolean	GLOBAL
innodb_trx_rseg_n_slots_debug	integer	GLOBAL
innodb_use_legacy_cardinality_algorithm	boolean	GLOBAL
insert_id	integer	SESSION
interactive_timeout	integer	GLOBAL | SESSION
join_buffer_size	integer	GLOBAL | SESSION
keep_files_on_create	boolean	GLOBAL | SESSION
key_buffer_size	integer	GLOBAL
key_cache_age_threshold	integer	GLOBAL
key_cache_block_size	integer	GLOBAL
key_cache_division_limit	integer	GLOBAL
last_insert_id	integer	SESSION
lc_time_names	string	GLOBAL | SESSION
local_infile	boolean	GLOBAL
log	filename	GLOBAL
log_bin_trust_function_creators	boolean	GLOBAL
log_bin_trust_routine_creators	boolean	GLOBAL
log_output	set	GLOBAL
log_queries_not_using_indexes	boolean	GLOBAL
log_slow_queries	boolean	GLOBAL
log_warnings	integer	GLOBAL | SESSION
long_query_time	numeric	GLOBAL | SESSION
low_priority_updates	boolean	GLOBAL | SESSION
max_allowed_packet	integer	GLOBAL | SESSION
max_binlog_cache_size	integer	GLOBAL
max_binlog_size	integer	GLOBAL
max_connect_errors	integer	GLOBAL
max_connections	integer	GLOBAL
max_delayed_threads	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
max_error_count	integer	GLOBAL | SESSION
max_heap_table_size	integer	GLOBAL | SESSION
max_insert_delayed_threads	integer	GLOBAL | SESSION
max_join_size	integer	GLOBAL | SESSION
max_length_for_sort_data	integer	GLOBAL | SESSION
max_prepared_stmt_count	integer	GLOBAL
max_relay_log_size	integer	GLOBAL
max_seeks_for_key	integer	GLOBAL | SESSION
max_sort_length	integer	GLOBAL | SESSION
max_sp_recursion_depth	integer	GLOBAL | SESSION
max_tmp_tables	integer	GLOBAL | SESSION
max_user_connections	integer	GLOBAL | SESSION
max_write_lock_count	integer	GLOBAL
min_examined_row_limit	integer	GLOBAL | SESSION
multi_range_count	integer	GLOBAL | SESSION
myisam_data_pointer_size	integer	GLOBAL
myisam_max_sort_file_size	integer	GLOBAL
myisam_repair_threads	integer	GLOBAL | SESSION
myisam_sort_buffer_size	integer	GLOBAL | SESSION
myisam_stats_method	enumeration	GLOBAL | SESSION
myisam_use_mmap	boolean	GLOBAL
ndb_autoincrement_prefetch_sz	integer	GLOBAL | SESSION
ndb_blob_read_batch_bytes	integer	GLOBAL | SESSION
ndb_blob_write_batch_bytes	integer	GLOBAL | SESSION
ndb_cache_check_time	integer	GLOBAL
ndb_deferred_constraints	integer	GLOBAL | SESSION
ndb_deferred_constraints	integer	GLOBAL | SESSION
ndb_distribution	enumeration	GLOBAL
ndb_distribution={KEYHASH|LINHASH}	enumeration	GLOBAL
ndb_eventbuffer_max_alloc	integer	GLOBAL
ndb_extra_logging	integer	GLOBAL
ndb_force_send	boolean	GLOBAL | SESSION
ndb_index_stat_cache_entries	integer	GLOBAL | SESSION
ndb_index_stat_enable	boolean	GLOBAL | SESSION
ndb_index_stat_option	string	GLOBAL | SESSION
ndb_index_stat_update_freq	integer	GLOBAL | SESSION
ndb_join_pushdown	boolean	GLOBAL | SESSION
ndb_log_bin	boolean	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
ndb_log_binlog_index	boolean	GLOBAL
ndb_log_empty_epochs	boolean	GLOBAL
ndb_log_empty_epochs	boolean	GLOBAL
ndb_log_update_as_write	boolean	GLOBAL
ndb_log_updated_only	boolean	GLOBAL
ndb_optimization_delay	integer	GLOBAL
ndb_report_thresh_binlog_epoch_slip	integer	GLOBAL
ndb_report_thresh_binlog_mem_usage	integer	GLOBAL
ndb_table_no_logging	boolean	SESSION
ndb_table_temporary	boolean	SESSION
ndb_use_exact_count	boolean	GLOBAL | SESSION
ndb_use_transactions	boolean	GLOBAL | SESSION
ndbinfo_max_bytes	integer	GLOBAL | SESSION
ndbinfo_max_rows	integer	GLOBAL | SESSION
ndbinfo_offline	boolean	GLOBAL
ndbinfo_show_hidden	boolean	GLOBAL | SESSION
ndbinfo_table_prefix	string	GLOBAL | SESSION
net_buffer_length	integer	GLOBAL | SESSION
net_read_timeout	integer	GLOBAL | SESSION
net_retry_count	integer	GLOBAL | SESSION
net_write_timeout	integer	GLOBAL | SESSION
new	boolean	GLOBAL | SESSION
old_alter_table	boolean	GLOBAL | SESSION
old_passwords	boolean	GLOBAL | SESSION
optimizer_prune_level	boolean	GLOBAL | SESSION
optimizer_search_depth	integer	GLOBAL | SESSION
optimizer_switch	set	GLOBAL | SESSION
preload_buffer_size	integer	GLOBAL | SESSION
profiling	boolean	SESSION
profiling_history_size	integer	GLOBAL | SESSION
pseudo_thread_id	integer	SESSION
query_alloc_block_size	integer	GLOBAL | SESSION
query_cache_limit	integer	GLOBAL
query_cache_min_res_unit	integer	GLOBAL
query_cache_size	integer	GLOBAL
query_cache_type	enumeration	GLOBAL | SESSION
query_cache_wlock_invalidate	boolean	GLOBAL | SESSION
query_prealloc_size	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
rand_seed1	integer	SESSION
rand_seed2	integer	SESSION
range_alloc_block_size	integer	GLOBAL | SESSION
read_buffer_size	integer	GLOBAL | SESSION
read_only	boolean	GLOBAL
read_rnd_buffer_size	integer	GLOBAL | SESSION
relay_log_purge	boolean	GLOBAL
rpl_recovery_rank	integer	GLOBAL
secure_auth	boolean	GLOBAL
server_id	integer	GLOBAL
slave_allow_batching	boolean	GLOBAL
slave_compressed_protocol	boolean	GLOBAL
slave_exec_mode	enumeration	GLOBAL
slave_max_allowed_packet	integer	GLOBAL
slave_net_timeout	integer	GLOBAL
slave_transaction_retries	integer	GLOBAL
slow_launch_time	integer	GLOBAL
slow_query_log	boolean	GLOBAL
slow_query_log_file	filename	GLOBAL
sort_buffer_size	integer	GLOBAL | SESSION
sql_auto_is_null	boolean	SESSION
sql_big_selects	boolean	SESSION
sql_big_tables	boolean	SESSION
sql_buffer_result	boolean	SESSION
sql_log_bin	boolean	SESSION
sql_log_off	boolean	SESSION
sql_log_update	boolean	SESSION
sql_low_priority_updates	boolean	GLOBAL | SESSION
sql_max_join_size	integer	GLOBAL | SESSION
sql_mode	set	GLOBAL | SESSION
sql_notes	boolean	SESSION
sql_quote_show_create	boolean	SESSION
sql_safe_updates	boolean	SESSION
sql_select_limit	integer	GLOBAL | SESSION
sql_slave_skip_counter	integer	GLOBAL
sql_warnings	boolean	SESSION
storage_engine	enumeration	GLOBAL | SESSION
sync_binlog	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
sync_frm	boolean	GLOBAL
table_cache	integer	GLOBAL
table_definition_cache	integer	GLOBAL
table_lock_wait_timeout	integer	GLOBAL
table_open_cache	integer	GLOBAL
table_type	enumeration	GLOBAL | SESSION
thread_cache_size	integer	GLOBAL
time_zone	string	GLOBAL | SESSION
timed_mutexes	boolean	GLOBAL
timestamp	numeric	SESSION
tmp_table_size	integer	GLOBAL | SESSION
transaction_alloc_block_size	integer	GLOBAL | SESSION
transaction_allow_batching	boolean	SESSION
transaction_prealloc_size	integer	GLOBAL | SESSION
tx_isolation	enumeration	GLOBAL | SESSION
unique_checks	boolean	SESSION
updatable_views_with_limit	boolean	GLOBAL | SESSION
wait_timeout	integer	GLOBAL | SESSION

5.1.6 Server Status Variables

The MySQL server maintains many status variables that provide information about its operation. You can view these variables and their values by using the SHOW [GLOBAL | SESSION] STATUS statement (see Section 13.7.5.37, "SHOW STATUS Syntax"). The optional GLOBAL keyword aggregates the values over all connections, and SESSION shows the values for the current connection.

```
mysql> SHOW GLOBAL STATUS;
+----------------------------------+------------+
| Variable_name                    | Value      |
+----------------------------------+------------+
| Aborted_clients                  | 0          |
| Aborted_connects                 | 0          |
| Bytes_received                   | 155372598  |
| Bytes_sent                       | 1176560426 |
...
| Connections                      | 30023      |
| Created_tmp_disk_tables          | 0          |
| Created_tmp_files                | 3          |
| Created_tmp_tables               | 2          |
...
| Threads_created                  | 217        |
| Threads_running                  | 88         |
| Uptime                           | 1389872    |
+----------------------------------+------------+
```

Several status variables provide statement counts. To determine the number of statements executed, use these relationships:

```
   SUM(Com_xxx) + Qcache_hits
= Questions + statements executed within stored programs
= Queries
```

Many status variables are reset to 0 by the FLUSH STATUS statement.

The following table lists all available server status variables:

Table 5.4 Status Variable Summary

Variable Name	Variable Type	Variable Scope
Aborted_clients	integer	GLOBAL
Aborted_connects	integer	GLOBAL
Binlog_cache_disk_use	integer	GLOBAL
Binlog_cache_use	integer	GLOBAL
Bytes_received	integer	GLOBAL | SESSION
Bytes_sent	integer	GLOBAL | SESSION
Com_admin_commands	integer	GLOBAL | SESSION
Com_alter_db	integer	GLOBAL | SESSION
Com_alter_db_upgrade	integer	GLOBAL | SESSION
Com_alter_event	integer	GLOBAL | SESSION
Com_alter_function	integer	GLOBAL | SESSION
Com_alter_procedure	integer	GLOBAL | SESSION
Com_alter_server	integer	GLOBAL | SESSION
Com_alter_table	integer	GLOBAL | SESSION
Com_alter_tablespace	integer	GLOBAL | SESSION
Com_analyze	integer	GLOBAL | SESSION
Com_assign_to_keycache	integer	GLOBAL | SESSION
Com_backup_table	integer	GLOBAL | SESSION
Com_begin	integer	GLOBAL | SESSION
Com_binlog	integer	GLOBAL | SESSION
Com_call_procedure	integer	GLOBAL | SESSION
Com_change_db	integer	GLOBAL | SESSION
Com_change_master	integer	GLOBAL | SESSION
Com_check	integer	GLOBAL | SESSION
Com_checksum	integer	GLOBAL | SESSION
Com_commit	integer	GLOBAL | SESSION
Com_create_db	integer	GLOBAL | SESSION
Com_create_event	integer	GLOBAL | SESSION
Com_create_function	integer	GLOBAL | SESSION
Com_create_index	integer	GLOBAL | SESSION
Com_create_procedure	integer	GLOBAL | SESSION
Com_create_server	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
Com_create_table	integer	GLOBAL | SESSION
Com_create_trigger	integer	GLOBAL | SESSION
Com_create_udf	integer	GLOBAL | SESSION
Com_create_user	integer	GLOBAL | SESSION
Com_create_view	integer	GLOBAL | SESSION
Com_dealloc_sql	integer	GLOBAL | SESSION
Com_delete	integer	GLOBAL | SESSION
Com_delete_multi	integer	GLOBAL | SESSION
Com_do	integer	GLOBAL | SESSION
Com_drop_db	integer	GLOBAL | SESSION
Com_drop_event	integer	GLOBAL | SESSION
Com_drop_function	integer	GLOBAL | SESSION
Com_drop_index	integer	GLOBAL | SESSION
Com_drop_procedure	integer	GLOBAL | SESSION
Com_drop_server	integer	GLOBAL | SESSION
Com_drop_table	integer	GLOBAL | SESSION
Com_drop_trigger	integer	GLOBAL | SESSION
Com_drop_user	integer	GLOBAL | SESSION
Com_drop_view	integer	GLOBAL | SESSION
Com_empty_query	integer	GLOBAL | SESSION
Com_execute_sql	integer	GLOBAL | SESSION
Com_flush	integer	GLOBAL | SESSION
Com_grant	integer	GLOBAL | SESSION
Com_ha_close	integer	GLOBAL | SESSION
Com_ha_open	integer	GLOBAL | SESSION
Com_ha_read	integer	GLOBAL | SESSION
Com_help	integer	GLOBAL | SESSION
Com_insert	integer	GLOBAL | SESSION
Com_insert_select	integer	GLOBAL | SESSION
Com_install_plugin	integer	GLOBAL | SESSION
Com_kill	integer	GLOBAL | SESSION
Com_load	integer	GLOBAL | SESSION
Com_lock_tables	integer	GLOBAL | SESSION
Com_optimize	integer	GLOBAL | SESSION
Com_preload_keys	integer	GLOBAL | SESSION
Com_prepare_sql	integer	GLOBAL | SESSION
Com_purge	integer	GLOBAL | SESSION
Com_purge_before_date	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
Com_release_savepoint	integer	GLOBAL | SESSION
Com_rename_table	integer	GLOBAL | SESSION
Com_rename_user	integer	GLOBAL | SESSION
Com_repair	integer	GLOBAL | SESSION
Com_replace	integer	GLOBAL | SESSION
Com_replace_select	integer	GLOBAL | SESSION
Com_reset	integer	GLOBAL | SESSION
Com_restore_table	integer	GLOBAL | SESSION
Com_revoke	integer	GLOBAL | SESSION
Com_revoke_all	integer	GLOBAL | SESSION
Com_rollback	integer	GLOBAL | SESSION
Com_rollback_to_savepoint	integer	GLOBAL | SESSION
Com_savepoint	integer	GLOBAL | SESSION
Com_select	integer	GLOBAL | SESSION
Com_set_option	integer	GLOBAL | SESSION
Com_show_authors	integer	GLOBAL | SESSION
Com_show_binlog_events	integer	GLOBAL | SESSION
Com_show_binlogs	integer	GLOBAL | SESSION
Com_show_charsets	integer	GLOBAL | SESSION
Com_show_collations	integer	GLOBAL | SESSION
Com_show_column_types	integer	GLOBAL | SESSION
Com_show_contributors	integer	GLOBAL | SESSION
Com_show_create_db	integer	GLOBAL | SESSION
Com_show_create_event	integer	GLOBAL | SESSION
Com_show_create_func	integer	GLOBAL | SESSION
Com_show_create_proc	integer	GLOBAL | SESSION
Com_show_create_table	integer	GLOBAL | SESSION
Com_show_create_trigger	integer	GLOBAL | SESSION
Com_show_databases	integer	GLOBAL | SESSION
Com_show_engine_logs	integer	GLOBAL | SESSION
Com_show_engine_mutex	integer	GLOBAL | SESSION
Com_show_engine_status	integer	GLOBAL | SESSION
Com_show_errors	integer	GLOBAL | SESSION
Com_show_events	integer	GLOBAL | SESSION
Com_show_fields	integer	GLOBAL | SESSION
Com_show_function_code	integer	GLOBAL | SESSION
Com_show_function_status	integer	GLOBAL | SESSION
Com_show_grants	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
`Com_show_keys`	integer	GLOBAL | SESSION
`Com_show_logs`	integer	GLOBAL | SESSION
`Com_show_master_status`	integer	GLOBAL | SESSION
`Com_show_ndb_status`	integer	GLOBAL | SESSION
`Com_show_new_master`	integer	GLOBAL | SESSION
`Com_show_open_tables`	integer	GLOBAL | SESSION
`Com_show_plugins`	integer	GLOBAL | SESSION
`Com_show_privileges`	integer	GLOBAL | SESSION
`Com_show_procedure_code`	integer	GLOBAL | SESSION
`Com_show_procedure_status`	integer	GLOBAL | SESSION
`Com_show_processlist`	integer	GLOBAL | SESSION
`Com_show_profile`	integer	GLOBAL | SESSION
`Com_show_profiles`	integer	GLOBAL | SESSION
`Com_show_slave_hosts`	integer	GLOBAL | SESSION
`Com_show_slave_status`	integer	GLOBAL | SESSION
`Com_show_status`	integer	GLOBAL | SESSION
`Com_show_storage_engines`	integer	GLOBAL | SESSION
`Com_show_table_status`	integer	GLOBAL | SESSION
`Com_show_tables`	integer	GLOBAL | SESSION
`Com_show_triggers`	integer	GLOBAL | SESSION
`Com_show_variables`	integer	GLOBAL | SESSION
`Com_show_warnings`	integer	GLOBAL | SESSION
`Com_slave_start`	integer	GLOBAL | SESSION
`Com_slave_stop`	integer	GLOBAL | SESSION
`Com_stmt_close`	integer	GLOBAL | SESSION
`Com_stmt_execute`	integer	GLOBAL | SESSION
`Com_stmt_fetch`	integer	GLOBAL | SESSION
`Com_stmt_prepare`	integer	GLOBAL | SESSION
`Com_stmt_reprepare`	integer	GLOBAL | SESSION
`Com_stmt_reset`	integer	GLOBAL | SESSION
`Com_stmt_send_long_data`	integer	GLOBAL | SESSION
`Com_truncate`	integer	GLOBAL | SESSION
`Com_uninstall_plugin`	integer	GLOBAL | SESSION
`Com_unlock_tables`	integer	GLOBAL | SESSION
`Com_update`	integer	GLOBAL | SESSION
`Com_update_multi`	integer	GLOBAL | SESSION
`Com_xa_commit`	integer	GLOBAL | SESSION
`Com_xa_end`	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
Com_xa_prepare	integer	GLOBAL | SESSION
Com_xa_recover	integer	GLOBAL | SESSION
Com_xa_rollback	integer	GLOBAL | SESSION
Com_xa_start	integer	GLOBAL | SESSION
Compression	integer	SESSION
Connections	integer	GLOBAL
Created_tmp_disk_tables	integer	GLOBAL | SESSION
Created_tmp_files	integer	GLOBAL
Created_tmp_tables	integer	GLOBAL | SESSION
Delayed_errors	integer	GLOBAL
Delayed_insert_threads	integer	GLOBAL
Delayed_writes	integer	GLOBAL
Flush_commands	integer	GLOBAL
Handler_commit	integer	GLOBAL | SESSION
Handler_delete	integer	GLOBAL | SESSION
Handler_discover	integer	GLOBAL | SESSION
Handler_prepare	integer	GLOBAL | SESSION
Handler_read_first	integer	GLOBAL | SESSION
Handler_read_key	integer	GLOBAL | SESSION
Handler_read_next	integer	GLOBAL | SESSION
Handler_read_prev	integer	GLOBAL | SESSION
Handler_read_rnd	integer	GLOBAL | SESSION
Handler_read_rnd_next	integer	GLOBAL | SESSION
Handler_rollback	integer	GLOBAL | SESSION
Handler_savepoint	integer	GLOBAL | SESSION
Handler_savepoint_rollback	integer	GLOBAL | SESSION
Handler_update	integer	GLOBAL | SESSION
Handler_write	integer	GLOBAL | SESSION
Innodb_buffer_pool_pages_data	integer	GLOBAL
Innodb_buffer_pool_pages_dirty	integer	GLOBAL
Innodb_buffer_pool_pages_flushed	integer	GLOBAL
Innodb_buffer_pool_pages_free	integer	GLOBAL
Innodb_buffer_pool_pages_latched	integer	GLOBAL
Innodb_buffer_pool_pages_misc	integer	GLOBAL
Innodb_buffer_pool_pages_total	integer	GLOBAL
Innodb_buffer_pool_read_ahead	integer	GLOBAL
Innodb_buffer_pool_read_ahead_evicted	integer	GLOBAL
Innodb_buffer_pool_read_ahead_rnd	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
`Innodb_buffer_pool_read_ahead_seq`	integer	GLOBAL
`Innodb_buffer_pool_read_requests`	integer	GLOBAL
`Innodb_buffer_pool_reads`	integer	GLOBAL
`Innodb_buffer_pool_wait_free`	integer	GLOBAL
`Innodb_buffer_pool_write_requests`	integer	GLOBAL
`Innodb_data_fsyncs`	integer	GLOBAL
`Innodb_data_pending_fsyncs`	integer	GLOBAL
`Innodb_data_pending_reads`	integer	GLOBAL
`Innodb_data_pending_writes`	integer	GLOBAL
`Innodb_data_read`	integer	GLOBAL
`Innodb_data_reads`	integer	GLOBAL
`Innodb_data_writes`	integer	GLOBAL
`Innodb_data_written`	integer	GLOBAL
`Innodb_dblwr_pages_written`	integer	GLOBAL
`Innodb_dblwr_writes`	integer	GLOBAL
`Innodb_have_atomic_builtins`	integer	GLOBAL
`Innodb_log_waits`	integer	GLOBAL
`Innodb_log_write_requests`	integer	GLOBAL
`Innodb_log_writes`	integer	GLOBAL
`Innodb_os_log_fsyncs`	integer	GLOBAL
`Innodb_os_log_pending_fsyncs`	integer	GLOBAL
`Innodb_os_log_pending_writes`	integer	GLOBAL
`Innodb_os_log_written`	integer	GLOBAL
`Innodb_page_size`	integer	GLOBAL
`Innodb_pages_created`	integer	GLOBAL
`Innodb_pages_read`	integer	GLOBAL
`Innodb_pages_written`	integer	GLOBAL
`Innodb_row_lock_current_waits`	integer	GLOBAL
`Innodb_row_lock_time`	integer	GLOBAL
`Innodb_row_lock_time_avg`	integer	GLOBAL
`Innodb_row_lock_time_max`	integer	GLOBAL
`Innodb_row_lock_waits`	integer	GLOBAL
`Innodb_rows_deleted`	integer	GLOBAL
`Innodb_rows_inserted`	integer	GLOBAL
`Innodb_rows_read`	integer	GLOBAL
`Innodb_rows_updated`	integer	GLOBAL
`Key_blocks_not_flushed`	integer	GLOBAL
`Key_blocks_unused`	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
`Key_blocks_used`	integer	GLOBAL
`Key_read_requests`	integer	GLOBAL
`Key_reads`	integer	GLOBAL
`Key_write_requests`	integer	GLOBAL
`Key_writes`	integer	GLOBAL
`Last_query_cost`	numeric	SESSION
`Max_used_connections`	integer	GLOBAL
`Ndb_api_bytes_received_count`	integer	GLOBAL
`Ndb_api_bytes_received_count_session`	integer	SESSION
`Ndb_api_bytes_received_count_slave`	integer	GLOBAL
`Ndb_api_bytes_sent_count`	integer	GLOBAL
`Ndb_api_bytes_sent_count_session`	integer	SESSION
`Ndb_api_bytes_sent_count_slave`	integer	GLOBAL
`Ndb_api_event_bytes_count`	integer	GLOBAL
`Ndb_api_event_bytes_count_injector`	integer	GLOBAL
`Ndb_api_event_data_count`	integer	GLOBAL
`Ndb_api_event_data_count_injector`	integer	GLOBAL
`Ndb_api_event_nondata_count`	integer	GLOBAL
`Ndb_api_event_nondata_count_injector`	integer	GLOBAL
`Ndb_api_pk_op_count`	integer	GLOBAL
`Ndb_api_pk_op_count_session`	integer	SESSION
`Ndb_api_pk_op_count_slave`	integer	GLOBAL
`Ndb_api_pruned_scan_count`	integer	GLOBAL
`Ndb_api_pruned_scan_count_session`	integer	SESSION
`Ndb_api_pruned_scan_count_slave`	integer	GLOBAL
`Ndb_api_range_scan_count`	integer	GLOBAL
`Ndb_api_range_scan_count_session`	integer	SESSION
`Ndb_api_range_scan_count_slave`	integer	GLOBAL
`Ndb_api_read_row_count`	integer	GLOBAL
`Ndb_api_read_row_count_session`	integer	SESSION
`Ndb_api_read_row_count_slave`	integer	GLOBAL
`Ndb_api_scan_batch_count`	integer	GLOBAL
`Ndb_api_scan_batch_count_session`	integer	SESSION
`Ndb_api_scan_batch_count_slave`	integer	GLOBAL
`Ndb_api_table_scan_count`	integer	GLOBAL
`Ndb_api_table_scan_count_session`	integer	SESSION
`Ndb_api_table_scan_count_slave`	integer	GLOBAL
`Ndb_api_trans_abort_count`	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Ndb_api_trans_abort_count_session	integer	SESSION
Ndb_api_trans_abort_count_slave	integer	GLOBAL
Ndb_api_trans_close_count	integer	GLOBAL
Ndb_api_trans_close_count_session	integer	SESSION
Ndb_api_trans_close_count_slave	integer	GLOBAL
Ndb_api_trans_commit_count	integer	GLOBAL
Ndb_api_trans_commit_count_session	integer	SESSION
Ndb_api_trans_commit_count_slave	integer	GLOBAL
Ndb_api_trans_local_read_row_count	integer	GLOBAL
Ndb_api_trans_local_read_row_count_session	integer	SESSION
Ndb_api_trans_local_read_row_count_slave	integer	GLOBAL
Ndb_api_trans_start_count	integer	GLOBAL
Ndb_api_trans_start_count_session	integer	SESSION
Ndb_api_trans_start_count_slave	integer	GLOBAL
Ndb_api_uk_op_count	integer	GLOBAL
Ndb_api_uk_op_count_session	integer	SESSION
Ndb_api_uk_op_count_slave	integer	GLOBAL
Ndb_api_wait_exec_complete_count	integer	GLOBAL
Ndb_api_wait_exec_complete_count_session	integer	SESSION
Ndb_api_wait_exec_complete_count_slave	integer	GLOBAL
Ndb_api_wait_meta_request_count	integer	GLOBAL
Ndb_api_wait_meta_request_count_session	integer	SESSION
Ndb_api_wait_meta_request_count_slave	integer	GLOBAL
Ndb_api_wait_nanos_count	integer	GLOBAL
Ndb_api_wait_nanos_count_session	integer	SESSION
Ndb_api_wait_nanos_count_slave	integer	GLOBAL
Ndb_api_wait_scan_result_count	integer	GLOBAL
Ndb_api_wait_scan_result_count_session	integer	SESSION
Ndb_api_wait_scan_result_count_slave	integer	GLOBAL
ndb_cluster_connection_pool	integer	GLOBAL
Ndb_cluster_node_id	integer	GLOBAL	SESSION
Ndb_config_from_host	integer	GLOBAL	SESSION
Ndb_config_from_port	integer	GLOBAL	SESSION
Ndb_conflict_fn_epoch	integer	GLOBAL
Ndb_conflict_fn_epoch_trans	integer	GLOBAL
Ndb_conflict_fn_max	integer	GLOBAL
Ndb_conflict_fn_old	integer	GLOBAL
Ndb_conflict_trans_conflict_commit_count	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Ndb_conflict_trans_detect_iter_count	integer	GLOBAL
Ndb_conflict_trans_reject_count	integer	GLOBAL
Ndb_conflict_trans_row_reject_count	integer	GLOBAL
Ndb_execute_count	integer	GLOBAL
Ndb_cluster_node_id	integer	GLOBAL
Ndb_number_of_data_nodes	integer	GLOBAL
Ndb_pruned_scan_count	integer	GLOBAL
Ndb_pushed_queries_defined	integer	GLOBAL
Ndb_pushed_queries_dropped	integer	GLOBAL
Ndb_pushed_queries_executed	integer	GLOBAL
Ndb_pushed_reads	integer	GLOBAL
Ndb_scan_count	integer	GLOBAL
Not_flushed_delayed_rows	integer	GLOBAL
Open_files	integer	GLOBAL
Open_streams	integer	GLOBAL
Open_table_definitions	integer	GLOBAL
Open_tables	integer	GLOBAL | SESSION
Opened_files	integer	GLOBAL
Opened_table_definitions	integer	GLOBAL | SESSION
Opened_tables	integer	GLOBAL | SESSION
Prepared_stmt_count	integer	GLOBAL
Qcache_free_blocks	integer	GLOBAL
Qcache_free_memory	integer	GLOBAL
Qcache_hits	integer	GLOBAL
Qcache_inserts	integer	GLOBAL
Qcache_lowmem_prunes	integer	GLOBAL
Qcache_not_cached	integer	GLOBAL
Qcache_queries_in_cache	integer	GLOBAL
Qcache_total_blocks	integer	GLOBAL
Queries	integer	GLOBAL | SESSION
Questions	integer	GLOBAL | SESSION
Rpl_status	string	GLOBAL
Select_full_join	integer	GLOBAL | SESSION
Select_full_range_join	integer	GLOBAL | SESSION
Select_range	integer	GLOBAL | SESSION
Select_range_check	integer	GLOBAL | SESSION
Select_scan	integer	GLOBAL | SESSION
Slave_heartbeat_period	numeric	GLOBAL

Variable Name	Variable Type	Variable Scope
Slave_open_temp_tables	integer	GLOBAL
Slave_received_heartbeats		GLOBAL
Slave_retried_transactions	integer	GLOBAL
Slave_running	boolean	GLOBAL
Slow_launch_threads	integer	GLOBAL | SESSION
Slow_queries	integer	GLOBAL | SESSION
Sort_merge_passes	integer	GLOBAL | SESSION
Sort_range	integer	GLOBAL | SESSION
Sort_rows	integer	GLOBAL | SESSION
Sort_scan	integer	GLOBAL | SESSION
Ssl_accept_renegotiates	integer	GLOBAL
Ssl_accepts	integer	GLOBAL
Ssl_callback_cache_hits	integer	GLOBAL
Ssl_cipher	string	GLOBAL | SESSION
Ssl_cipher_list	string	GLOBAL | SESSION
Ssl_client_connects	integer	GLOBAL
Ssl_connect_renegotiates	integer	GLOBAL
Ssl_ctx_verify_depth	integer	GLOBAL
Ssl_ctx_verify_mode	integer	GLOBAL
Ssl_default_timeout	integer	GLOBAL | SESSION
Ssl_finished_accepts	integer	GLOBAL
Ssl_finished_connects	integer	GLOBAL
Ssl_session_cache_hits	integer	GLOBAL
Ssl_session_cache_misses	integer	GLOBAL
Ssl_session_cache_mode	string	GLOBAL
Ssl_session_cache_overflows	integer	GLOBAL
Ssl_session_cache_size	integer	GLOBAL
Ssl_session_cache_timeouts	integer	GLOBAL
Ssl_sessions_reused	integer	GLOBAL | SESSION
Ssl_used_session_cache_entries	integer	GLOBAL
Ssl_verify_depth	integer	GLOBAL | SESSION
Ssl_verify_mode	integer	GLOBAL | SESSION
Ssl_version	string	GLOBAL | SESSION
Table_locks_immediate	integer	GLOBAL
Table_locks_waited	integer	GLOBAL
Tc_log_max_pages_used	integer	GLOBAL
Tc_log_page_size	integer	GLOBAL
Tc_log_page_waits	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
`Threads_cached`	integer	`GLOBAL`
`Threads_connected`	integer	`GLOBAL`
`Threads_created`	integer	`GLOBAL`
`Threads_running`	integer	`GLOBAL`
`Uptime`	integer	`GLOBAL`
`Uptime_since_flush_status`	integer	`GLOBAL`

The status variables have the following meanings. For meanings of status variables specific to MySQL Cluster, see MySQL Cluster Status Variables.

- `Aborted_clients`

  The number of connections that were aborted because the client died without closing the connection properly. See Section B.5.2.11, "Communication Errors and Aborted Connections".

- `Aborted_connects`

  The number of failed attempts to connect to the MySQL server. See Section B.5.2.11, "Communication Errors and Aborted Connections".

- `Binlog_cache_disk_use`

  The number of transactions that used the temporary binary log cache but that exceeded the value of `binlog_cache_size` and used a temporary file to store statements from the transaction.

- `Binlog_cache_use`

  The number of transactions that used the temporary binary log cache.

- `Bytes_received`

  The number of bytes received from all clients.

- `Bytes_sent`

  The number of bytes sent to all clients.

- `Com_xxx`

  The `Com_xxx` statement counter variables indicate the number of times each `xxx` statement has been executed. There is one status variable for each type of statement. For example, `Com_delete` and `Com_update` count `DELETE` and `UPDATE` statements, respectively. `Com_delete_multi` and `Com_update_multi` are similar but apply to `DELETE` and `UPDATE` statements that use multiple-table syntax.

  If a query result is returned from query cache, the server increments the `Qcache_hits` status variable, not `Com_select`. See Section 8.10.3.4, "Query Cache Status and Maintenance".

  The discussion at the beginning of this section indicates how to relate these statement-counting status variables to other such variables.

  All of the `Com_stmt_xxx` variables are increased even if a prepared statement argument is unknown or an error occurred during execution. In other words, their values correspond to the number of requests issued, not to the number of requests successfully completed.

The `Com_stmt_xxx` status variables are as follows:

- `Com_stmt_prepare`

- `Com_stmt_execute`

- `Com_stmt_fetch`

- `Com_stmt_send_long_data`

- `Com_stmt_reset`

- `Com_stmt_close`

Those variables stand for prepared statement commands. Their names refer to the `COM_xxx` command set used in the network layer. In other words, their values increase whenever prepared statement API calls such as `mysql_stmt_prepare()`, `mysql_stmt_execute()`, and so forth are executed. However, `Com_stmt_prepare`, `Com_stmt_execute` and `Com_stmt_close` also increase for `PREPARE`, `EXECUTE`, or `DEALLOCATE PREPARE`, respectively. Additionally, the values of the older statement counter variables `Com_prepare_sql`, `Com_execute_sql`, and `Com_dealloc_sql` increase for the `PREPARE`, `EXECUTE`, and `DEALLOCATE PREPARE` statements. `Com_stmt_fetch` stands for the total number of network round-trips issued when fetching from cursors.

`Com_stmt_reprepare` indicates the number of times statements were automatically reprepared by the server after metadata changes to tables or views referred to by the statement. This variable was added in MySQL 5.1.25. A reprepare operation increments `Com_stmt_reprepare`, and also `Com_stmt_prepare`.

- `Compression`

Whether the client connection uses compression in the client/server protocol. Added in MySQL 5.1.2.

- `Connections`

The number of connection attempts (successful or not) to the MySQL server.

- `Created_tmp_disk_tables`

The number of internal on-disk temporary tables created by the server while executing statements.

If an internal temporary table is created initially as an in-memory table but becomes too large, MySQL automatically converts it to an on-disk table. The maximum size for in-memory temporary tables is the minimum of the `tmp_table_size` and `max_heap_table_size` values. If `Created_tmp_disk_tables` is large, you may want to increase the `tmp_table_size` or `max_heap_table_size` value to lessen the likelihood that internal temporary tables in memory will be converted to on-disk tables.

You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

See also Section 8.4.4, "Internal Temporary Table Use in MySQL".

- `Created_tmp_files`

How many temporary files `mysqld` has created.

- `Created_tmp_tables`

  The number of internal temporary tables created by the server while executing statements.

  You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

  See also Section 8.4.4, "Internal Temporary Table Use in MySQL".

  Each invocation of the `SHOW STATUS` statement uses an internal temporary table and increments the global `Created_tmp_tables` value.

- `Delayed_errors`

  The number of rows written with `INSERT DELAYED` for which some error occurred (probably `duplicate key`).

- `Delayed_insert_threads`

  The number of `INSERT DELAYED` handler threads in use.

- `Delayed_writes`

  The number of `INSERT DELAYED` rows written.

- `Flush_commands`

  The number of times the server flushes tables, whether because a user executed a `FLUSH TABLES` statement or due to internal server operation. It is also incremented by receipt of a `COM_REFRESH` packet. This is in contrast to `Com_flush`, which indicates how many `FLUSH` statements have been executed, whether `FLUSH TABLES`, `FLUSH LOGS`, and so forth.

- `Handler_commit`

  The number of internal `COMMIT` statements.

- `Handler_delete`

  The number of times that rows have been deleted from tables.

- `Handler_prepare`

  A counter for the prepare phase of two-phase commit operations.

- `Handler_read_first`

  The number of times the first entry in an index was read. If this value is high, it suggests that the server is doing a lot of full index scans; for example, `SELECT col1 FROM foo`, assuming that `col1` is indexed.

- `Handler_read_key`

  The number of requests to read a row based on a key. If this value is high, it is a good indication that your tables are properly indexed for your queries.

- `Handler_read_next`

The number of requests to read the next row in key order. This value is incremented if you are querying an index column with a range constraint or if you are doing an index scan.

- `Handler_read_prev`

  The number of requests to read the previous row in key order. This read method is mainly used to optimize `ORDER BY ... DESC`.

- `Handler_read_rnd`

  The number of requests to read a row based on a fixed position. This value is high if you are doing a lot of queries that require sorting of the result. You probably have a lot of queries that require MySQL to scan entire tables or you have joins that do not use keys properly.

- `Handler_read_rnd_next`

  The number of requests to read the next row in the data file. This value is high if you are doing a lot of table scans. Generally this suggests that your tables are not properly indexed or that your queries are not written to take advantage of the indexes you have.

- `Handler_rollback`

  The number of requests for a storage engine to perform a rollback operation.

- `Handler_savepoint`

  The number of requests for a storage engine to place a savepoint.

- `Handler_savepoint_rollback`

  The number of requests for a storage engine to roll back to a savepoint.

- `Handler_update`

  The number of requests to update a row in a table.

- `Handler_write`

  The number of requests to insert a row in a table.

- `Innodb_buffer_pool_pages_data`

  The number of pages containing data (dirty or clean).

- `Innodb_buffer_pool_pages_dirty`

  The number of pages currently dirty.

- `Innodb_buffer_pool_pages_flushed`

  The number of buffer pool page-flush requests.

- `Innodb_buffer_pool_pages_free`

  The number of free pages.

- `Innodb_buffer_pool_pages_latched`

The number of latched pages in `InnoDB` buffer pool. These are pages currently being read or written or that cannot be flushed or removed for some other reason. Calculation of this variable is expensive, so as of MySQL 5.1.28, it is available only when the `UNIV_DEBUG` system is defined at server build time.

- `Innodb_buffer_pool_pages_misc`

  The number of pages that are busy because they have been allocated for administrative overhead such as row locks or the adaptive hash index. This value can also be calculated as `Innodb_buffer_pool_pages_total` − `Innodb_buffer_pool_pages_free` − `Innodb_buffer_pool_pages_data`.

- `Innodb_buffer_pool_pages_total`

  The total size of the buffer pool, in pages.

- `Innodb_buffer_pool_read_ahead`

  (`InnoDB Plugin` only) The number of pages read into the `InnoDB` buffer pool by the read-ahead background thread.

  This variable was added in MySQL 5.1.41.

- `Innodb_buffer_pool_read_ahead_evicted`

  (`InnoDB Plugin` only) The number of pages read into the `InnoDB` buffer pool by the read-ahead background thread that were subsequently evicted without having been accessed by queries.

  This variable was added in MySQL 5.1.41.

- `Innodb_buffer_pool_read_ahead_rnd`

  The number of "random" read-aheads initiated by `InnoDB`. This happens when a query scans a large portion of a table but in random order.

  For `InnoDB Plugin`, this variable was removed in MySQL 5.1.41.

- `Innodb_buffer_pool_read_ahead_seq`

  The number of sequential read-aheads initiated by `InnoDB`. This happens when `InnoDB` does a sequential full table scan.

  For `InnoDB Plugin`, this variable was removed in MySQL 5.1.41.

- `Innodb_buffer_pool_read_requests`

  The number of logical read requests.

- `Innodb_buffer_pool_reads`

  The number of logical reads that `InnoDB` could not satisfy from the buffer pool, and had to read directly from the disk.

- `Innodb_buffer_pool_wait_free`

  Normally, writes to the `InnoDB` buffer pool happen in the background. However, if it is necessary to read or create a page and no clean pages are available, it is also necessary to wait for pages to be flushed first. This counter counts instances of these waits. If the buffer pool size has been set properly, this value should be small.

- `Innodb_buffer_pool_write_requests`

  The number writes done to the `InnoDB` buffer pool.

- `Innodb_data_fsyncs`

  The number of `fsync()` operations so far.

- `Innodb_data_pending_fsyncs`

  The current number of pending `fsync()` operations.

- `Innodb_data_pending_reads`

  The current number of pending reads.

- `Innodb_data_pending_writes`

  The current number of pending writes.

- `Innodb_data_read`

  The amount of data read since the server was started.

- `Innodb_data_reads`

  The total number of data reads.

- `Innodb_data_writes`

  The total number of data writes.

- `Innodb_data_written`

  The amount of data written so far, in bytes.

- `Innodb_dblwr_pages_written`

  The number of pages that have been written for doublewrite operations. See Section 14.6.7.1, "InnoDB Disk I/O".

- `Innodb_dblwr_writes`

  The number of doublewrite operations that have been performed. See Section 14.6.7.1, "InnoDB Disk I/O".

- `Innodb_have_atomic_builtins`

  (`InnoDB Plugin` only) Indicates whether the server was built with atomic instructions. This variable was added in MySQL 5.1.38.

- `Innodb_log_waits`

  The number of times that the log buffer was too small and a wait was required for it to be flushed before continuing.

- `Innodb_log_write_requests`

  The number of log write requests.

- `Innodb_log_writes`

  The number of physical writes to the log file.

- `Innodb_os_log_fsyncs`

  The number of `fsync()` writes done to the log file.

- `Innodb_os_log_pending_fsyncs`

  The number of pending log file `fsync()` operations.

- `Innodb_os_log_pending_writes`

  The number of pending log file writes.

- `Innodb_os_log_written`

  The number of bytes written to the log file.

- `Innodb_page_size`

  The compiled-in `InnoDB` page size (default 16KB). Many values are counted in pages; the page size enables them to be easily converted to bytes.

- `Innodb_pages_created`

  The number of pages created.

- `Innodb_pages_read`

  The number of pages read.

- `Innodb_pages_written`

  The number of pages written.

- `Innodb_row_lock_current_waits`

  The number of row locks currently being waited for.

- `Innodb_row_lock_time`

  The total time spent in acquiring row locks, in milliseconds.

- `Innodb_row_lock_time_avg`

  The average time to acquire a row lock, in milliseconds.

- `Innodb_row_lock_time_max`

  The maximum time to acquire a row lock, in milliseconds.

- `Innodb_row_lock_waits`

  The number of times a row lock had to be waited for.

- `Innodb_rows_deleted`

  The number of rows deleted from `InnoDB` tables.

- `Innodb_rows_inserted`

  The number of rows inserted into `InnoDB` tables.

- `Innodb_rows_read`

  The number of rows read from `InnoDB` tables.

- `Innodb_rows_updated`

  The number of rows updated in `InnoDB` tables.

- `Key_blocks_not_flushed`

  The number of key blocks in the key cache that have changed but have not yet been flushed to disk.

- `Key_blocks_unused`

  The number of unused blocks in the key cache. You can use this value to determine how much of the key cache is in use; see the discussion of `key_buffer_size` in Section 5.1.4, "Server System Variables".

- `Key_blocks_used`

  The number of used blocks in the key cache. This value is a high-water mark that indicates the maximum number of blocks that have ever been in use at one time.

- `Key_read_requests`

  The number of requests to read a key block from the cache.

- `Key_reads`

  The number of physical reads of a key block from disk. If `Key_reads` is large, then your `key_buffer_size` value is probably too small. The cache miss rate can be calculated as `Key_reads`/`Key_read_requests`.

- `Key_write_requests`

  The number of requests to write a key block to the cache.

- `Key_writes`

  The number of physical writes of a key block to disk.

- `Last_query_cost`

  The total cost of the last compiled query as computed by the query optimizer. This is useful for comparing the cost of different query plans for the same query. The default value of 0 means that no query has been compiled yet. The default value is 0. `Last_query_cost` has session scope.

  The `Last_query_cost` value can be computed accurately only for simple "flat" queries, not complex queries such as those with subqueries or `UNION`. For the latter, the value is set to 0.

- `Max_used_connections`

  The maximum number of connections that have been in use simultaneously since the server started.

- `Not_flushed_delayed_rows`

The number of rows waiting to be written in `INSERT DELAYED` queues.

- `Open_files`

  The number of files that are open. This count includes regular files opened by the server. It does not include other types of files such as sockets or pipes. Also, the count does not include files that storage engines open using their own internal functions rather than asking the server level to do so.

- `Open_streams`

  The number of streams that are open (used mainly for logging).

- `Open_table_definitions`

  The number of cached `.frm` files. This variable was added in MySQL 5.1.3.

- `Open_tables`

  The number of tables that are open.

- `Opened_files`

  The number of files that have been opened with `my_open()` (a `mysys` library function). Parts of the server that open files without using this function do not increment the count. This variable was added in MySQL 5.1.21.

- `Opened_table_definitions`

  The number of `.frm` files that have been cached. This variable was added in MySQL 5.1.24.

- `Opened_tables`

  The number of tables that have been opened. If `Opened_tables` is big, your `table_open_cache` value is probably too small.

- `Prepared_stmt_count`

  The current number of prepared statements. (The maximum number of statements is given by the `max_prepared_stmt_count` system variable.) This variable was added in MySQL 5.1.14.

- `Qcache_free_blocks`

  The number of free memory blocks in the query cache.

- `Qcache_free_memory`

  The amount of free memory for the query cache.

- `Qcache_hits`

  The number of query cache hits.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- `Qcache_inserts`

  The number of queries added to the query cache.

- `Qcache_lowmem_prunes`

  The number of queries that were deleted from the query cache because of low memory.

- `Qcache_not_cached`

  The number of noncached queries (not cacheable, or not cached due to the `query_cache_type` setting).

- `Qcache_queries_in_cache`

  The number of queries registered in the query cache.

- `Qcache_total_blocks`

  The total number of blocks in the query cache.

- `Queries`

  The number of statements executed by the server. This variable includes statements executed within stored programs, unlike the `Questions` variable. It does not count `COM_PING` or `COM_STATISTICS` commands. This variable was added in MySQL 5.1.31.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- `Questions`

  The number of statements executed by the server. As of MySQL 5.1.31, this includes only statements sent to the server by clients and no longer includes statements executed within stored programs, unlike the `Queries` variable. This variable does not count `COM_PING`, `COM_STATISTICS`, `COM_STMT_PREPARE`, `COM_STMT_CLOSE`, or `COM_STMT_RESET` commands.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- `Rpl_status`

  The status of fail-safe replication (not implemented). This variable is unused and is removed in MySQL 5.6.

- `Select_full_join`

  The number of joins that perform table scans because they do not use indexes. If this value is not 0, you should carefully check the indexes of your tables.

- `Select_full_range_join`

  The number of joins that used a range search on a reference table.

- `Select_range`

  The number of joins that used ranges on the first table. This is normally not a critical issue even if the value is quite large.

- `Select_range_check`

  The number of joins without keys that check for key usage after each row. If this is not 0, you should carefully check the indexes of your tables.

- Select_scan

  The number of joins that did a full scan of the first table.

- Slave_open_temp_tables

  The number of temporary tables that the slave SQL thread currently has open. If the value is greater than zero, it is not safe to shut down the slave; see Section 16.4.1.23, "Replication and Temporary Tables".

- Slave_retried_transactions

  The total number of times since startup that the replication slave SQL thread has retried transactions.

- Slave_running

  This is ON if this server is a replication slave that is connected to a replication master, and both the I/O and SQL threads are running; otherwise, it is OFF.

- Slow_launch_threads

  The number of threads that have taken more than slow_launch_time seconds to create.

- Slow_queries

  The number of queries that have taken more than long_query_time seconds. This counter increments regardless of whether the slow query log is enabled. For information about that log, see Section 5.4.5, "The Slow Query Log".

- Sort_merge_passes

  The number of merge passes that the sort algorithm has had to do. If this value is large, you should consider increasing the value of the sort_buffer_size system variable.

- Sort_range

  The number of sorts that were done using ranges.

- Sort_rows

  The number of sorted rows.

- Sort_scan

  The number of sorts that were done by scanning the table.

- Ssl_accept_renegotiates

  The number of negotiates needed to establish the connection.

- Ssl_accepts

  The number of accepted SSL connections.

- Ssl_callback_cache_hits

  The number of callback cache hits.

- Ssl_cipher

The current encryption cipher (empty for unencrypted connections).

- `Ssl_cipher_list`

  The list of possible SSL ciphers (empty for non-SSL connections).

- `Ssl_client_connects`

  The number of SSL connection attempts to an SSL-enabled master.

- `Ssl_connect_renegotiates`

  The number of negotiates needed to establish the connection to an SSL-enabled master.

- `Ssl_ctx_verify_depth`

  The SSL context verification depth (how many certificates in the chain are tested).

- `Ssl_ctx_verify_mode`

  The SSL context verification mode.

- `Ssl_default_timeout`

  The default SSL timeout.

- `Ssl_finished_accepts`

  The number of successful SSL connections to the server.

- `Ssl_finished_connects`

  The number of successful slave connections to an SSL-enabled master.

- `Ssl_session_cache_hits`

  The number of SSL session cache hits.

- `Ssl_session_cache_misses`

  The number of SSL session cache misses.

- `Ssl_session_cache_mode`

  The SSL session cache mode.

- `Ssl_session_cache_overflows`

  The number of SSL session cache overflows.

- `Ssl_session_cache_size`

  The SSL session cache size.

- `Ssl_session_cache_timeouts`

  The number of SSL session cache timeouts.

- `Ssl_sessions_reused`

How many SSL connections were reused from the cache.

- `Ssl_used_session_cache_entries`

  How many SSL session cache entries were used.

- `Ssl_verify_depth`

  The verification depth for replication SSL connections.

- `Ssl_verify_mode`

  The verification mode for replication SSL connections.

- `Ssl_version`

  The SSL protocol version of the connection; for example, TLSv1. If the connection is not encrypted, the value is empty.

- `Table_locks_immediate`

  The number of times that a request for a table lock could be granted immediately.

- `Table_locks_waited`

  The number of times that a request for a table lock could not be granted immediately and a wait was needed. If this is high and you have performance problems, you should first optimize your queries, and then either split your table or tables or use replication.

- `Tc_log_max_pages_used`

  For the memory-mapped implementation of the log that is used by `mysqld` when it acts as the transaction coordinator for recovery of internal XA transactions, this variable indicates the largest number of pages used for the log since the server started. If the product of `Tc_log_max_pages_used` and `Tc_log_page_size` is always significantly less than the log size, the size is larger than necessary and can be reduced. (The size is set by the `--log-tc-size` option. This variable is unused: It is unneeded for binary log-based recovery, and the memory-mapped recovery log method is not used unless the number of storage engines that are capable of two-phase commit and that support XA transactions is greater than one. (`InnoDB` is the only applicable engine.)

- `Tc_log_page_size`

  The page size used for the memory-mapped implementation of the XA recovery log. The default value is determined using `getpagesize()`. This variable is unused for the same reasons as described for `Tc_log_max_pages_used`.

- `Tc_log_page_waits`

  For the memory-mapped implementation of the recovery log, this variable increments each time the server was not able to commit a transaction and had to wait for a free page in the log. If this value is large, you might want to increase the log size (with the `--log-tc-size` option). For binary log-based recovery, this variable increments each time the binary log cannot be closed because there are two-phase commits in progress. (The close operation waits until all such transactions are finished.)

- `Threads_cached`

  The number of threads in the thread cache.

- `Threads_connected`

  The number of currently open connections.

- `Threads_created`

  The number of threads created to handle connections. If `Threads_created` is big, you may want to increase the `thread_cache_size` value. The cache miss rate can be calculated as `Threads_created`/`Connections`.

- `Threads_running`

  The number of threads that are not sleeping.

- `Uptime`

  The number of seconds that the server has been up.

- `Uptime_since_flush_status`

  The number of seconds since the most recent `FLUSH STATUS` statement. This variable was added in 5.1.24.

5.1.7 Server SQL Modes

The MySQL server can operate in different SQL modes, and can apply these modes differently for different clients, depending on the value of the `sql_mode` system variable. DBAs can set the global SQL mode to match site server operating requirements, and each application can set its session SQL mode to its own requirements.

Modes affect the SQL syntax MySQL supports and the data validation checks it performs. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers.

- Setting the SQL Mode

- The Most Important SQL Modes

- Full List of SQL Modes

- Strict SQL Mode

- Combination SQL Modes

When working with `InnoDB` tables using the InnoDB Plugin, consider also the `innodb_strict_mode` system variable. It enables additional error checks for `InnoDB` tables.

Setting the SQL Mode

The default SQL mode is empty (no modes set).

To set the SQL mode at server startup, use the `--sql-mode="modes"` option on the command line, or `sql-mode="modes"` in an option file such as `my.cnf` (Unix operating systems) or `my.ini` (Windows). `modes` is a list of different modes separated by commas. To clear the SQL mode explicitly, set it to an empty string using `--sql-mode=""` on the command line, or `sql-mode=""` in an option file.

> **Note**
>
> MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

To change the SQL mode at runtime, set the global or session `sql_mode` system variable using a `SET` statement:

```
SET GLOBAL sql_mode = 'modes';
SET SESSION sql_mode = 'modes';
```

Setting the `GLOBAL` variable requires the `SUPER` privilege and affects the operation of all clients that connect from that time on. Setting the `SESSION` variable affects only the current client. Each client can change its session `sql_mode` value at any time.

To determine the current global or session `sql_mode` value, use the following statements:

```
SELECT @@GLOBAL.sql_mode;
SELECT @@SESSION.sql_mode;
```

> **Important**
>
> **SQL mode and user-defined partitioning.**   Changing the server SQL mode after creating and inserting data into partitioned tables can cause major changes in the behavior of such tables, and could lead to loss or corruption of data. It is strongly recommended that you never change the SQL mode once you have created tables employing user-defined partitioning.
>
> When replicating partitioned tables, differing SQL modes on master and slave can also lead to problems. For best results, you should always use the same server SQL mode on the master and on the slave.
>
> See Section 18.5, "Restrictions and Limitations on Partitioning", for more information.

The Most Important SQL Modes

The most important `sql_mode` values are probably these:

- `ANSI`

  This mode changes syntax and behavior to conform more closely to standard SQL. It is one of the special combination modes listed at the end of this section.

- `STRICT_TRANS_TABLES`

  If a value could not be inserted as given into a transactional table, abort the statement. For a nontransactional table, abort the statement if the value occurs in a single-row statement or the first row of a multiple-row statement. More details are given later in this section.

- `TRADITIONAL`

  Make MySQL behave like a "traditional" SQL database system. A simple description of this mode is "give an error instead of a warning" when inserting an incorrect value into a column. It is one of the special combination modes listed at the end of this section.

  > **Note**
  >
  > The `INSERT` or `UPDATE` aborts as soon as the error is noticed. This may not be what you want if you are using a nontransactional storage engine, because data changes made prior to the error may not be rolled back, resulting in a "partially done" update.

When this manual refers to "strict mode," it means a mode with either or both `STRICT_TRANS_TABLES` or `STRICT_ALL_TABLES` enabled.

Full List of SQL Modes

The following list describes all supported SQL modes:

- `ALLOW_INVALID_DATES`

  Do not perform full checking of dates. Check only that the month is in the range from 1 to 12 and the day is in the range from 1 to 31. This is very convenient for Web applications where you obtain year, month, and day in three different fields and you want to store exactly what the user inserted (without date validation). This mode applies to `DATE` and `DATETIME` columns. It does not apply `TIMESTAMP` columns, which always require a valid date.

  The server requires that month and day values be legal, and not merely in the range 1 to 12 and 1 to 31, respectively. With strict mode disabled, invalid dates such as `'2004-04-31'` are converted to `'0000-00-00'` and a warning is generated. With strict mode enabled, invalid dates generate an error. To permit such dates, enable `ALLOW_INVALID_DATES`.

- `ANSI_QUOTES`

  Treat "`"`" as an identifier quote character (like the "`` ` ``" quote character) and not as a string quote character. You can still use "`` ` ``" to quote identifiers with this mode enabled. With `ANSI_QUOTES` enabled, you cannot use double quotation marks to quote literal strings, because it is interpreted as an identifier.

- `ERROR_FOR_DIVISION_BY_ZERO`

  The `ERROR_FOR_DIVISION_BY_ZERO` mode affects handling of division by zero, which includes `MOD(N,0)`. For data-change operations (`INSERT`, `UPDATE`), its effect also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, division by zero inserts `NULL` and produces no warning.

  - If this mode is enabled, division by zero inserts `NULL` and produces a warning.

  - If this mode and strict mode are enabled, division by zero produces an error, unless `IGNORE` is given as well. For `INSERT IGNORE` and `UPDATE IGNORE`, division by zero inserts `NULL` and produces a warning.

  For `SELECT`, division by zero returns `NULL`. Enabling `ERROR_FOR_DIVISION_BY_ZERO` causes a warning to be produced as well, regardless of whether strict mode is enabled.

- `HIGH_NOT_PRECEDENCE`

  The precedence of the `NOT` operator is such that expressions such as `NOT a BETWEEN b AND c` are parsed as `NOT (a BETWEEN b AND c)`. In some older versions of MySQL, the expression was parsed as `(NOT a) BETWEEN b AND c`. The old higher-precedence behavior can be obtained by enabling the `HIGH_NOT_PRECEDENCE` SQL mode.

```
mysql> SET sql_mode = '';
mysql> SELECT NOT 1 BETWEEN -5 AND 5;
        -> 0
mysql> SET sql_mode = 'HIGH_NOT_PRECEDENCE';
mysql> SELECT NOT 1 BETWEEN -5 AND 5;
        -> 1
```

- `IGNORE_SPACE`

  Permit spaces between a function name and the "`(`" character. This causes built-in function names to be treated as reserved words. As a result, identifiers that are the same as function names must be quoted as described in Section 9.2, "Schema Object Names". For example, because there is a `COUNT()` function, the use of `count` as a table name in the following statement causes an error:

  ```
  mysql> CREATE TABLE count (i INT);
  ERROR 1064 (42000): You have an error in your SQL syntax
  ```

  The table name should be quoted:

  ```
  mysql> CREATE TABLE `count` (i INT);
  Query OK, 0 rows affected (0.00 sec)
  ```

  The `IGNORE_SPACE` SQL mode applies to built-in functions, not to user-defined functions or stored functions. It is always permissible to have spaces after a UDF or stored function name, regardless of whether `IGNORE_SPACE` is enabled.

  For further discussion of `IGNORE_SPACE`, see Section 9.2.4, "Function Name Parsing and Resolution".

- `NO_AUTO_CREATE_USER`

  Prevent the `GRANT` statement from automatically creating new users if it would otherwise do so, unless a nonempty password also is specified.

- `NO_AUTO_VALUE_ON_ZERO`

  `NO_AUTO_VALUE_ON_ZERO` affects handling of `AUTO_INCREMENT` columns. Normally, you generate the next sequence number for the column by inserting either `NULL` or `0` into it. `NO_AUTO_VALUE_ON_ZERO` suppresses this behavior for `0` so that only `NULL` generates the next sequence number.

  This mode can be useful if `0` has been stored in a table's `AUTO_INCREMENT` column. (Storing `0` is not a recommended practice, by the way.) For example, if you dump the table with `mysqldump` and then reload it, MySQL normally generates new sequence numbers when it encounters the `0` values, resulting in a table with contents different from the one that was dumped. Enabling `NO_AUTO_VALUE_ON_ZERO` before reloading the dump file solves this problem. `mysqldump` now automatically includes in its output a statement that enables `NO_AUTO_VALUE_ON_ZERO`, to avoid this problem.

- `NO_BACKSLASH_ESCAPES`

  Disable the use of the backslash character ("`\`") as an escape character within strings. With this mode enabled, backslash becomes an ordinary character like any other.

- `NO_DIR_IN_CREATE`

  When creating a table, ignore all `INDEX DIRECTORY` and `DATA DIRECTORY` directives. This option is useful on slave replication servers.

- `NO_ENGINE_SUBSTITUTION`

  Control automatic substitution of the default storage engine when a statement such as `CREATE TABLE` or `ALTER TABLE` specifies a storage engine that is disabled or not compiled in.

  Up through MySQL 5.1.11, with `NO_ENGINE_SUBSTITUTION` disabled, the default engine is used and a warning occurs if the desired engine is known but disabled or not compiled in. If the desired engine is invalid (not a known engine name), an error occurs and the table is not created or altered.

With `NO_ENGINE_SUBSTITUTION` enabled, an error occurs and the table is not created or altered if the desired engine is unavailable for any reason (whether disabled or invalid).

As of MySQL 5.1.12, storage engines can be pluggable at runtime, so the distinction between disabled and invalid no longer applies. All unavailable engines are treated the same way:

With `NO_ENGINE_SUBSTITUTION` disabled, for `CREATE TABLE` the default engine is used and a warning occurs if the desired engine is unavailable. For `ALTER TABLE`, a warning occurs and the table is not altered.

With `NO_ENGINE_SUBSTITUTION` enabled, an error occurs and the table is not created or altered if the desired engine is unavailable.

- `NO_FIELD_OPTIONS`

  Do not print MySQL-specific column options in the output of `SHOW CREATE TABLE`. This mode is used by `mysqldump` in portability mode.

- `NO_KEY_OPTIONS`

  Do not print MySQL-specific index options in the output of `SHOW CREATE TABLE`. This mode is used by `mysqldump` in portability mode.

- `NO_TABLE_OPTIONS`

  Do not print MySQL-specific table options (such as `ENGINE`) in the output of `SHOW CREATE TABLE`. This mode is used by `mysqldump` in portability mode.

- `NO_UNSIGNED_SUBTRACTION`

  By default, subtraction between integer operands produces an `UNSIGNED` result if any operand is `UNSIGNED`. When `NO_UNSIGNED_SUBTRACTION` is enabled, the subtraction result is signed, *even if any operand is unsigned*. For example, compare the type of column `c2` in table `t1` with that of column `c2` in table `t2`:

```
mysql> SET sql_mode='';
mysql> CREATE TABLE test (c1 BIGINT UNSIGNED NOT NULL);
mysql> CREATE TABLE t1 SELECT c1 - 1 AS c2 FROM test;
mysql> DESCRIBE t1;
+-------+---------------------+------+-----+---------+-------+
| Field | Type                | Null | Key | Default | Extra |
+-------+---------------------+------+-----+---------+-------+
| c2    | bigint(21) unsigned | NO   |     | 0       |       |
+-------+---------------------+------+-----+---------+-------+

mysql> SET sql_mode='NO_UNSIGNED_SUBTRACTION';
mysql> CREATE TABLE t2 SELECT c1 - 1 AS c2 FROM test;
mysql> DESCRIBE t2;
+-------+------------+------+-----+---------+-------+
| Field | Type       | Null | Key | Default | Extra |
+-------+------------+------+-----+---------+-------+
| c2    | bigint(21) | NO   |     | 0       |       |
+-------+------------+------+-----+---------+-------+
```

  This means that `BIGINT UNSIGNED` is not 100% usable in all contexts. See Section 12.10, "Cast Functions and Operators".

```
mysql> SET sql_mode = '';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+------------------------+
|    18446744073709551615 |
+------------------------+

mysql> SET sql_mode = 'NO_UNSIGNED_SUBTRACTION';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+------------------------+
|                     -1 |
+------------------------+
```

- NO_ZERO_DATE

  The NO_ZERO_DATE mode affects whether the server permits '0000-00-00' as a valid date. Its effect also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, '0000-00-00' is permitted and inserts produce no warning.

  - If this mode is enabled, '0000-00-00' is permitted and inserts produce a warning.

  - If this mode and strict mode are enabled, '0000-00-00' is not permitted and inserts produce an error, unless IGNORE is given as well. For INSERT IGNORE and UPDATE IGNORE, '0000-00-00' is permitted and inserts produce a warning.

- NO_ZERO_IN_DATE

  The NO_ZERO_IN_DATE mode affects whether the server permits dates in which the year part is nonzero but the month or day part is 0. (This mode affects dates such as '2010-00-01' or '2010-01-00', but not '0000-00-00'. To control whether the server permits '0000-00-00', use the NO_ZERO_DATE mode.) The effect of NO_ZERO_IN_DATE also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, dates with zero parts are permitted and inserts produce no warning.

  - If this mode is enabled, dates with zero parts are inserted as '0000-00-00' and produce a warning.

  - If this mode and strict mode are enabled, dates with zero parts are not permitted and inserts produce an error, unless IGNORE is given as well. For INSERT IGNORE and UPDATE IGNORE, dates with zero parts are inserted as '0000-00-00' and produce a warning.

- ONLY_FULL_GROUP_BY

  Reject queries for which the select list or (as of MySQL 5.1.10) HAVING condition refer to nonaggregated columns that are not named in the GROUP BY clause.

  A MySQL extension to standard SQL permits references in the HAVING clause to aliased expressions in the select list. Enabling ONLY_FULL_GROUP_BY disables this extension, thus requiring the HAVING clause to be written using unaliased expressions.

  For additional discussion and examples, see Section 12.17.3, "MySQL Handling of GROUP BY".

- PAD_CHAR_TO_FULL_LENGTH

  By default, trailing spaces are trimmed from CHAR column values on retrieval. If PAD_CHAR_TO_FULL_LENGTH is enabled, trimming does not occur and retrieved CHAR values are

padded to their full length. This mode does not apply to `VARCHAR` columns, for which trailing spaces are retained on retrieval. This mode was added in MySQL 5.1.20.

```
mysql> CREATE TABLE t1 (c1 CHAR(10));
Query OK, 0 rows affected (0.37 sec)

mysql> INSERT INTO t1 (c1) VALUES('xy');
Query OK, 1 row affected (0.01 sec)

mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT c1, CHAR_LENGTH(c1) FROM t1;
+------+-----------------+
| c1   | CHAR_LENGTH(c1) |
+------+-----------------+
| xy   |               2 |
+------+-----------------+
1 row in set (0.00 sec)

mysql> SET sql_mode = 'PAD_CHAR_TO_FULL_LENGTH';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT c1, CHAR_LENGTH(c1) FROM t1;
+------------+-----------------+
| c1         | CHAR_LENGTH(c1) |
+------------+-----------------+
| xy         |              10 |
+------------+-----------------+
1 row in set (0.00 sec)
```

- `PIPES_AS_CONCAT`

  Treat `||` as a string concatenation operator (same as `CONCAT()`) rather than as a synonym for `OR`.

- `REAL_AS_FLOAT`

  Treat `REAL` as a synonym for `FLOAT`. By default, MySQL treats `REAL` as a synonym for `DOUBLE`.

- `STRICT_ALL_TABLES`

  Enable strict SQL mode for all storage engines. Invalid data values are rejected. For details, see Strict SQL Mode.

- `STRICT_TRANS_TABLES`

  Enable strict SQL mode for transactional storage engines, and when possible for nontransactional storage engines. For details, see Strict SQL Mode.

Combination SQL Modes

The following special modes are provided as shorthand for combinations of mode values from the preceding list.

- `ANSI`

  Equivalent to `REAL_AS_FLOAT`, `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`.

  As of MySQL 5.1.18, `ANSI` mode also causes the server to return an error for queries where a set function S with an outer reference $S(outer\_ref)$ cannot be aggregated in the outer query against which the outer reference has been resolved. This is such a query:

```
SELECT * FROM t1 WHERE t1.a IN (SELECT MAX(t1.b) FROM t2 WHERE ...);
```

Here, `MAX(t1.b)` cannot aggregated in the outer query because it appears in the `WHERE` clause of that query. Standard SQL requires an error in this situation. If `ANSI` mode is not enabled, the server treats `S(outer_ref)` in such queries the same way that it would interpret `S(const)`, as was always done prior to 5.1.18.

See Section 1.8, "MySQL Standards Compliance".

- `DB2`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`.

- `MAXDB`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_AUTO_CREATE_USER`.

- `MSSQL`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`.

- `MYSQL323`

  Equivalent to `MYSQL323`, `HIGH_NOT_PRECEDENCE`. This means `HIGH_NOT_PRECEDENCE` plus some `SHOW CREATE TABLE` behaviors specific to `MYSQL323`:

  - `TIMESTAMP` column display does not include `DEFAULT` or `ON UPDATE` attributes that were introduced in MySQL 4.1.

  - String column display does not include character set and collation attributes that were introduced in MySQL 4.1. For `CHAR` and `VARCHAR` columns, if the collation is binary, `BINARY` is appended to the column type.

  - The `ENGINE=engine_name` table option displays as `TYPE=engine+name`.

  - For `MEMORY` tables, the storage engine is displayed as `HEAP`.

- `MYSQL40`

  Equivalent to `MYSQL40`, `HIGH_NOT_PRECEDENCE`. This means `HIGH_NOT_PRECEDENCE` plus some behaviors specific to `MYSQL40`. These are the same as for `MYSQL323`, except that `SHOW CREATE TABLE` does not display `HEAP` as the storage engine for `MEMORY` tables.

- `ORACLE`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_AUTO_CREATE_USER`.

- `POSTGRESQL`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`.

- `TRADITIONAL`

Equivalent to `STRICT_TRANS_TABLES`, `STRICT_ALL_TABLES`, `NO_ZERO_IN_DATE`, `NO_ZERO_DATE`, `ERROR_FOR_DIVISION_BY_ZERO`, `NO_AUTO_CREATE_USER`.

Strict SQL Mode

Strict mode controls how MySQL handles invalid or missing values in data-change statements such as `INSERT` or `UPDATE`. A value can be invalid for several reasons. For example, it might have the wrong data type for the column, or it might be out of range. A value is missing when a new row to be inserted does not contain a value for a non-`NULL` column that has no explicit `DEFAULT` clause in its definition. (For a `NULL` column, `NULL` is inserted if the value is missing.)

If strict mode is not in effect, MySQL inserts adjusted values for invalid or missing values and produces warnings (see Section 13.7.5.42, "SHOW WARNINGS Syntax"). In strict mode, you can produce this behavior by using `INSERT IGNORE` or `UPDATE IGNORE`.

For statements such as `SELECT` that do not change data, invalid values generate a warning in strict mode, not an error.

Strict mode does not affect whether foreign key constraints are checked. `foreign_key_checks` can be used for that. (See Section 5.1.4, "Server System Variables".)

Strict SQL mode is in effect if either `STRICT_ALL_TABLES` or `STRICT_TRANS_TABLES` is enabled, although the effects of these modes differ somewhat:

- For transactional tables, an error occurs for invalid or missing values in a data-change statement when either `STRICT_ALL_TABLES` or `STRICT_TRANS_TABLES` is enabled. The statement is aborted and rolled back.

- For nontransactional tables, the behavior is the same for either mode if the bad value occurs in the first row to be inserted or updated: The statement is aborted and the table remains unchanged. If the statement inserts or modifies multiple rows and the bad value occurs in the second or later row, the result depends on which strict mode is enabled:

  - For `STRICT_ALL_TABLES`, MySQL returns an error and ignores the rest of the rows. However, because the earlier rows have been inserted or updated, the result is a partial update. To avoid this, use single-row statements, which can be aborted without changing the table.

  - For `STRICT_TRANS_TABLES`, MySQL converts an invalid value to the closest valid value for the column and inserts the adjusted value. If a value is missing, MySQL inserts the implicit default value for the column data type. In either case, MySQL generates a warning rather than an error and continues processing the statement. Implicit defaults are described in Section 11.6, "Data Type Default Values".

Strict mode also affects handling of division by zero, zero dates, and zeros in dates, in conjunction with the `ERROR_FOR_DIVISION_BY_ZERO`, `NO_ZERO_DATE`, and `NO_ZERO_IN_DATE` modes. For details, see the descriptions of those modes.

5.1.8 Server Plugins

MySQL 5.1 and up supports a plugin API that enables creation of server components. Plugins can be loaded at server startup, or loaded and unloaded at runtime without restarting the server. The components supported by this interface include, but are not limited to, storage engines, `INFORMATION_SCHEMA` tables, full-text parser plugins, partitioning support, and server extensions.

5.1.8.1 Installing and Uninstalling Plugins

Server plugins must be loaded into the server before they can be used. MySQL supports plugin loading at server startup and runtime. It is also possible to control the activation of loaded plugins at startup, and to unload them at runtime.

- Installing plugins

- Controlling plugin activation

- Uninstalling plugins

While a plugin is loaded, information about it is available at runtime from several sources, such as the `INFORMATION_SCHEMA.PLUGINS` table and the `SHOW PLUGINS` statement. See Section 5.1.8.2, "Obtaining Server Plugin Information".

Installing Plugins

Before a server plugin can be used, it must be installed using one of the following methods. In the descriptions, `plugin_name` stands for a plugin name such as `innodb` or `csv`.

Built-in plugins:

A built-in plugin is known by the server automatically. Normally, the server enables the plugin at startup. Some built-in plugins permit this to be changed with the `--plugin_name[=activation_state]` option.

Plugins registered in the `mysql.plugin` system table:

The `mysql.plugin` table serves as a registry of plugins (other than built-in plugins, which need not be registered). The server loads each plugin listed in the table at startup. Normally, for a plugin loaded from the `mysql.plugin` table, the server also enables the plugin. This can be changed with the `--plugin_name[=activation_state]` option.

If the server is started with the `--skip-grant-tables` option, it does not consult the `mysql.plugin` table and does not load the plugins listed there.

Plugins named with the `--plugin-load` option:

A plugin located in a plugin library file can be loaded at server startup with the `--plugin-load` option. Normally, for a plugin loaded at startup, the server also enables the plugin. This can be changed with the `--plugin_name[=activation_state]` option.

The value of each plugin-loading option is a semicolon-separated list of `name=plugin_library` and `plugin_library` values. Each `name` is the name of a plugin to load, and `plugin_library` is the name of the library object file that contains the plugin code. If a plugin library is named without any preceding plugin name, the server loads all plugins in the library. The server looks for plugin library files in the directory named by the `plugin_dir` system variable.

Plugin-loading options do not register any plugin in the `mysql.plugin` table. For subsequent restarts, the server loads the plugin again only if `--plugin-load` is given again. That is, the option produces a one-time plugin-installation operation that persists for a single server invocation.

`--plugin-load` enables plugins to be loaded even when `--skip-grant-tables` is given (which causes the server to ignore the `mysql.plugin` table). `--plugin-load` also enables plugins to be loaded at startup under configurations when plugins cannot be loaded at runtime.

Plugins installed with the `INSTALL PLUGIN` statement:

A plugin located in a plugin library file can be loaded at runtime with the `INSTALL PLUGIN` statement. The statement also registers the plugin in the `mysql.plugin` table to cause the server to load it on subsequent restarts. For this reason, `INSTALL PLUGIN` requires the `INSERT` privilege for the `mysql.plugin` table.

The plugin library file base name depends on your platform. Common suffixes are `.so` for Unix and Unix-like systems, `.dll` for Windows.

Example: The `--plugin-load` option installs a plugin at server startup. To install a plugin named `myplugin` from a plugin library file named `somepluglib.so`, use these lines in a `my.cnf` file:

```
[mysqld]
plugin-load=myplugin=somepluglib.so
```

In this case, the plugin is not registered in `mysql.plugin`. Restarting the server without the `--plugin-load` option causes the plugin not to be loaded at startup.

Alternatively, the `INSTALL PLUGIN` statement causes the server to load the plugin code from the library file at runtime:

```
mysql> INSTALL PLUGIN myplugin SONAME 'somepluglib.so';
```

`INSTALL PLUGIN` also causes "permanent" plugin registration: The plugin is listed in the `mysql.plugin` table to ensure that the server loads it on subsequent restarts.

Many plugins can be loaded either at server startup or at runtime. However, if a plugin is designed such that it must be loaded and initialized during server startup, attempts to load it using `INSTALL PLUGIN` produce an error:

```
mysql> INSTALL PLUGIN myplugin SONAME 'somepluglib.so';
ERROR 1721 (HY000): Plugin 'myplugin' is marked as not dynamically
installable. You have to stop the server to install it.
```

In this case, you must use `--plugin-load`.

If a plugin is named both using a `--plugin-load` option and (as a result of an earlier `INSTALL PLUGIN` statement) in the `mysql.plugin` table, the server starts but writes these messages to the error log:

```
[ERROR] Function 'plugin_name' already exists
[Warning] Couldn't load plugin named 'plugin_name'
with soname 'plugin_object_file'.
```

Controlling Plugin Activation

If the server knows about a plugin when it starts (for example, because the plugin is named using a `--plugin-load` option or is registered in the `mysql.plugin` table), the server loads and enables the plugin by default. It is possible to control activation state for such a plugin using a `--plugin_name[=activation_state]` startup option, where `plugin_name` is the name of the plugin to affect, such as `innodb` or `csv`. As with other options, dashes and underscores are interchangeable in option names. Also, activation state values are not case sensitive. For example, `--my_plugin=ON` and `--my-plugin=on` are equivalent.

As of MySQL 5.1.36, these options control plugin loading:

- `--plugin_name=OFF`

Tells the server to disable the plugin.

- `--plugin_name[=ON]`

  Tells the server to enable the plugin. (Specifying the option as `--plugin_name` without a value has the same effect.) If the plugin fails to initialize, the server runs with the plugin disabled.

- `--plugin_name=FORCE`

  Tells the server to enable the plugin, but if plugin initialization fails, the server does not start. In other words, this option forces the server to run with the plugin enabled or not at all.

The values `OFF`, `ON`, and `FORCE` are not case sensitive.

Suppose that `CSV`, `BLACKHOLE`, and `ARCHIVE` are built-in pluggable storage engines and that you want the server to load them at startup, subject to these conditions: The server is permitted to run if `CSV` initialization fails, must require that `BLACKHOLE` initialization succeeds, and should disable `ARCHIVE`. To accomplish that, use these lines in an option file:

```
[mysqld]
csv=ON
blackhole=FORCE
archive=OFF
```

The `--enable-plugin_name` option format is a synonym for `--plugin_name=ON`. The `--disable-plugin_name` and `--skip-plugin_name` option formats are synonyms for `--plugin_name=OFF`.

Before MySQL 5.1.36, plugin options are boolean options (see Section 4.2.5, "Program Option Modifiers"). That is, any of these options enable the plugin:

```
--plugin_name
--plugin_name=1
--enable-plugin_name
```

And these options disable the plugin:

```
--plugin_name=0
--disable-plugin_name
--skip-plugin_name
```

If you upgrade to MySQL 5.1.36 or later from an older version and previously used options of the form `--plugin_name=0` or `--plugin_name=1`, the equivalent options are now `--plugin_name=OFF` and `--plugin_name=ON`, respectively. You also have the choice of requiring plugins to start successfully by using `--plugin_name=FORCE`.

If a plugin is disabled, either explicitly with `OFF` or implicitly because it was enabled with `ON` but failed to initialize, aspects of server operation that require the plugin will change. For example, if the plugin implements a storage engine, existing tables for the storage engine become inaccessible, and attempts to create new tables for the storage engine result in tables that use the default storage engine unless the `NO_ENGINE_SUBSTITUTION` SQL mode is enabled to cause an error to occur instead.

Disabling a plugin may require adjustment to other options. For example, if you start the server using `--skip-innodb` to disable `InnoDB`, other `innodb_xxx` options likely will need to be omitted from the startup command. In addition, if the server is configured to use `InnoDB` as the default storage engine, it will not start unless you specify another available storage engine with `--default-storage-engine`.

Uninstalling Plugins

At runtime, the `UNINSTALL PLUGIN` statement disables and uninstalls a plugin known to the server. The statement unloads the plugin and removes it from the `mysql.plugin` table, if it is registered there. For this reason, `UNINSTALL PLUGIN` statement requires the `DELETE` privilege for the `mysql.plugin` table. With the plugin no longer registered in the table, the server will not load the plugin automatically for subsequent restarts.

`UNINSTALL PLUGIN` can unload a plugin regardless of whether it was loaded at runtime with `INSTALL PLUGIN` or at startup with a plugin-loading option.

`UNINSTALL PLUGIN` cannot unload plugins that are built in to the server. These can be identified as those that have a library name of `NULL` in the output from `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`.

To uninstall a plugin that currently is loaded at server startup with a plugin-loading option, use this procedure.

1. Remove any options related to the plugin from the `my.cnf` file.

2. Restart the server.

3. Plugins normally are installed using either a plugin-loading option at startup or with `INSTALL PLUGIN` at runtime, but not both. However, removing options for a plugin from the `my.cnf` file may not be sufficient to uninstall it if at some point `INSTALL PLUGIN` has also been used. If the plugin still appears in the output from `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`, use `UNINSTALL PLUGIN` to remove it from the `mysql.plugin` table. Then restart the server again.

5.1.8.2 Obtaining Server Plugin Information

There are several ways to determine which plugins are installed in the server:

- The `INFORMATION_SCHEMA.PLUGINS` table contains a row for each loaded plugin. Any that have a `PLUGIN_LIBRARY` value of `NULL` are built in and cannot be unloaded.

```
mysql> SELECT * FROM information_schema.PLUGINS\G
*************************** 1. row ***************************
           PLUGIN_NAME: binlog
        PLUGIN_VERSION: 1.0
         PLUGIN_STATUS: ACTIVE
           PLUGIN_TYPE: STORAGE ENGINE
   PLUGIN_TYPE_VERSION: 50158.0
        PLUGIN_LIBRARY: NULL
PLUGIN_LIBRARY_VERSION: NULL
         PLUGIN_AUTHOR: MySQL AB
    PLUGIN_DESCRIPTION: This is a pseudo storage engine to represent the binlog in a transaction
        PLUGIN_LICENSE: GPL
...
*************************** 10. row ***************************
           PLUGIN_NAME: InnoDB
        PLUGIN_VERSION: 1.0
         PLUGIN_STATUS: ACTIVE
           PLUGIN_TYPE: STORAGE ENGINE
   PLUGIN_TYPE_VERSION: 50158.0
        PLUGIN_LIBRARY: ha_innodb_plugin.so
PLUGIN_LIBRARY_VERSION: 1.0
         PLUGIN_AUTHOR: Innobase Oy
    PLUGIN_DESCRIPTION: Supports transactions, row-level locking,
                       and foreign keys
        PLUGIN_LICENSE: GPL
...
```

- The `SHOW PLUGINS` statement displays a row for each loaded plugin. Any that have a `Library` value of `NULL` are built in and cannot be unloaded.

```
mysql> SHOW PLUGINS\G
*************************** 1. row ***************************
   Name: binlog
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
...
*************************** 10. row ***************************
   Name: InnoDB
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: ha_innodb_plugin.so
License: GPL
...
```

- The `mysql.plugin` table shows which plugins have been registered with `INSTALL PLUGIN`. The table contains only plugin names and library file names, so it does not provide as much information as the `PLUGINS` table or the `SHOW PLUGINS` statement.

5.1.9 Server-Side Help

MySQL Server supports a `HELP` statement that returns information from the MySQL Reference manual (see Section 13.8.3, "HELP Syntax"). Several tables in the `mysql` system database contain the information needed to support this statement (see Section 5.3, "The mysql System Database"). The proper operation of this statement requires that these help tables be initialized, which is done by processing the contents of the `fill_help_tables.sql` script.

If you install MySQL using a binary or source distribution on Unix, help table content initialization occurs when you initialize the data directory (see Section 2.12.1, "Initializing the Data Directory"). For an RPM distribution on Linux or binary distribution on Windows, content initialization occurs as part of the MySQL installation process.

If you upgrade MySQL using a binary distribution, help table content is not upgraded automatically, but you can upgrade it manually. Locate the `fill_help_tables.sql` file in the `share` or `share/mysql` directory. Change location into that directory and process the file with the `mysql` client as follows:

```
shell> mysql -u root mysql < fill_help_tables.sql
```

You can also obtain the latest `fill_help_tables.sql` at any time to upgrade your help tables. Download the proper file for your version of MySQL from http://dev.mysql.com/doc/index-other.html. After downloading and uncompressing the file, process it with `mysql` as described previously.

If you are working with Bazaar and a MySQL development source tree, you must use a downloaded copy of the `fill_help_tables.sql` file because the source tree contains only a "stub" version.

> **Note**
>
> For a server that participates in replication, the help table content upgrade process involves multiple servers. For details, see Section 16.4.1.30, "Replication of Server-Side Help Tables".

5.1.10 Server Response to Signals

On Unix, signals can be sent to processes. `mysqld` responds to signals sent to it as follows:

- `SIGTERM` causes the server to shut down.

- `SIGHUP` causes the server to reload the grant tables and to flush tables, logs, the thread cache, and the host cache. These actions are like various forms of the `FLUSH` statement. The server also writes a status report to the error log that has this format:

```
Status information:

Current dir: /var/mysql/data/
Running threads: 0  Stack size: 196608
Current locks:

Key caches:
default
Buffer_size:       8388600
Block_size:           1024
Division_limit:        100
Age_limit:             300
blocks used:             0
not flushed:             0
w_requests:              0
writes:                  0
r_requests:              0
reads:                   0

handler status:
read_key:            0
read_next:           0
read_rnd             0
read_first:          1
write:               0
delete               0
update:              0

Table status:
Opened tables:           5
Open tables:             0
Open files:              7
Open streams:            0

Alarm status:
Active alarms:    1
Max used alarms: 2
Next alarm time: 67
```

5.1.11 The Server Shutdown Process

The server shutdown process takes place as follows:

1. The shutdown process is initiated.

   This can occur initiated several ways. For example, a user with the `SHUTDOWN` privilege can execute a `mysqladmin shutdown` command. `mysqladmin` can be used on any platform supported by MySQL. Other operating system-specific shutdown initiation methods are possible as well: The server shuts down on Unix when it receives a `SIGTERM` signal. A server running as a service on Windows shuts down when the services manager tells it to.

2. The server creates a shutdown thread if necessary.

   Depending on how shutdown was initiated, the server might create a thread to handle the shutdown process. If shutdown was requested by a client, a shutdown thread is created. If shutdown is the result of receiving a `SIGTERM` signal, the signal thread might handle shutdown itself, or it might create a

separate thread to do so. If the server tries to create a shutdown thread and cannot (for example, if memory is exhausted), it issues a diagnostic message that appears in the error log:

```
Error: Can't create thread to kill server
```

3. The server stops accepting new connections.

   To prevent new activity from being initiated during shutdown, the server stops accepting new client connections by closing the handlers for the network interfaces to which it normally listens for connections: the TCP/IP port, the Unix socket file, the Windows named pipe, and shared memory on Windows.

4. The server terminates current activity.

   For each thread associated with a client connection, the server breaks the connection to the client and marks the thread as killed. Threads die when they notice that they are so marked. Threads for idle connections die quickly. Threads that currently are processing statements check their state periodically and take longer to die. For additional information about thread termination, see Section 13.7.6.4, "KILL Syntax", in particular for the instructions about killed `REPAIR TABLE` or `OPTIMIZE TABLE` operations on `MyISAM` tables.

   For threads that have an open transaction, the transaction is rolled back. If a thread is updating a nontransactional table, an operation such as a multiple-row `UPDATE` or `INSERT` may leave the table partially updated because the operation can terminate before completion.

   If the server is a master replication server, it treats threads associated with currently connected slaves like other client threads. That is, each one is marked as killed and exits when it next checks its state.

   If the server is a slave replication server, it stops the I/O and SQL threads, if they are active, before marking client threads as killed. The SQL thread is permitted to finish its current statement (to avoid causing replication problems), and then stops. In MySQL 5.1.34 and earlier, if the SQL thread was in the middle of a transaction at this point, the transaction was rolled back; in MySQL 5.1.35 and later, the server waits until the current replication event group (if any) has finished executing, or until the user issues a `KILL QUERY` or `KILL CONNECTION` statement. See also Section 13.4.2.8, "STOP SLAVE Syntax".

   If the slave is updating a nontransactional table when it is forcibly killed, the slave's data may become inconsistent with the master.

5. The server shuts down or closes storage engines.

   At this stage, the server flushes the table cache and closes all open tables.

   Each storage engine performs any actions necessary for tables that it manages. For example, `MyISAM` flushes any pending index writes for a table. `InnoDB` flushes its buffer pool to disk (unless `innodb_fast_shutdown` is 2), writes the current LSN to the tablespace, and terminates its own internal threads.

6. The server exits.

5.2 The MySQL Data Directory

Information managed by the MySQL server is stored under a directory known as the data directory. The following list briefly describes the items typically found in the data directory, with cross references for additional information:

- Each data directory subdirectory corresponds to a database managed by the server:

  - The `mysql` directory corresponds to the `mysql` system database, which contains information required by the MySQL server as it runs. See Section 5.3, "The mysql System Database".

  - Other subdirectories correspond to databases created by users or applications.

- Log files written by the server. See Section 5.4, "MySQL Server Logs".

- `InnoDB` tablespace and log files. See Section 14.6, "The InnoDB Storage Engine".

- The server process ID file (while the server is running).

Some items in the preceding list can be relocated elsewhere; for any given MySQL installation, check the server configuration to determine whether items have been moved. In addition, the location of the data directory itself can be discovered or configured using the `datadir` system variable.

5.3 The mysql System Database

The `mysql` database is the system database. It contains tables that store information required by the MySQL server as it runs.

Tables in the `mysql` database fall into these categories:

- Grant tables

- Object information tables

- General log and slow query log tables

- Server-side help tables

- Time zone tables

- Replication tables

- Miscellaneous tables

Grant System Tables

These system tables contain grant information about user accounts and the privileges held by them:

- `user`: User accounts, global privileges, and other non-privilege columns.

- `db`: Database-level privileges.

- `host`: Obsolete.

- `tables_priv`: Table-level privileges.

- `columns_priv`: Column-level privileges.

- `procs_priv`: Stored procedure and function privileges.

For more information about the structure, contents, and purpose of the grant tables, see Section 6.2.2, "Grant Tables".

Object Information System Tables

These system tables contain information about stored programs, user-defined functions, and server-side plugins:

- `event`: Information about Event Scheduler events. See Section 19.4, "Using the Event Scheduler".

- `func`: Information about user-defined functions. See Section 22.3, "Adding New Functions to MySQL".

- `plugin`: Information about server plugins. See Section 5.1.8.1, "Installing and Uninstalling Plugins", and Section 22.2, "The MySQL Plugin API".

- `proc`: Information about stored procedures and functions. See Section 19.2, "Using Stored Routines (Procedures and Functions)".

Log System Tables

The server uses these system tables for logging:

- `general_log`: The general query log table.

- `slow_log`: The slow query log table.

For more information, see Section 5.4, "MySQL Server Logs".

Server-Side Help System Tables

These system tables contain server-side help information:

- `help_category`: Information about help categories.

- `help_keyword`: Keywords associated with help topics.

- `help_relation`: Mappings between help keywords and topics.

- `help_topic`: Help topic contents.

For more information, see Section 5.1.9, "Server-Side Help".

Time Zone System Tables

These system tables contain time zone information:

- `time_zone`: List of time zone IDs and whether they use leap seconds.

- `time_zone_leap_second`: When leap seconds occur.

- `time_zone_name`: Mappings between time zone IDs and names.

- `time_zone_transition`, `time_zone_transition_type`: Time zone descriptions.

For more information, see Section 10.6, "MySQL Server Time Zone Support".

Replication System Tables

The server uses the `ndb_binlog_index` system table to store binary log information for MySQL Cluster replication. See Section 17.6.4, "MySQL Cluster Replication Schema and Tables".

Miscellaneous System Tables

Other system tables do not fit the preceding categories:

- `servers`: Used by the `FEDERATED` storage engine. See Section 14.11.2.2, "Creating a FEDERATED Table Using CREATE SERVER".

5.4 MySQL Server Logs

MySQL Server has several logs that can help you find out what activity is taking place.

Log Type	Information Written to Log
Error log	Problems encountered starting, running, or stopping `mysqld`
General query log	Established client connections and statements received from clients
Binary log	Statements that change data (also used for replication)
Relay log	Data changes received from a replication master server
Slow query log	Queries that took more than `long_query_time` seconds to execute
DDL log (metadata log)	Metadata operations performed by DDL statements

By default, no logs are enabled, except the error log on Windows. (The DDL log is always created when required, and has no user-configurable options; see Section 5.4.6, "The DDL Log".) The following log-specific sections provide information about the server options that enable logging.

By default, the server writes files for all enabled logs in the data directory. You can force the server to close and reopen the log files (or in some cases switch to a new log file) by flushing the logs. Log flushing occurs when you issue a `FLUSH LOGS` statement; execute `mysqladmin` with a `flush-logs` or `refresh` argument; or execute `mysqldump` with a `--flush-logs` or `--master-data` option. See Section 13.7.6.3, "FLUSH Syntax", Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server", and Section 4.5.4, "`mysqldump` — A Database Backup Program". In addition, the binary log is flushed when its size reaches the value of the `max_binlog_size` system variable.

You can control the general query and slow query logs during runtime. You can enable or disable logging, or change the log file name. You can tell the server to write general query and slow query entries to log tables, log files, or both. For details, see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations", Section 5.4.3, "The General Query Log", and Section 5.4.5, "The Slow Query Log".

The relay log is used only on slave replication servers, to hold data changes from the master server that must also be made on the slave. For discussion of relay log contents and configuration, see Section 16.2.2.1, "The Slave Relay Log".

For information about log maintenance operations such as expiration of old log files, see Section 5.4.7, "Server Log Maintenance".

For information about keeping logs secure, see Section 6.1.2.3, "Passwords and Logging".

5.4.1 Selecting General Query and Slow Query Log Output Destinations

As of MySQL 5.1.6, MySQL Server provides flexible control over the destination of output to the general query log and the slow query log, if those logs are enabled. Possible destinations for log entries are log files or the `general_log` and `slow_log` tables in the `mysql` database. Either or both destinations can be selected. (Before MySQL 5.1.6, the server uses only log files as the destination for general query log and slow query log entries.)

> **Note**
>
> For new installations of MySQL 5.1.6 or higher, the log tables are created during the installation procedure along with the other system tables. If you upgrade MySQL from a release older than 5.1.6 to MySQL 5.1.6 or higher, you must upgrade the system tables after upgrading to make sure that the log tables exist. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

Logging to tables incurs significantly more server overhead than logging to files. If you enable the general log or slow query log and require highest performance, you should use file logging, not table logging.

Log control at server startup. The `--log-output` option specifies the destination for log output, if logging is enabled. This option does not in itself enable the logs. Its syntax is `--log-output[=value,...]`:

- If `--log-output` is given with a value, the value should be a comma-separated list of one or more of the words `TABLE` (log to tables), `FILE` (log to files), or `NONE` (do not log to tables or files). `NONE`, if present, takes precedence over any other specifiers.

- If `--log-output` is omitted or given without a value, the default is `FILE`. (For MySQL 5.1.6 through 5.1.20, the default logging destination is `TABLE`.)

The `general_log` system variable controls logging to the general query log for the selected log destinations. If specified at server startup, `general_log` takes an optional argument of 1 or 0 to enable or disable the log. To specify a file name other than the default for file logging, set the `general_log_file` variable. Similarly, the `slow_query_log` variable controls logging to the slow query log for the selected destinations and setting `slow_query_log_file` specifies a file name for file logging. If either log is enabled, the server opens the corresponding log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. Prior to MySQL 5.1.29, the `--log` and `--log-slow-queries` options enable the general query log and slow query log. Either option may be given with a file name argument to specify a log file name to override the default.

Examples:

- To write general query log entries to the log table and the log file, use `--log-output=TABLE,FILE` to select both log destinations and `--general_log` to enable the general query log.

- To write general and slow query log entries only to the log tables, use `--log-output=TABLE` to select tables as the log destination and `--general_log` and `--slow_query_log` to enable both logs.

- To write slow query log entries only to the log file, use `--log-output=FILE` to select files as the log destination and `--slow_query_log` to enable the slow query log. (In this case, because the default log destination is `FILE`, you could omit the `--log-output` option.)

Log control at runtime. The system variables associated with log tables and files enable runtime control over logging:

- The global `log_output` system variable indicates the current logging destination. It can be modified at runtime to change the destination.

- The global `general_log` and `slow_query_log` variables indicate whether the general query log and slow query log are enabled (`ON`) or disabled (`OFF`). You can set these variables at runtime to control whether the logs are enabled.

- The global `general_log_file` and `slow_query_log_file` variables indicate the names of the general query log and slow query log files. As of MySQL 5.1.29, you can set these variables at server startup or at runtime to change the names of the log files. Before MySQL 5.1.29, you can set these

variables only at runtime, but the `--log` and `--log-slow-queries` options can be given with a file name argument at startup to change the log file names from their default values.

- To disable or enable general query logging for the current connection, set the session `sql_log_off` variable to `ON` or `OFF`.

The use of tables for log output offers the following benefits:

- Log entries have a standard format. To display the current structure of the log tables, use these statements:

```
SHOW CREATE TABLE mysql.general_log;
SHOW CREATE TABLE mysql.slow_log;
```

- Log contents are accessible through SQL statements. This enables the use of queries that select only those log entries that satisfy specific criteria. For example, to select log contents associated with a particular client (which can be useful for identifying problematic queries from that client), it is easier to do this using a log table than a log file.

- Logs are accessible remotely through any client that can connect to the server and issue queries (if the client has the appropriate log table privileges). It is not necessary to log in to the server host and directly access the file system.

The log table implementation has the following characteristics:

- In general, the primary purpose of log tables is to provide an interface for users to observe the runtime execution of the server, not to interfere with its runtime execution.

- `CREATE TABLE`, `ALTER TABLE`, and `DROP TABLE` are valid operations on a log table. For `ALTER TABLE` and `DROP TABLE`, the log table cannot be in use and must be disabled, as described later.

- By default, the log tables use the `CSV` storage engine that writes data in comma-separated values format. For users who have access to the `.CSV` files that contain log table data, the files are easy to import into other programs such as spreadsheets that can process CSV input.

  Beginning with MySQL 5.1.12, the log tables can be altered to use the `MyISAM` storage engine. You cannot use `ALTER TABLE` to alter a log table that is in use. The log must be disabled first. No engines other than `CSV` or `MyISAM` are legal for the log tables.

- To disable logging so that you can alter (or drop) a log table, you can use the following strategy. The example uses the general query log; the procedure for the slow query log is similar but uses the `slow_log` table and `slow_query_log` system variable.

```
SET @old_log_state = @@global.general_log;
SET GLOBAL general_log = 'OFF';
ALTER TABLE mysql.general_log ENGINE = MyISAM;
SET GLOBAL general_log = @old_log_state;
```

- `TRUNCATE TABLE` is a valid operation on a log table. It can be used to expire log entries.

- As of MySQL 5.1.13, `RENAME TABLE` is a valid operation on a log table. You can atomically rename a log table (to perform log rotation, for example) using the following strategy:

```
USE mysql;
DROP TABLE IF EXISTS general_log2;
CREATE TABLE general_log2 LIKE general_log;
RENAME TABLE general_log TO general_log_backup, general_log2 TO general_log;
```

- `LOCK TABLES` cannot be used on a log table.

- `INSERT`, `DELETE`, and `UPDATE` cannot be used on a log table. These operations are permitted only internally to the server itself.

- `FLUSH TABLES WITH READ LOCK` and the state of the `read_only` system variable have no effect on log tables. The server can always write to the log tables.

- Entries written to the log tables are not written to the binary log and thus are not replicated to slave servers.

- To flush the log tables or log files, use `FLUSH TABLES` or `FLUSH LOGS`, respectively. (From MySQL 5.1.12 to 5.1.20, `FLUSH TABLES` ignores log tables and `FLUSH LOGS` flushes both the log tables and files.)

- Partitioning of log tables is not permitted beginning with MySQL 5.1.20, and not recommended before that.

- Before MySQL 5.1.64, `mysqldump` does not dump the `general_log` or `slow_query_log` tables for dumps of the `mysql` database. As of 5.1.64, the dump includes statements to recreate those tables so that they are not missing after reloading the dump file. Log table contents are not dumped.

5.4.2 The Error Log

The error log contains information indicating when `mysqld` was started and stopped and also any critical errors that occur while the server is running. If `mysqld` notices a table that needs to be automatically checked or repaired, it writes a message to the error log.

On some operating systems, the error log contains a stack trace if `mysqld` exits abnormally. The trace can be used to determine where `mysqld` exited. See Section 22.4, "Debugging and Porting MySQL".

If `mysqld_safe` is used to start `mysqld` and `mysqld` exits abnormally, `mysqld_safe` notices this, restarts `mysqld`, and writes a `mysqld restarted` message to the error log.

In the following discussion, "console" means `stderr`, the standard error output; this is your terminal or console window unless the standard error output has been redirected. (For example, if invoked with the `--syslog` option, `mysqld_safe` arranges for the server's `stderr` to be sent to `syslog`, as described later.)

On Windows, the `--log-error`, `--pid-file`, and `--console` options affect error logging:

- If no log file name is specified, the default log file is *host_name*`.err` in the data directory, unless the `--pid-file` option is specified. In that case, the default name is the PID file base name with a suffix of `.err` in the data directory.

- Without `--log-error`, `mysqld` writes error messages to the default log file.

- With `--log-error[=`*file_name*`]`, `mysqld` writes error messages to an error log file. `mysqld` writes to the named file if present, creating it in the data directory unless an absolute path name is given to specify a different directory. If no file is named, `mysqld` writes to the default log file.

- With `--console`, `mysqld` writes error messages to the console, unless `--log-error` is also given. If both options are present, the last one takes precedence.

In addition, on Windows, the server writes events and error messages to the Windows Event Log within the Application log. Entries marked as `Warning` and `Note` are written to the Event Log, but not informational

messages such as information statements from individual storage engines. These log entries have a source of `MySQL`. You cannot disable writing information to the Windows Event Log.

On Unix and Unix-like systems, `mysqld` writes error log messages as follows:

- Without `--log-error`, `mysqld` writes error messages to the console.

- With `--log-error[=file_name]`, `mysqld` writes error messages to an error log file. The server uses the named file if present, creating it in the data directory unless an absolute path name is given to specify a different directory. If no file is named, the default name is *host_name*`.err` in the data directory.

At runtime, `log_error` system variable indicates the error log file name if error output is written to a file.

If you specify `--log-error` in an option file in a `[mysqld]`, `[server]`, or `[mysqld_safe]` section, `mysqld_safe` will find and use the option.

If you flush the logs using `FLUSH LOGS` or `mysqladmin flush-logs` and `mysqld` is writing the error log to a file (for example, if it was started with the `--log-error` option), the effect is version dependent:

- As of MySQL 5.1.51, the server closes and reopens the log file. To rename the file, do so manually before flushing. Then flushing the logs reopens a new file with the original file name. For example, to rename the file and create a new one, use the following commands:

```
shell> mv host_name.err host_name.err-old
shell> mysqladmin flush-logs
shell> mv host_name.err-old backup-directory
```

  On Windows, use `rename` rather than `mv`.

- Prior to MySQL 5.1.51, the server renames the current log file with the suffix `-old`, then creates a new empty log file. Be aware that a second log-flushing operation thus causes the original error log file to be lost unless you save it under a different name. On Windows, you cannot rename the error log while the server has it open before MySQL 5.1.51. To avoid a restart, flush the logs first to cause the server to rename the original file and create a new one, then save the renamed file. That also works on Unix, or you can use the commands shown earlier.

If the server is not writing to a named file, no error log renaming occurs when the logs are flushed.

If you use `mysqld_safe` to start `mysqld`, `mysqld_safe` arranges for `mysqld` to write error messages to a log file or (as of MySQL 5.1.20) to `syslog`:

- Before 5.1.20, `mysqld_safe` behavior is to log to a file, using the default error log file if the `--log-error` option is not given to `mysqld_safe`. Otherwise, `mysqld_safe` uses the file name specified using `--log-error=file_name`.

- From 5.1.20 on, `mysqld_safe` has two additional error-logging options, `--syslog` and `--skip-syslog`.

  In 5.1.21 and up, the default with no logging options is `--skip-syslog`, which is compatible with the default behavior of writing an error log file for releases prior to 5.1.20. To explicitly specify use of an error log file, specify `--log-error=file_name` to `mysqld_safe`, and `mysqld_safe` will arrange for `mysqld` to write messages to a log file. To use `syslog` instead, specify the `--syslog` option.

  In 5.1.20 *only*, **the following conditions apply**: 1) The default is to use `syslog`, which is not compatible with releases prior to 5.1.20. 2) Logging to `syslog` may fail to operate correctly in some cases; if so, use `--skip-syslog` or `--log-error`.

For logging to `syslog`, messages from `mysqld_safe` and `mysqld` are written with a tag of `mysqld_safe` and `mysqld`, respectively. As of MySQL 5.1.21, to specify a suffix for the tag, use `--syslog-tag=tag`, which modifies the tags to be `mysqld_safe-tag` and `mysqld-tag`.

The `--log-warnings` option or `log_warnings` system variable can be used to control warning logging to the error log. The default value is enabled (1). Warning logging can be disabled using a value of 0. If the value is greater than 1, aborted connections are written to the error log. See Section B.5.2.11, "Communication Errors and Aborted Connections".

5.4.3 The General Query Log

The general query log is a general record of what `mysqld` is doing. The server writes information to this log when clients connect or disconnect, and it logs each SQL statement received from clients. The general query log can be very useful when you suspect an error in a client and want to know exactly what the client sent to `mysqld`.

`mysqld` writes statements to the query log in the order that it receives them, which might differ from the order in which they are executed. This logging order is in contrast with that of the binary log, for which statements are written after they are executed but before any locks are released. In addition, the query log may contain statements that only select data while such statements are never written to the binary log.

When using statement-based binary logging on a replication master server, statements received by its slaves are written to the query log of each slave. Statements are written to the query log of the master server if a client reads events with the `mysqlbinlog` utility and passes them to the server.

However, when using row-based binary logging, updates are sent as row changes rather than SQL statements, and thus these statements are never written to the query log when `binlog_format` is `ROW`. A given update also might not be written to the query log when this variable is set to `MIXED`, depending on the statement used. See Section 16.1.2.1, "Advantages and Disadvantages of Statement-Based and Row-Based Replication", for more information.

Control the general query log at server startup as follows:

- Before 5.1.6, the general query log destination is always a file. To enable the log, start `mysqld` with the `--log[=file_name]` or `-l [file_name]` option.

- As of MySQL 5.1.6, the destination can be a file or a table, or both. Start `mysqld` with the `--log[=file_name]` or `-l [file_name]` option to enable the general query log, and optionally use `--log-output` to specify the log destination (as described in Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations").

- As of MySQL 5.1.12, as an alternative to `--log` or `-l`, use `--general_log[={0|1}]` to specify the initial general query log state. In this case, the default general query log file name is used. With no argument or an argument of 1, `--general_log` enables the log. With an argument of 0, this option disables the log.

- As of MySQL 5.1.29, use `--general_log[={0|1}]` to enable or disable the general query log, and optionally `--general_log_file=file_name` to specify a log file name. The `--log` and `-l` options are deprecated.

If the general query log file is enabled but no name is specified, the default name is `host_name.log` and the server creates the file in the same directory where it creates the PID file. If a name is given, the server creates the file in the data directory unless an absolute path name is given to specify a different directory.

To disable or enable the general query log or change the log file name at runtime, use the global `general_log` and `general_log_file` system variables. Set `general_log` to 0 (or `OFF`) to disable

the log or to 1 (or `ON`) to enable it. Set `general_log_file` to specify the name of the log file. If a log file already is open, it is closed and the new file is opened.

When the general query log is enabled, the server writes output to any destinations specified by the `--log-output` option or `log_output` system variable. If you enable the log, the server opens the log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. If the destination is `NONE`, the server writes no queries even if the general log is enabled. Setting the log file name has no effect on logging if the log destination value does not contain `FILE`.

Server restarts and log flushing do not cause a new general query log file to be generated (although flushing closes and reopens it). On Unix, you can rename the file and create a new one by using the following commands:

```
shell> mv host_name.log host_name-old.log
shell> mysqladmin flush-logs
shell> mv host_name-old.log backup-directory
```

On Windows, you cannot rename the general query log file while the server has it open before MySQL 5.1.3. You must stop the server, rename the file, and then restart the server to create a new log file.

As of MySQL 5.1.12, you can rename the general query log file at runtime by disabling the log:

```
SET GLOBAL general_log = 'OFF';
```

With the log disabled, rename the log file externally; for example, from the command line. Then enable the log again:

```
SET GLOBAL general_log = 'ON';
```

This method works on any platform and does not require a server restart.

The session `sql_log_off` variable can be set to `ON` or `OFF` to disable or enable general query logging for the current connection.

The general query log should be protected because logged statements might contain passwords. See Section 6.1.2.3, "Passwords and Logging".

5.4.4 The Binary Log

The binary log contains "events" that describe database changes such as table creation operations or changes to table data. It also contains events for statements that potentially could have made changes (for example, a `DELETE` which matched no rows), unless row-based logging is used. The binary log also contains information about how long each statement took that updated data. The binary log has two important purposes:

- For replication, the binary log on a master replication server provides a record of the data changes to be sent to slave servers. The master server sends the events contained in its binary log to its slaves, which execute those events to make the same data changes that were made on the master. See Section 16.2, "Replication Implementation".

- Certain data recovery operations require use of the binary log. After a backup has been restored, the events in the binary log that were recorded after the backup was made are re-executed. These events

bring databases up to date from the point of the backup. See Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log".

The binary log is not used for statements such as `SELECT` or `SHOW` that do not modify data. To log all statements (for example, to identify a problem query), use the general query log. See Section 5.4.3, "The General Query Log".

Running a server with binary logging enabled makes performance slightly slower. However, the benefits of the binary log in enabling you to set up replication and for restore operations generally outweigh this minor performance decrement.

The binary log should be protected because logged statements might contain passwords. See Section 6.1.2.3, "Passwords and Logging".

The following discussion describes some of the server options and variables that affect the operation of binary logging. For a complete list, see Section 16.1.3.4, "Binary Log Options and Variables".

To enable the binary log, start the server with the `--log-bin[=base_name]` option. If no `base_name` value is given, the default name is the value of the `pid-file` option (which by default is the name of host machine) followed by `-bin`. If the base name is given, the server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. It is recommended that you specify a base name explicitly rather than using the default of the host name; see Section B.5.7, "Known Issues in MySQL", for the reason.

> **Note**
>
> From MySQL 5.1.18 through 5.1.22, "mysql" was used when no `base_name` was specified. Also in these versions, a path given as part of the `--log-bin` options was treated as absolute rather than relative. The previous behaviors were restored in MySQL 5.1.23. (See Bug #28603 and Bug #28597.)

If you supply an extension in the log name (for example, `--log-bin=base_name.extension`), the extension is silently removed and ignored.

`mysqld` appends a numeric extension to the binary log base name to generate binary log file names. The number increases each time the server creates a new log file, thus creating an ordered series of files. The server creates a new file in the series each time it starts or flushes the logs. The server also creates a new binary log file automatically after the current log's size reaches `max_binlog_size`. A binary log file may become larger than `max_binlog_size` if you are using large transactions because a transaction is written to the file in one piece, never split between files.

To keep track of which binary log files have been used, `mysqld` also creates a binary log index file that contains the names of all used binary log files. By default, this has the same base name as the binary log file, with the extension `'.index'`. You can change the name of the binary log index file with the `--log-bin-index[=file_name]` option. You should not manually edit this file while `mysqld` is running; doing so would confuse `mysqld`.

The term "binary log file" generally denotes an individual numbered file containing database events. The term "binary log" collectively denotes the set of numbered binary log files plus the index file.

A client that has the `SUPER` privilege can disable binary logging of its own statements by using a `SET sql_log_bin=0` statement. See Section 5.1.4, "Server System Variables".

The format of the events recorded in the binary log is dependent on the binary logging format. Three format types are supported, row-based logging, statement-based logging and mixed-base logging. The binary logging format used depends on the MySQL version. For general descriptions of the logging formats, see

Section 5.4.4.1, "Binary Logging Formats". For detailed information about the format of the binary log, see MySQL Internals: The Binary Log.

The server evaluates the `--binlog-do-db` and `--binlog-ignore-db` options in the same way as it does the `--replicate-do-db` and `--replicate-ignore-db` options. For information about how this is done, see Section 16.2.3.1, "Evaluation of Database-Level Replication and Binary Logging Options".

If you are replicating from a MySQL Cluster to a standalone MySQL Server, you should be aware that the `NDB` storage engine uses default values for some binary logging options (including options specific to `NDB` such as `--ndb-log-update-as-write`) that differ from those used by other storage engines. If not corrected for, these differences can lead to divergence of the master's and slave's binary logs. For more information, see Replication from NDB to other storage engines. In particular, if you are using a nontransactional storage engine such as `MyISAM` on the slave, see Replication from NDB to a nontransactional storage engine.

A replication slave server by default does not write to its own binary log any data modifications that are received from the replication master. To log these modifications, start the slave with the `--log-slave-updates` option in addition to the `--log-bin` option (see Section 16.1.3.3, "Replication Slave Options and Variables"). This is done when a slave is also to act as a master to other slaves in chained replication.

You can delete all binary log files with the `RESET MASTER` statement, or a subset of them with `PURGE BINARY LOGS`. See Section 13.7.6.6, "RESET Syntax", and Section 13.4.1.1, "PURGE BINARY LOGS Syntax".

If you are using replication, you should not delete old binary log files on the master until you are sure that no slave still needs to use them. For example, if your slaves never run more than three days behind, once a day you can execute `mysqladmin flush-logs` on the master and then remove any logs that are more than three days old. You can remove the files manually, but it is preferable to use `PURGE BINARY LOGS`, which also safely updates the binary log index file for you (and which can take a date argument). See Section 13.4.1.1, "PURGE BINARY LOGS Syntax".

You can display the contents of binary log files with the `mysqlbinlog` utility. This can be useful when you want to reprocess statements in the log for a recovery operation. For example, you can update a MySQL server from the binary log as follows:

```
shell> mysqlbinlog log_file | mysql -h server_name
```

`mysqlbinlog` also can be used to display replication slave relay log file contents because they are written using the same format as binary log files. For more information on the `mysqlbinlog` utility and how to use it, see Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files". For more information about the binary log and recovery operations, see Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log".

Binary logging is done immediately after a statement or transaction completes but before any locks are released or any commit is done. This ensures that the log is logged in commit order.

Updates to nontransactional tables are stored in the binary log immediately after execution. In MySQL 5.1.22 and earlier versions of MySQL 5.1, an `UPDATE` statement using a stored function that modified a nontransactional table was not logged if it failed, and an `INSERT ... ON DUPLICATE KEY UPDATE` statement that encountered a duplicate key constraint—but did not actually change any data—was not logged. Beginning with MySQL 5.1.23, both of these statements are written to the binary log. (Bug #23333)

Within an uncommitted transaction, all updates (`UPDATE`, `DELETE`, or `INSERT`) that change transactional tables such as `InnoDB` tables are cached until a `COMMIT` statement is received by the server. At that point, `mysqld` writes the entire transaction to the binary log before the `COMMIT` is executed.

Modifications to nontransactional tables cannot be rolled back. If a transaction that is rolled back includes modifications to nontransactional tables, the entire transaction is logged with a `ROLLBACK` statement at the end to ensure that the modifications to those tables are replicated.

When a thread that handles the transaction starts, it allocates a buffer of `binlog_cache_size` to buffer statements. If a statement is bigger than this, the thread opens a temporary file to store the transaction. The temporary file is deleted when the thread ends.

The `Binlog_cache_use` status variable shows the number of transactions that used this buffer (and possibly a temporary file) for storing statements. The `Binlog_cache_disk_use` status variable shows how many of those transactions actually had to use a temporary file. These two variables can be used for tuning `binlog_cache_size` to a large enough value that avoids the use of temporary files.

The `max_binlog_cache_size` system variable (default 4GB, which is also the maximum) can be used to restrict the total size used to cache a multiple-statement transaction. If a transaction is larger than this many bytes, it fails and rolls back. The minimum value is 4096.

If you are using the binary log and row based logging, concurrent inserts are converted to normal inserts for `CREATE ... SELECT` or `INSERT ... SELECT` statements. This is done to ensure that you can re-create an exact copy of your tables by applying the log during a backup operation. If you are using statement-based logging, the original statement is written to the log.

The binary log format has some known limitations that can affect recovery from backups. See Section 16.4.1, "Replication Features and Issues".

Binary logging for stored programs is done as described in Section 19.7, "Binary Logging of Stored Programs".

Note that the binary log format differs in MySQL 5.1 from previous versions of MySQL, due to enhancements in replication. See Section 16.4.2, "Replication Compatibility Between MySQL Versions".

Writes to the binary log file and binary log index file are handled in the same way as writes to `MyISAM` tables. See Section B.5.3.4, "How MySQL Handles a Full Disk".

By default, the binary log is not synchronized to disk at each write. So if the operating system or machine (not only the MySQL server) crashes, there is a chance that the last statements of the binary log are lost. To prevent this, you can make the binary log be synchronized to disk after every N writes to the binary log, with the `sync_binlog` system variable. See Section 5.1.4, "Server System Variables". 1 is the safest value for `sync_binlog`, but also the slowest. Even with `sync_binlog` set to 1, there is still the chance of an inconsistency between the table content and binary log content in case of a crash. For example, if you are using `InnoDB` tables and the MySQL server processes a `COMMIT` statement, it writes the whole transaction to the binary log and then commits this transaction into `InnoDB`. If the server crashes between those two operations, the transaction is rolled back by `InnoDB` at restart but still exists in the binary log. To resolve this, you should set `--innodb_support_xa` to 1. Although this option is related to the support of XA transactions in InnoDB, it also ensures that the binary log and InnoDB data files are synchronized.

For this option to provide a greater degree of safety, the MySQL server should also be configured to synchronize the binary log and the `InnoDB` logs to disk at every transaction. The `InnoDB` logs are synchronized by default, and `sync_binlog=1` can be used to synchronize the binary log. The effect of this option is that at restart after a crash, after doing a rollback of transactions, the MySQL server cuts rolled back `InnoDB` transactions from the binary log. This ensures that the binary log reflects the exact data of `InnoDB` tables, and so, that the slave remains in synchrony with the master (not receiving a statement which has been rolled back).

If the MySQL server discovers at crash recovery that the binary log is shorter than it should have been, it lacks at least one successfully committed `InnoDB` transaction. This should not happen if `sync_binlog=1`

and the disk/file system do an actual sync when they are requested to (some do not), so the server prints an error message `The binary log file_name is shorter than its expected size`. In this case, this binary log is not correct and replication should be restarted from a fresh snapshot of the master's data.

For MySQL 5.1.20 and later (and MySQL 5.0.46 and later for backward compatibility), the session values of the following system variables are written to the binary log and honored by the replication slave when parsing the binary log:

- `sql_mode` (except that the `NO_DIR_IN_CREATE` mode is not replicated; see Section 16.4.1.38, "Replication and Variables")

- `foreign_key_checks`

- `unique_checks`

- `character_set_client`

- `collation_connection`

- `collation_database`

- `collation_server`

- `sql_auto_is_null`

5.4.4.1 Binary Logging Formats

The server uses several logging formats to record information in the binary log. The exact format employed depends on the version of MySQL being used. There are three logging formats:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called *statement-based logging*. You can cause this format to be used by starting the server with `--binlog-format=STATEMENT`.

- In *row-based logging*, the master writes events to the binary log that indicate how individual table rows are affected. You can cause the server to use row-based logging by starting it with `--binlog-format=ROW`.

- A third option is also available: *mixed logging*. With mixed logging, statement-based logging is used by default, but the logging mode switches automatically to row-based in certain cases as described below. You can cause MySQL to use mixed logging explicitly by starting `mysqld` with the option `--binlog-format=MIXED`.

Support for row-based logging was added in MySQL 5.1.5. Mixed logging is available beginning with MySQL 5.1.8. In MySQL 5.1.12, `MIXED` become the default logging mode; in 5.1.29, the default was changed back to `STATEMENT` for compatibility with MySQL 5.0.

Starting with MySQL 5.1.20, the logging format can also be set or limited by the storage engine being used. This helps to eliminate issues when replicating certain statements between a master and slave that are using different storage engines.

With statement-based replication, there may be issues with replicating nondeterministic statements. In deciding whether or not a given statement is safe for statement-based replication, MySQL determines whether it can guarantee that the statement can be replicated using statement-based logging. If MySQL cannot make this guarantee, it marks the statement as potentially unreliable and issues the warning, `Statement may not be safe to log in statement format`.

Prior to MySQL 5.1.36, this warning read, `Statement is not safe to log in statement format`. (Bug #42415)

You can avoid these issues by using MySQL's row-based replication instead.

5.4.4.2 Setting The Binary Log Format

You can select the binary logging format explicitly by starting the MySQL server with `--binlog-format=type`. The supported values for `type` are:

- `STATEMENT` causes logging to be statement based.

- `ROW` causes logging to be row based.

- `MIXED` causes logging to use mixed format.

The default binary logging format depends on the version of MySQL you are using:

- For MySQL 5.1.11 and earlier, and for MySQL 5.1.29 and later, statement-based logging is used by default.

- For MySQL 5.1.12 through MySQL 5.1.28, mixed logging is used by default.

Exception.   For all MySQL Cluster releases using version 6.1 or later of the `NDBCLUSTER` storage engine (even those releases based on MySQL 5.1.29 and later), the default binary log format is `MIXED`. See Section 17.6, "MySQL Cluster Replication".

The logging format also can be switched at runtime. To specify the format globally for all clients, set the global value of the `binlog_format` system variable:

```
mysql> SET GLOBAL binlog_format = 'STATEMENT';
mysql> SET GLOBAL binlog_format = 'ROW';
mysql> SET GLOBAL binlog_format = 'MIXED';
```

An individual client can control the logging format for its own statements by setting the session value of `binlog_format`:

```
mysql> SET SESSION binlog_format = 'STATEMENT';
mysql> SET SESSION binlog_format = 'ROW';
mysql> SET SESSION binlog_format = 'MIXED';
```

Note

Each MySQL Server can set its own and only its own binary logging format (true whether `binlog_format` is set with global or session scope). This means that changing the logging format on a replication master does not cause a slave to change its logging format to match. (When using `STATEMENT` mode, the `binlog_format` system variable is not replicated; when using `MIXED` or `ROW` logging mode, it is replicated but is ignored by the slave.) Changing the binary logging format on the master while replication is ongoing, or without also changing it on the slave can cause replication to fail with errors such as `Error executing row event: 'Cannot execute statement: impossible to write to binary log since statement is in row format and BINLOG_FORMAT = STATEMENT.'`

To change the global `binlog_format` value, you must have the `SUPER` privilege. This is also true for the session value as of MySQL 5.1.29.

There are several reasons why a client might want to set binary logging on a per-session basis:

- A session that makes many small changes to the database might want to use row-based logging.

- A session that performs updates that match many rows in the `WHERE` clause might want to use statement-based logging because it will be more efficient to log a few statements than many rows.

- Some statements require a lot of execution time on the master, but result in just a few rows being modified. It might therefore be beneficial to replicate them using row-based logging.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger

- If the `NDBCLUSTER` storage engine is enabled

- If the session is currently in row-based replication mode and has open temporary tables

Trying to switch the format in any of these cases results in an error.

If you are using `InnoDB` tables and the transaction isolation level is `READ COMMITTED` or `READ UNCOMMITTED`, only row-based logging can be used. It is *possible* to change the logging format to `STATEMENT`, but doing so at runtime leads very rapidly to errors because `InnoDB` can no longer perform inserts.

Switching the replication format at runtime is not recommended when any temporary tables exist, because temporary tables are logged only when using statement-based replication, whereas with row-based replication they are not logged. With mixed replication, temporary tables are usually logged; exceptions happen with user-defined functions (UDFs) and with the `UUID()` function.

With the binary log format set to `ROW`, many changes are written to the binary log using the row-based format. Some changes, however, still use the statement-based format. Examples include all DDL (data definition language) statements such as `CREATE TABLE`, `ALTER TABLE`, or `DROP TABLE`.

The `--binlog-row-event-max-size` option is available for servers that are capable of row-based replication. Rows are stored into the binary log in chunks having a size in bytes not exceeding the value of this option. The value must be a multiple of 256. The default value is 1024.

Warning

When using *statement-based logging* for replication, it is possible for the data on the master and slave to become different if a statement is designed in such a way that the data modification is *nondeterministic*; that is, it is left to the will of the query optimizer. In general, this is not a good practice even outside of replication. For a detailed explanation of this issue, see Section B.5.7, "Known Issues in MySQL".

5.4.4.3 Mixed Binary Logging Format

When running in `MIXED` logging format, the server automatically switches from statement-based to row-based logging under the following conditions:

- When a DML statement updates an `NDBCLUSTER` table.

- When a function contains `UUID()`.

- Prior to MySQL 5.1.40, when two or more tables with `AUTO_INCREMENT` columns are updated. As of 5.1.40, when one or more tables with `AUTO_INCREMENT` columns are updated and a trigger or stored function is invoked. Unlike other unsafe statements, this does not generate a warning if `binlog_format = STATEMENT`.

For more information, see Section 16.4.1.1, "Replication and AUTO_INCREMENT".

- When any `INSERT DELAYED` is executed.

- When the body of a view requires row-based replication, the statement creating the view also uses it. For example, this occurs when the statement creating a view uses the `UUID()` function.

- When a call to a UDF is involved.

- If a statement is logged by row and the session that executed the statement has any temporary tables, logging by row is used for all subsequent statements (except for those accessing temporary tables) until all temporary tables in use by that session are dropped.

  This is true whether or not any temporary tables are actually logged.

  Temporary tables cannot be logged using row-based format; thus, once row-based logging is used, all subsequent statements using that table are unsafe. The server approximates this condition by treating all statements executed during the session as unsafe until the session no longer holds any temporary tables.

- Beginning with MySQL 5.1.23:

  - When `FOUND_ROWS()` or `ROW_COUNT()` is used. (Bug #12092, Bug #30244)

  - When `USER()`, `CURRENT_USER()`, or `CURRENT_USER` is used. (Bug #28086)

- Beginning with MySQL 5.1.24, when a statement refers to one or more system variables. (Bug #31168)

  Exception. The following system variables, when used with session scope (only), do not cause the logging format to switch:

  - `auto_increment_increment`

  - `auto_increment_offset`

  - `character_set_client`

  - `character_set_connection`

  - `character_set_database`

  - `character_set_server`

  - `collation_connection`

  - `collation_database`

  - `collation_server`

  - `foreign_key_checks`

  - `identity`

  - `last_insert_id`

  - `lc_time_names`

  - `pseudo_thread_id`

- `sql_auto_is_null`

- `time_zone`

- `timestamp`

- `unique_checks`

For information about determining system variable scope, see Section 5.1.5, "Using System Variables".

For information about how replication treats `sql_mode`, see Section 16.4.1.38, "Replication and Variables".

- Beginning with MySQL 5.1.30, when one of the tables involved is a log table in the `mysql` database.

- Beginning with MySQL 5.1.34, when the `LOAD_FILE()` function is used. (Bug #39701)

> **Note**
>
> Starting with MySQL 5.1.20, a warning is generated if you try to execute a statement using statement-based logging that should be written using row-based logging. The warning is shown both in the client (in the output of `SHOW WARNINGS`) and through the `mysqld` error log. A warning is added to the `SHOW WARNINGS` table each time such a statement is executed. However, only the first statement that generated the warning for each client session is written to the error log to prevent flooding the log.

Starting with MySQL 5.1.20, in addition to the decisions above, individual engines can also determine the logging format used when information in a table is updated. The logging capabilities of an individual engine can be defined as follows:

- If an engine supports row-based logging, the engine is said to be *row-logging capable*.

- If an engine supports statement-based logging, the engine is said to be *statement-logging capable*.

A given storage engine can support either or both logging formats. The following table lists the logging formats supported by each storage engine.

Storage Engine	Row Logging Supported	Statement Logging Supported
`ARCHIVE`	Yes	Yes
`BLACKHOLE`	Yes	Yes
`CSV`	Yes	Yes
`EXAMPLE`	Yes	No
`FEDERATED`	Yes	Yes
`HEAP`	Yes	Yes
`InnoDB`	Yes	Yes when the transaction isolation level is `REPEATABLE READ` or `SERIALIZABLE`; No otherwise.
`MyISAM`	Yes	Yes

Storage Engine	Row Logging Supported	Statement Logging Supported
`MERGE`	Yes	Yes
`NDBCLUSTER`	Yes	No

When determining the logging mode to be used, the capabilities of all the tables affected by the event are combined. The set of affected tables is then marked according to these rules:

- A set of tables is defined as *row-logging restricted* if the tables are row-logging capable but not statement-logging capable.

- A set of tables is defined as *statement-logging restricted* if the tables are statement-logging capable but not row-logging capable.

Once the determination of the possible logging formats required by the statement is complete it is compared to the current `binlog_format` setting. The following table is used to decide how the information is recorded in the binary log or, if appropriate, whether an error is raised. In the table, a safe operation is defined as one that is deterministic.

Several rules decide whether the statement is deterministic, as shown in the following table, where **SLR** stands for "statement-logging restricted" and **RLR** stands for "row-logging restricted". A statement is *statement-logging restricted* if one or more of the tables it accesses is not row-logging capable. Similarly, a statement is *row-logging restricted* if any table accessed by the statement is not statement-logging capable.

Condition				Action	
Safe/ unsafe	`binlog_format`	SLR	RLR	Error/Warning	Logged as
Safe	`STATEMENT`	Yes	Yes	`Error: not loggable`	
Safe	`STATEMENT`	Yes	No		`STATEMENT`
Safe	`STATEMENT`	No	Yes	`Error: not loggable`	
Safe	`STATEMENT`	No	No		`STATEMENT`
Safe	`MIXED`	Yes	Yes	`Error: not loggable`	
Safe	`MIXED`	Yes	No		`STATEMENT`
Safe	`MIXED`	No	Yes		`ROW`
Safe	`MIXED`	No	No		`STATEMENT`
Safe	`ROW`	Yes	Yes	`Error: not loggable`	
Safe	`ROW`	Yes	No	`Error: not loggable`	
Safe	`ROW`	No	Yes		`ROW`
Safe	`ROW`	No	No		`ROW`
Unsafe	`STATEMENT`	Yes	Yes	`Error: not loggable`	
Unsafe	`STATEMENT`	Yes	No	`Warning: unsafe`	`STATEMENT`

Condition				Action	
Safe/ unsafe	`binlog_format`	SLR	RLR	Error/Warning	Logged as
Unsafe	`STATEMENT`	No	Yes	`Error: not loggable`	
Unsafe	`STATEMENT`	No	No	`Warning: unsafe`	`STATEMENT`
Unsafe	`MIXED`	Yes	Yes	`Error: not loggable`	
Unsafe	`MIXED`	Yes	No	`Error: not loggable`	
Unsafe	`MIXED`	No	Yes		`ROW`
Unsafe	`MIXED`	No	No		`ROW`
Unsafe	`ROW`	Yes	Yes	`Error: not loggable`	
Unsafe	`ROW`	Yes	No	`Error: not loggable`	
Unsafe	`ROW`	No	Yes		`ROW`
Unsafe	`ROW`	No	No		`ROW`

When a warning is produced by the determination, a standard MySQL warning is produced (and is available using `SHOW WARNINGS`). The information is also written to the `mysqld` error log. Only one error for each error instance per client connection is logged to prevent flooding the log. The log message includes the SQL statement that was attempted.

If a slave server was started with `--log-warnings` enabled, the slave prints messages to the error log to provide information about its status, such as the binary log and relay log coordinates where it starts its job, when it is switching to another relay log, when it reconnects after a disconnect, and so forth.

5.4.4.4 Logging Format for Changes to mysql Database Tables

The contents of the grant tables in the `mysql` database can be modified directly (for example, with `INSERT` or `DELETE`) or indirectly (for example, with `GRANT` or `CREATE USER`). As of MySQL 5.1.17, statements that affect `mysql` database tables are written to the binary log using the following rules:

- Data manipulation statements that change data in `mysql` database tables directly are logged according to the setting of the `binlog_format` system variable. This pertains to statements such as `INSERT`, `UPDATE`, `DELETE`, `REPLACE`, `DO`, `LOAD DATA INFILE`, `SELECT`, and `TRUNCATE TABLE`.

- Statements that change the `mysql` database indirectly are logged as statements regardless of the value of `binlog_format`. This pertains to statements such as `GRANT`, `REVOKE`, `SET PASSWORD`, `RENAME USER`, `CREATE` (all forms except `CREATE TABLE ... SELECT`), `ALTER` (all forms), and `DROP` (all forms).

`CREATE TABLE ... SELECT` is a combination of data definition and data manipulation. The `CREATE TABLE` part is logged using statement format and the `SELECT` part is logged according to the value of `binlog_format`.

5.4.5 The Slow Query Log

The slow query log consists of SQL statements that took more than `long_query_time` seconds to execute and (as of MySQL 5.1.21) required at least `min_examined_row_limit` rows to be examined.

The default value of `long_query_time` is 10. Beginning with MySQL 5.1.21, the minimum is 0, and the value can be specified to a resolution of microseconds. For logging to a file, times are written including the microseconds part. For logging to tables, only integer times are written; the microseconds part is ignored. Prior to MySQL 5.1.21, the minimum value is 1, and the value for this variable must be an integer.

By default, administrative statements are not logged, nor are queries that do not use indexes for lookups. This behavior can be changed using `--log-slow-admin-statements` and `--log-queries-not-using-indexes`, as described later.

The time to acquire the initial locks is not counted as execution time. `mysqld` writes a statement to the slow query log after it has been executed and after all locks have been released, so log order might differ from execution order.

Control the slow query log at server startup as follows:

* Before 5.1.6, the slow query log destination is always a file. To enable the log, start `mysqld` with the `--log-slow-queries[=file_name]` option.

* As of MySQL 5.1.6, the destination can be a file or a table, or both. Start `mysqld` with the `--log-slow-queries[=file_name]` option to enable the slow query log, and optionally use `--log-output` to specify the log destination (as described in Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations").

* As of MySQL 5.1.12, as an alternative to `--log-slow-queries`, use `--slow_query_log[={0|1}]` to specify the initial slow query log state. In this case, the default slow query log file name is used. With no argument or an argument of 1, `--slow_query_log` enables the log. With an argument of 0, this option disables the log.

* As of MySQL 5.1.29, use `--slow_query_log[={0|1}]` to enable or disable the slow query log, and optionally `--slow_query_log_file=file_name` to specify a log file name. The `--log-slow-queries` option is deprecated.

If the slow query log file is enabled but no name is specified, the default name is `host_name-slow.log` and the server creates the file in the same directory where it creates the PID file. If a name is given, the server creates the file in the data directory unless an absolute path name is given to specify a different directory.

To disable or enable the slow query log or change the log file name at runtime, use the global `slow_query_log` and `slow_query_log_file` system variables. Set `slow_query_log` to 0 (or `OFF`) to disable the log or to 1 (or `ON`) to enable it. Set `slow_query_log_file` to specify the name of the log file. If a log file already is open, it is closed and the new file is opened.

When the slow query log is enabled, the server writes output to any destinations specified by the `--log-output` option or `log_output` system variable. If you enable the log, the server opens the log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. If the destination is `NONE`, the server writes no queries even if the slow query log is enabled. Setting the log file name has no effect on logging if the log destination value does not contain `FILE`.

The server writes less information to the slow query log if you use the `--log-short-format` option.

To include slow administrative statements in the statements written to the slow query log, use the `--log-slow-admin-statements` server option. Administrative statements include `ALTER TABLE`, `ANALYZE TABLE`, `CHECK TABLE`, `CREATE INDEX`, `DROP INDEX`, `OPTIMIZE TABLE`, and `REPAIR TABLE`.

To include queries that do not use indexes for row lookups in the statements written to the slow query log, use the `--log-queries-not-using-indexes` server option. See Section 5.1.3, "Server Command Options". When such queries are logged, the slow query log may grow quickly.

The server uses the controlling parameters in the following order to determine whether to write a query to the slow query log:

1. The query must either not be an administrative statement, or `--log-slow-admin-statements` must have been specified.

2. The query must have taken at least `long_query_time` seconds, or `--log-queries-not-using-indexes` must have been specified and the query used no indexes for row lookups.

3. The query must have examined at least `min_examined_row_limit` rows.

The server does not write queries handled by the query cache to the slow query log, nor queries that would not benefit from the presence of an index because the table has zero rows or one row.

Prior to MySQL 5.1.45, replication slaves did not write replicated queries to the slow query log, even if the same queries were written to the slow query log on the master. (Bug #23300) In MySQL 5.1.45 and later, this behavior can be overridden using the `--log-slow-slave-statements` option.

The slow query log should be protected because logged statements might contain passwords. See Section 6.1.2.3, "Passwords and Logging".

The slow query log can be used to find queries that take a long time to execute and are therefore candidates for optimization. However, examining a long slow query log can become a difficult task. To make this easier, you can process a slow query log file using the `mysqldumpslow` command to summarize the queries that appear in the log. See Section 4.6.8, "`mysqldumpslow` — Summarize Slow Query Log Files".

5.4.6 The DDL Log

In MySQL 5.1 and later, the DDL log, or metadata log, records metadata operations generated by data definition statements such as `DROP TABLE` and `ALTER TABLE`. MySQL uses this log to recover from crashes occurring in the middle of a metadata operation. When executing the statement `DROP TABLE t1, t2`, we need to ensure that both `t1` and `t2` are dropped, and that each table drop is complete. Another example of this type of SQL statement is `ALTER TABLE t3 DROP PARTITION p2`, where we must make certain that the partition is completely dropped and that its definition is removed from the list of partitions for table `t3`.

A record of metadata operations such as those just described are written to the file `ddl_log.log`, in the MySQL data directory. This is a binary file; it is not intended to be human-readable, and you should not attempt to modify it in any way.

`ddl_log.log` is not created until it is actually needed for recording metadata statements, so it is possible for this file not to be present on a MySQL server that is functioning in a completely normal manner.

There are no user-configurable server options or variables associated with this file.

5.4.7 Server Log Maintenance

As described in Section 5.4, "MySQL Server Logs", MySQL Server can create several different log files to help you see what activity is taking place. However, you must clean up these files regularly to ensure that the logs do not take up too much disk space.

When using MySQL with logging enabled, you may want to back up and remove old log files from time to time and tell MySQL to start logging to new files. See Section 7.2, "Database Backup Methods".

On a Linux (Red Hat) installation, you can use the `mysql-log-rotate` script for this. If you installed MySQL from an RPM distribution, this script should have been installed automatically. Be careful with this

script if you are using the binary log for replication. You should not remove binary logs until you are certain that their contents have been processed by all slaves.

On other systems, you must install a short script yourself that you start from `cron` (or its equivalent) for handling log files.

For the binary log, you can set the `expire_logs_days` system variable to expire binary log files automatically after a given number of days (see Section 5.1.4, "Server System Variables"). If you are using replication, you should set the variable no lower than the maximum number of days your slaves might lag behind the master. To remove binary logs on demand, use the `PURGE BINARY LOGS` statement (see Section 13.4.1.1, "PURGE BINARY LOGS Syntax").

You can force MySQL to start using new log files by flushing the logs. Log flushing occurs when you issue a `FLUSH LOGS` statement or execute a `mysqladmin flush-logs`, `mysqladmin refresh`, `mysqldump --flush-logs`, or `mysqldump --master-data` command. See Section 13.7.6.3, "FLUSH Syntax", Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server", and Section 4.5.4, "`mysqldump` — A Database Backup Program". In addition, the binary log is flushed when its size reaches the value of the `max_binlog_size` system variable.

A log-flushing operation does the following:

- If general query logging or slow query logging to a log file is enabled, the server closes and reopens the general query log file or slow query log file.

- If binary logging is enabled, the server closes the current binary log file and opens a new log file with the next sequence number.

- If the server was started with the `--log-error` option to cause the error log to be written to a file, the result of a log-flushing operation is version dependent:

  - As of MySQL 5.1.51, the server closes and reopens the log file.

  - Prior to MySQL 5.1.51, the server renames the current log file with the suffix `-old`, then creates a new empty log file.

The server creates a new binary log file when you flush the logs. However, it just closes and reopens the general and slow query log files. To cause new files to be created on Unix, rename the current log files before flushing them. At flush time, the server opens new log files with the original names. For example, if the general and slow query log files are named `mysql.log` and `mysql-slow.log`, you can use a series of commands like this:

```
shell> cd mysql-data-directory
shell> mv mysql.log mysql.old
shell> mv mysql-slow.log mysql-slow.old
shell> mysqladmin flush-logs
```

On Windows, use `rename` rather than `mv`.

At this point, you can make a backup of `mysql.old` and `mysql-slow.old` and then remove them from disk.

As of MySQL 5.1.12, you can rename the general query log or slow query log at runtime by disabling the log:

```
SET GLOBAL general_log = 'OFF';
```

```
SET GLOBAL slow_query_log = 'OFF';
```

With the logs disabled, rename the log files externally; for example, from the command line. Then enable the logs again:

```
SET GLOBAL general_log = 'ON';
SET GLOBAL slow_query_log = 'ON';
```

This method works on any platform and does not require a server restart.

For older versions of MySQL on Windows, you cannot rename certain log files while the server has them open. Before MySQL 5.1.3, this restriction applies to all log files. You must stop the server, rename the file, then restart the server to create a new log file. From 5.1.4 to 5.1.50, the restriction applies only to the error log file. To rename the error log file, a stop and restart can be avoided by flushing the logs to cause the server to rename the current log file with the suffix `-old` and create a new empty error log file. For further information, see Section 5.4.2, "The Error Log".

5.5 Running Multiple MySQL Instances on One Machine

In some cases, you might want to run multiple instances of MySQL on a single machine. You might want to test a new MySQL release while leaving an existing production setup undisturbed. Or you might want to give different users access to different `mysqld` servers that they manage themselves. (For example, you might be an Internet Service Provider that wants to provide independent MySQL installations for different customers.)

It is possible to use a different MySQL server binary per instance, or use the same binary for multiple instances, or any combination of the two approaches. For example, you might run a server from MySQL 5.0 and one from MySQL 5.1, to see how different versions handle a given workload. Or you might run multiple instances of the current production version, each managing a different set of databases.

Whether or not you use distinct server binaries, each instance that you run must be configured with unique values for several operating parameters. This eliminates the potential for conflict between instances. Parameters can be set on the command line, in option files, or by setting environment variables. See Section 4.2.3, "Specifying Program Options". To see the values used by a given instance, connect to it and execute a `SHOW VARIABLES` statement.

The primary resource managed by a MySQL instance is the data directory. Each instance should use a different data directory, the location of which is specified using the `--datadir=dir_name` option. For methods of configuring each instance with its own data directory, and warnings about the dangers of failing to do so, see Section 5.5.1, "Setting Up Multiple Data Directories".

In addition to using different data directories, several other options must have different values for each server instance:

- `--port=port_num`

  `--port` controls the port number for TCP/IP connections. Alternatively, if the host has multiple network addresses, you can use `--bind-address` to cause each server to listen to a different address.

- `--socket={file_name|pipe_name}`

  `--socket` controls the Unix socket file path on Unix or the named pipe name on Windows. On Windows, it is necessary to specify distinct pipe names only for those servers configured to permit named-pipe connections.

- `--shared-memory-base-name=name`

This option is used only on Windows. It designates the shared-memory name used by a Windows server to permit clients to connect using shared memory. It is necessary to specify distinct shared-memory names only for those servers configured to permit shared-memory connections.

- `--pid-file=file_name`

This option indicates the path name of the file in which the server writes its process ID.

If you use the following log file options, their values must differ for each server:

- `--general_log_file=file_name`

- `--log-bin[=file_name]`

- `--slow_query_log_file=file_name`

- `--log-error[=file_name]`

For further discussion of log file options, see Section 5.4, "MySQL Server Logs".

To achieve better performance, you can specify the following option differently for each server, to spread the load between several physical disks:

- `--tmpdir=dir_name`

Having different temporary directories also makes it easier to determine which MySQL server created any given temporary file.

If you have multiple MySQL installations in different locations, you can specify the base directory for each installation with the `--basedir=dir_name` option. This causes each instance to automatically use a different data directory, log files, and PID file because the default for each of those parameters is relative to the base directory. In that case, the only other options you need to specify are the `--socket` and `--port` options. Suppose that you install different versions of MySQL using `tar` file binary distributions. These install in different locations, so you can start the server for each installation using the command `bin/mysqld_safe` under its corresponding base directory. `mysqld_safe` determines the proper `--basedir` option to pass to `mysqld`, and you need specify only the `--socket` and `--port` options to `mysqld_safe`.

As discussed in the following sections, it is possible to start additional servers by specifying appropriate command options or by setting environment variables. However, if you need to run multiple servers on a more permanent basis, it is more convenient to use option files to specify for each server those option values that must be unique to it. The `--defaults-file` option is useful for this purpose.

5.5.1 Setting Up Multiple Data Directories

Each MySQL Instance on a machine should have its own data directory. The location is specified using the `--datadir=dir_name` option.

There are different methods of setting up a data directory for a new instance:

- Create a new data directory.

- Copy an existing data directory.

The following discussion provides more detail about each method.

> **Warning**
>
> Normally, you should never have two servers that update data in the same databases. This may lead to unpleasant surprises if your operating system does not support fault-free system locking. If (despite this warning) you run multiple servers using the same data directory and they have logging enabled, you must use the appropriate options to specify log file names that are unique to each server. Otherwise, the servers try to log to the same files.
>
> Even when the preceding precautions are observed, this kind of setup works only with `MyISAM` and `MERGE` tables, and not with any of the other storage engines. Also, this warning against sharing a data directory among servers always applies in an NFS environment. Permitting multiple MySQL servers to access a common data directory over NFS is a *very bad idea*. The primary problem is that NFS is the speed bottleneck. It is not meant for such use. Another risk with NFS is that you must devise a way to ensure that two or more servers do not interfere with each other. Usually NFS file locking is handled by the `lockd` daemon, but at the moment there is no platform that performs locking 100% reliably in every situation.

Create a New Data Directory

With this method, the data directory will be in the same state as when you first install MySQL. It will have the default set of MySQL accounts and no user data.

On Unix, initialize the data directory. See Section 2.12, "Postinstallation Setup and Testing".

On Windows, the data directory is included in MySQL distributions. If you obtain a distribution in Windows Zip archive format, you can unpack it into a temporary location, then copy the `data` directory from this location to where you are setting up the new instance.

Copy an Existing Data Directory

With this method, any MySQL accounts or user data present in the data directory are carried over to the new data directory.

1. Stop the existing MySQL instance using the data directory. This must be a clean shutdown so that the instance flushes any pending changes to disk.

2. Copy the data directory to the location where the new data directory should be.

3. Copy the `my.cnf` or `my.ini` option file used by the existing instance. This serves as a basis for the new instance.

4. Modify the new option file so that any pathnames referring to the original data directory refer to the new data directory. Also, modify any other options that must be unique per instance, such as the TCP/IP port number and the log files. For a list of parameters that must be unique per instance, see Section 5.5, "Running Multiple MySQL Instances on One Machine".

5. Start the new instance, telling it to use the new option file.

5.5.2 Running Multiple MySQL Instances on Windows

You can run multiple servers on Windows by starting them manually from the command line, each with appropriate operating parameters, or by installing several servers as Windows services and running them that way. General instructions for running MySQL from the command line or as a service are given in

Section 2.3, "Installing MySQL on Microsoft Windows". The following sections describe how to start each server with different values for those options that must be unique per server, such as the data directory. These options are listed in Section 5.5, "Running Multiple MySQL Instances on One Machine".

5.5.2.1 Starting Multiple MySQL Instances at the Windows Command Line

The procedure for starting a single MySQL server manually from the command line is described in Section 2.3.6.5, "Starting MySQL Server from the Windows Command Line". To start multiple servers this way, you can specify the appropriate options on the command line or in an option file. It is more convenient to place the options in an option file, but it is necessary to make sure that each server gets its own set of options. To do this, create an option file for each server and tell the server the file name with a `--defaults-file` option when you run it.

Suppose that you want to run one instance of `mysqld` on port 3307 with a data directory of `C:\mydata1`, and another instance on port 3308 with a data directory of `C:\mydata2`. Use this procedure:

1. Make sure that each data directory exists, including its own copy of the `mysql` database that contains the grant tables.

2. Create two option files. For example, create one file named `C:\my-opts1.cnf` that looks like this:

   ```
   [mysqld]
   datadir = C:/mydata1
   port = 3307
   ```

   Create a second file named `C:\my-opts2.cnf` that looks like this:

   ```
   [mysqld]
   datadir = C:/mydata2
   port = 3308
   ```

3. Use the `--defaults-file` option to start each server with its own option file:

   ```
   C:\> C:\mysql\bin\mysqld --defaults-file=C:\my-opts1.cnf
   C:\> C:\mysql\bin\mysqld --defaults-file=C:\my-opts2.cnf
   ```

   Each server starts in the foreground (no new prompt appears until the server exits later), so you will need to issue those two commands in separate console windows.

To shut down the servers, connect to each using the appropriate port number:

```
C:\> C:\mysql\bin\mysqladmin --port=3307 --host=127.0.0.1 --user=root --password shutdown
C:\> C:\mysql\bin\mysqladmin --port=3308 --host=127.0.0.1 --user=root --password shutdown
```

Servers configured as just described permit clients to connect over TCP/IP. If your version of Windows supports named pipes and you also want to permit named-pipe connections, use the `mysqld-nt` (MySQL 5.1.20 and earlier) or `mysqld` (MySQL 5.1.21 and later) server and specify options that enable the named pipe and specify its name. Each server that supports named-pipe connections must use a unique pipe name. For example, the `C:\my-opts1.cnf` file might be written like this:

```
[mysqld]
datadir = C:/mydata1
port = 3307
enable-named-pipe
socket = mypipe1
```

Modify `C:\my-opts2.cnf` similarly for use by the second server. Then start the servers as described previously.

A similar procedure applies for servers that you want to permit shared-memory connections. Enable such connections with the `--shared-memory` option and specify a unique shared-memory name for each server with the `--shared-memory-base-name` option.

5.5.2.2 Starting Multiple MySQL Instances as Windows Services

On Windows, a MySQL server can run as a Windows service. The procedures for installing, controlling, and removing a single MySQL service are described in Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

To set up multiple MySQL services, you must make sure that each instance uses a different service name in addition to the other parameters that must be unique per instance.

For the following instructions, suppose that you want to run the `mysqld` server from two different versions of MySQL that are installed at `C:\mysql-5.0.92` and `C:\mysql-5.1.73`, respectively. (This might be the case if you are running 5.0.92 as your production server, but also want to conduct tests using 5.1.73.)

To install MySQL as a Windows service, use the `--install` or `--install-manual` option. For information about these options, see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

Based on the preceding information, you have several ways to set up multiple services. The following instructions describe some examples. Before trying any of them, shut down and remove any existing MySQL services.

- **Approach 1:** Specify the options for all services in one of the standard option files. To do this, use a different service name for each server. Suppose that you want to run the 5.0.92 `mysqld` using the service name of `mysqld1` and the 5.1.73 `mysqld` using the service name `mysqld2`. In this case, you can use the `[mysqld1]` group for 5.0.92 and the `[mysqld2]` group for 5.1.73. For example, you can set up `C:\my.cnf` like this:

```
# options for mysqld1 service
[mysqld1]
basedir = C:/mysql-5.0.92
port = 3307
enable-named-pipe
socket = mypipe1

# options for mysqld2 service
[mysqld2]
basedir = C:/mysql-5.1.73
port = 3308
enable-named-pipe
socket = mypipe2
```

  Install the services as follows, using the full server path names to ensure that Windows registers the correct executable program for each service:

```
C:\> C:\mysql-5.0.92\bin\mysqld --install mysqld1
C:\> C:\mysql-5.1.73\bin\mysqld --install mysqld2
```

  To start the services, use the services manager, or use NET START with the appropriate service names:

```
C:\> NET START mysqld1
```

```
C:\> NET START mysqld2
```

To stop the services, use the services manager, or use NET STOP with the appropriate service names:

```
C:\> NET STOP mysqld1
C:\> NET STOP mysqld2
```

- **Approach 2:** Specify options for each server in separate files and use `--defaults-file` when you install the services to tell each server what file to use. In this case, each file should list options using a `[mysqld]` group.

  With this approach, to specify options for the 5.0.92 `mysqld-nt`, create a file `C:\my-opts1.cnf` that looks like this:

```
[mysqld]
basedir = C:/mysql-5.0.92
port = 3307
enable-named-pipe
socket = mypipe1
```

  For the 5.1.73 `mysqld`, create a file `C:\my-opts2.cnf` that looks like this:

```
[mysqld]
basedir = C:/mysql-5.1.73
port = 3308
enable-named-pipe
socket = mypipe2
```

  Install the services as follows (enter each command on a single line):

```
C:\> C:\mysql-5.0.92\bin\mysqld --install mysqld1
          --defaults-file=C:\my-opts1.cnf
C:\> C:\mysql-5.1.73\bin\mysqld --install mysqld2
          --defaults-file=C:\my-opts2.cnf
```

  When you install a MySQL server as a service and use a `--defaults-file` option, the service name must precede the option.

  After installing the services, start and stop them the same way as in the preceding example.

To remove multiple services, use `mysqld --remove` for each one, specifying a service name following the `--remove` option. If the service name is the default (`MySQL`), you can omit it.

5.5.3 Running Multiple MySQL Instances on Unix

One way is to run multiple MySQL instances on Unix is to compile different servers with different default TCP/IP ports and Unix socket files so that each one listens on different network interfaces. Compiling in different base directories for each installation also results automatically in a separate, compiled-in data directory, log file, and PID file location for each server.

Assume that an existing 5.0 server is configured for the default TCP/IP port number (3306) and Unix socket file (`/tmp/mysql.sock`). To configure a new 5.1.73 server to have different operating parameters, use a `configure` command something like this:

```
shell> ./configure --with-tcp-port=port_number \
          --with-unix-socket-path=file_name \
```

```
                --prefix=/usr/local/mysql-5.1.73
```

Here, `port_number` and `file_name` must be different from the default TCP/IP port number and Unix socket file path name, and the `--prefix` value should specify an installation directory different from the one under which the existing MySQL installation is located.

If you have a MySQL server listening on a given port number, you can use the following command to find out what operating parameters it is using for several important configurable variables, including the base directory and Unix socket file name:

```
shell> mysqladmin --host=host_name --port=port_number variables
```

With the information displayed by that command, you can tell what option values *not* to use when configuring an additional server.

If you specify `localhost` as the host name, `mysqladmin` defaults to using a Unix socket file connection rather than TCP/IP. To explicitly specify the connection protocol, use the `--protocol={TCP|SOCKET|PIPE|MEMORY}` option.

You need not compile a new MySQL server just to start with a different Unix socket file and TCP/IP port number. It is also possible to use the same server binary and start each invocation of it with different parameter values at runtime. One way to do so is by using command-line options:

```
shell> mysqld_safe --socket=file_name --port=port_number
```

To start a second server, provide different `--socket` and `--port` option values, and pass a `--datadir=dir_name` option to `mysqld_safe` so that the server uses a different data directory.

Alternatively, put the options for each server in a different option file, then start each server using a `--defaults-file` option that specifies the path to the appropriate option file. For example, if the option files for two server instances are named `/usr/local/mysql/my.cnf` and `/usr/local/mysql/my.cnf2`, start the servers like this: command:

```
shell> mysqld_safe --defaults-file=/usr/local/mysql/my.cnf
shell> mysqld_safe --defaults-file=/usr/local/mysql/my.cnf2
```

Another way to achieve a similar effect is to use environment variables to set the Unix socket file name and TCP/IP port number:

```
shell> MYSQL_UNIX_PORT=/tmp/mysqld-new.sock
shell> MYSQL_TCP_PORT=3307
shell> export MYSQL_UNIX_PORT MYSQL_TCP_PORT
shell> mysql_install_db --user=mysql
shell> mysqld_safe --datadir=/path/to/datadir &
```

This is a quick way of starting a second server to use for testing. The nice thing about this method is that the environment variable settings apply to any client programs that you invoke from the same shell. Thus, connections for those clients are automatically directed to the second server.

Section 2.14, "Environment Variables", includes a list of other environment variables you can use to affect MySQL programs.

On Unix, the `mysqld_multi` script provides another way to start multiple servers. See Section 4.3.4, "`mysqld_multi` — Manage Multiple MySQL Servers".

5.5.4 Using Client Programs in a Multiple-Server Environment

To connect with a client program to a MySQL server that is listening to different network interfaces from those compiled into your client, you can use one of the following methods:

- Start the client with `--host=host_name --port=port_number` to connect using TCP/IP to a remote server, with `--host=127.0.0.1 --port=port_number` to connect using TCP/IP to a local server, or with `--host=localhost --socket=file_name` to connect to a local server using a Unix socket file or a Windows named pipe.

- Start the client with `--protocol=TCP` to connect using TCP/IP, `--protocol=SOCKET` to connect using a Unix socket file, `--protocol=PIPE` to connect using a named pipe, or `--protocol=MEMORY` to connect using shared memory. For TCP/IP connections, you may also need to specify `--host` and `--port` options. For the other types of connections, you may need to specify a `--socket` option to specify a Unix socket file or Windows named-pipe name, or a `--shared-memory-base-name` option to specify the shared-memory name. Shared-memory connections are supported only on Windows.

- On Unix, set the `MYSQL_UNIX_PORT` and `MYSQL_TCP_PORT` environment variables to point to the Unix socket file and TCP/IP port number before you start your clients. If you normally use a specific socket file or port number, you can place commands to set these environment variables in your `.login` file so that they apply each time you log in. See Section 2.14, "Environment Variables".

- Specify the default Unix socket file and TCP/IP port number in the `[client]` group of an option file. For example, you can use `C:\my.cnf` on Windows, or the `.my.cnf` file in your home directory on Unix. See Section 4.2.6, "Using Option Files".

- In a C program, you can specify the socket file or port number arguments in the `mysql_real_connect()` call. You can also have the program read option files by calling `mysql_options()`. See Section 21.8.7, "C API Function Descriptions".

- If you are using the Perl `DBD::mysql` module, you can read options from MySQL option files. For example:

```
$dsn = "DBI:mysql:test;mysql_read_default_group=client;"
       . "mysql_read_default_file=/usr/local/mysql/data/my.cnf";
$dbh = DBI->connect($dsn, $user, $password);
```

See Section 21.10, "MySQL Perl API".

Other programming interfaces may provide similar capabilities for reading option files.

Chapter 6 Security

Table of Contents

When thinking about security within a MySQL installation, you should consider a wide range of possible topics and how they affect the security of your MySQL server and related applications:

- General factors that affect security. These include choosing good passwords, not granting unnecessary privileges to users, ensuring application security by preventing SQL injections and data corruption, and others. See Section 6.1, "General Security Issues".

- Security of the installation itself. The data files, log files, and the all the application files of your installation should be protected to ensure that they are not readable or writable by unauthorized parties. For more information, see Section 2.12, "Postinstallation Setup and Testing".

- Access control and security within the database system itself, including the users and databases granted with access to the databases, views and stored programs in use within the database. For more information, see Section 6.2, "The MySQL Access Privilege System", and Section 6.3, "MySQL User Account Management".

- Network security of MySQL and your system. The security is related to the grants for individual users, but you may also wish to restrict MySQL so that it is available only locally on the MySQL server host, or to a limited set of other hosts.

- Ensure that you have adequate and appropriate backups of your database files, configuration and log files. Also be sure that you have a recovery solution in place and test that you are able to successfully recover the information from your backups. See Chapter 7, *Backup and Recovery*.

6.1 General Security Issues

This section describes general security issues to be aware of and what you can do to make your MySQL installation more secure against attack or misuse. For information specifically about the access control system that MySQL uses for setting up user accounts and checking database access, see Section 2.12, "Postinstallation Setup and Testing".

For answers to some questions that are often asked about MySQL Server security issues, see Section A.9, "MySQL 5.1 FAQ: Security".

6.1.1 Security Guidelines

Anyone using MySQL on a computer connected to the Internet should read this section to avoid the most common security mistakes.

In discussing security, it is necessary to consider fully protecting the entire server host (not just the MySQL server) against all types of applicable attacks: eavesdropping, altering, playback, and denial of service. We do not cover all aspects of availability and fault tolerance here.

MySQL uses security based on Access Control Lists (ACLs) for all connections, queries, and other operations that users can attempt to perform. There is also support for SSL-encrypted connections between MySQL clients and servers. Many of the concepts discussed here are not specific to MySQL at all; the same general ideas apply to almost all applications.

When running MySQL, follow these guidelines:

- **Do not ever give anyone (except MySQL `root` accounts) access to the `user` table in the `mysql` database!** This is critical.

- Learn how the MySQL access privilege system works (see Section 6.2, "The MySQL Access Privilege System"). Use the `GRANT` and `REVOKE` statements to control access to MySQL. Do not grant more privileges than necessary. Never grant privileges to all hosts.

  Checklist:

  - Try `mysql -u root`. If you are able to connect successfully to the server without being asked for a password, anyone can connect to your MySQL server as the MySQL `root` user with full privileges! Review the MySQL installation instructions, paying particular attention to the information about setting a `root` password. See Section 2.12.4, "Securing the Initial MySQL Accounts".

  - Use the `SHOW GRANTS` statement to check which accounts have access to what. Then use the `REVOKE` statement to remove those privileges that are not necessary.

- Do not store cleartext passwords in your database. If your computer becomes compromised, the intruder can take the full list of passwords and use them. Instead, use `SHA1()`, `MD5()`, or some other one-way hashing function and store the hash value.

  To prevent password recovery using rainbow tables, do not use these functions on a plain password; instead, choose some string to be used as a salt, and use hash(hash(password)+salt) values.

- Do not choose passwords from dictionaries. Special programs exist to break passwords. Even passwords like "xfish98" are very bad. Much better is "duag98" which contains the same word "fish" but typed one key to the left on a standard QWERTY keyboard. Another method is to use a password that is taken from the first characters of each word in a sentence (for example, "Four score and seven years ago" results in a password of "Fsasya"). The password is easy to remember and type, but difficult to guess for someone who does not know the sentence. In this case, you can additionally substitute digits for the number words to obtain the phrase "4 score and 7 years ago", yielding the password "4sa7ya" which is even more difficult to guess.

- Invest in a firewall. This protects you from at least 50% of all types of exploits in any software. Put MySQL behind the firewall or in a demilitarized zone (DMZ).

  Checklist:

  - Try to scan your ports from the Internet using a tool such as `nmap`. MySQL uses port 3306 by default. This port should not be accessible from untrusted hosts. As a simple way to check whether your MySQL port is open, try the following command from some remote machine, where *server_host* is the host name or IP address of the host on which your MySQL server runs:

    ```
    shell> telnet server_host 3306
    ```

    If `telnet` hangs or the connection is refused, the port is blocked, which is how you want it to be. If you get a connection and some garbage characters, the port is open, and should be closed on your firewall or router, unless you really have a good reason to keep it open.

- Applications that access MySQL should not trust any data entered by users, and should be written using proper defensive programming techniques. See Section 6.1.7, "Client Programming Security Guidelines".

- Do not transmit plain (unencrypted) data over the Internet. This information is accessible to everyone who has the time and ability to intercept it and use it for their own purposes. Instead, use an encrypted protocol such as SSL or SSH. MySQL supports internal SSL connections. Another technique is to use SSH port-forwarding to create an encrypted (and compressed) tunnel for the communication.

- Learn to use the `tcpdump` and `strings` utilities. In most cases, you can check whether MySQL data streams are unencrypted by issuing a command like the following:

  ```
  shell> tcpdump -l -i eth0 -w - src or dst port 3306 | strings
  ```

  This works under Linux and should work with small modifications under other systems.

  > **Warning**
  >
  > If you do not see cleartext data, this does not always mean that the information actually is encrypted. If you need high security, consult with a security expert.

6.1.2 Keeping Passwords Secure

Passwords occur in several contexts within MySQL. The following sections provide guidelines that enable end users and administrators to keep these passwords secure and avoid exposing them. There is also a discussion of how MySQL uses password hashing internally.

6.1.2.1 End-User Guidelines for Password Security

MySQL users should use the following guidelines to keep passwords secure.

When you run a client program to connect to the MySQL server, it is inadvisable to specify your password in a way that exposes it to discovery by other users. The methods you can use to specify your password when you run client programs are listed here, along with an assessment of the risks of each method. In short, the safest methods are to have the client program prompt for the password or to specify the password in a properly protected option file.

- Use a `-pyour_pass` or `--password=your_pass` option on the command line. For example:

```
shell> mysql -u francis -pfrank db_name
```

This is convenient *but insecure*. On some systems, your password becomes visible to system status programs such as `ps` that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

If your operating environment is set up to display your current command in the title bar of your terminal window, the password remains visible as long as the command is running, even if the command has scrolled out of view in the window content area.

- Use the `-p` or `--password` option on the command line with no password value specified. In this case, the client program solicits the password interactively:

```
shell> mysql -u francis -p db_name
Enter password: ********
```

The "`*`" characters indicate where you enter your password. The password is not displayed as you enter it.

It is more secure to enter your password this way than to specify it on the command line because it is not visible to other users. However, this method of entering a password is suitable only for programs that you run interactively. If you want to invoke a client from a script that runs noninteractively, there is no opportunity to enter the password from the keyboard. On some systems, you may even find that the first line of your script is read and interpreted (incorrectly) as your password.

- Store your password in an option file. For example, on Unix, you can list your password in the `[client]` section of the `.my.cnf` file in your home directory:

```
[client]
password=your_pass
```

To keep the password safe, the file should not be accessible to anyone but yourself. To ensure this, set the file access mode to `400` or `600`. For example:

```
shell> chmod 600 .my.cnf
```

To name from the command line a specific option file containing the password, use the `--defaults-file=file_name` option, where `file_name` is the full path name to the file. For example:

```
shell> mysql --defaults-file=/home/francis/mysql-opts
```

Section 4.2.6, "Using Option Files", discusses option files in more detail.

- Store your password in the `MYSQL_PWD` environment variable. See Section 2.14, "Environment Variables".

  This method of specifying your MySQL password must be considered *extremely insecure* and should not be used. Some versions of `ps` include an option to display the environment of running processes. On some systems, if you set `MYSQL_PWD`, your password is exposed to any other user who runs `ps`. Even on systems without such a version of `ps`, it is unwise to assume that there are no other methods by which users can examine process environments.

On Unix, the `mysql` client writes a record of executed statements to a history file (see Section 4.5.1.3, "mysql Logging"). By default, this file is named `.mysql_history` and is created in your home directory. Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, so if you use these statements, they are logged in the history file. To keep this file safe, use a restrictive access mode, the same way as described earlier for the `.my.cnf` file.

If your command interpreter is configured to maintain a history, any file in which the commands are saved will contain MySQL passwords entered on the command line. For example, `bash` uses `~/.bash_history`. Any such file should have a restrictive access mode.

6.1.2.2 Administrator Guidelines for Password Security

Database administrators should use the following guidelines to keep passwords secure.

MySQL stores passwords for user accounts in the `mysql.user` table. Access to this table should never be granted to any nonadministrative accounts.

A user who has access to modify the plugin directory (the value of the `plugin_dir` system variable) or the `my.cnf` file that specifies the location of the plugin directory can replace plugins and modify the capabilities provided by plugins.

Files such as log files to which passwords might be written should be protected. See Section 6.1.2.3, "Passwords and Logging".

6.1.2.3 Passwords and Logging

Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, `SET PASSWORD`, and statements that invoke the `PASSWORD()` function. If such statements are logged by the MySQL server as written, passwords in them become visible to anyone with access to the logs. This applies to the general query log, the slow query log, and the binary log (see Section 5.4, "MySQL Server Logs").

To guard log files against unwarranted exposure, locate them in a directory that restricts access to the server and the database administrator. If the server logs to tables in the `mysql` database, grant access to those tables only to the database administrator.

Replication slaves store the password for the replication master in the `master.info` file. Restrict this file to be accessible only to the database administrator.

Use a restricted access mode to protect database backups that include log tables or log files containing passwords.

6.1.2.4 Password Hashing in MySQL

MySQL lists user accounts in the `user` table of the `mysql` database. Each MySQL account can be assigned a password, although the `user` table does not store the cleartext version of the password, but a hash value computed from it.

MySQL uses passwords in two phases of client/server communication:

- When a client attempts to connect to the server, there is an initial authentication step in which the client must present a password that has a hash value matching the hash value stored in the `user` table for the account the client wants to use.

- After the client connects, it can (if it has sufficient privileges) set or change the password hash for accounts listed in the `user` table. The client can do this by using the `PASSWORD()` function to generate a password hash, or by using a password-generating statement (`CREATE USER`, `GRANT`, or `SET PASSWORD`).

In other words, the server *checks* hash values during authentication when a client first attempts to connect. The server *generates* hash values if a connected client invokes the `PASSWORD()` function or uses a password-generating statement to set or change a password.

Password hashing methods in MySQL have the history described following. These changes are illustrated by changes in the result from the `PASSWORD()` function that computes password hash values and in the structure of the `user` table where passwords are stored.

The Original (Pre-4.1) Hashing Method

The original hashing method produced a 16-byte string. Such hashes look like this:

```
mysql> SELECT PASSWORD('mypass');
+--------------------+
| PASSWORD('mypass') |
+--------------------+
| 6f8c114b58f2ce9e   |
+--------------------+
```

To store account passwords, the `Password` column of the `user` table was at this point 16 bytes long.

The 4.1 Hashing Method

MySQL 4.1 introduced password hashing that provided better security and reduced the risk of passwords being intercepted. There were several aspects to this change:

- Different format of password values produced by the `PASSWORD()` function

- Widening of the `Password` column

- Control over the default hashing method

- Control over the permitted hashing methods for clients attempting to connect to the server

The changes in MySQL 4.1 took place in two stages:

- MySQL 4.1.0 used a preliminary version of the 4.1 hashing method. This method was short lived and the following discussion says nothing more about it.

- In MySQL 4.1.1, the hashing method was modified to produce a longer 41-byte hash value:

```
mysql> SELECT PASSWORD('mypass');
+-------------------------------------------+
| PASSWORD('mypass')                        |
+-------------------------------------------+
| *6C8989366EAF75BB670AD8EA7A7FC1176A95CEF4 |
```

```
+-------------------------------------------+
```

The longer password hash format has better cryptographic properties, and client authentication based on long hashes is more secure than that based on the older short hashes.

To accommodate longer password hashes, the `Password` column in the `user` table was changed at this point to be 41 bytes, its current length.

A widened `Password` column can store password hashes in both the pre-4.1 and 4.1 formats. The format of any given hash value can be determined two ways:

- The length: 4.1 and pre-4.1 hashes are 41 and 16 bytes, respectively.

- Password hashes in the 4.1 format always begin with a "`*`" character, whereas passwords in the pre-4.1 format never do.

To permit explicit generation of pre-4.1 password hashes, two additional changes were made:

- The `OLD_PASSWORD()` function was added, which returns hash values in the 16-byte format.

- For compatibility purposes, the `old_passwords` system variable was added, to enable DBAs and applications control over the hashing method. The default `old_passwords` value of 0 causes hashing to use the 4.1 method (41-byte hash values), but setting `old_passwords=1` causes hashing to use the pre-4.1 method. In this case, `PASSWORD()` produces 16-byte values and is equivalent to `OLD_PASSWORD()`

To permit DBAs control over how clients are permitted to connect, the `secure_auth` system variable was added. Starting the server with this variable disabled or enabled permits or prohibits clients to connect using the older pre-4.1 password hashing method. Before MySQL 5.6.5, `secure_auth` is disabled by default. As of 5.6.5, `secure_auth` is enabled by default to promote a more secure default configuration. (DBAs can disable it at their discretion, but this is not recommended.)

In addition, the `mysql` client supports a `--secure-auth` option that is analogous to `secure_auth`, but from the client side. It can be used to prevent connections to less secure accounts that use pre-4.1 password hashing. This option is disabled by default before MySQL 5.6.7, enabled thereafter.

Compatibility Issues Related to Hashing Methods

The widening of the `Password` column in MySQL 4.1 from 16 bytes to 41 bytes affects installation or upgrade operations as follows:

- If you perform a new installation of MySQL, the `Password` column is made 41 bytes long automatically.

- Upgrades from MySQL 4.1 or later to current versions of MySQL should not give rise to any issues in regard to the `Password` column because both versions use the same column length and password hashing method.

- For upgrades from a pre-4.1 release to 4.1 or later, you must upgrade the system tables after upgrading. (See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".)

The 4.1 hashing method is understood only by MySQL 4.1 (and newer) servers and clients, which can result in some compatibility problems. A 4.1 or newer client can connect to a pre-4.1 server, because the client understands both the pre-4.1 and 4.1 password hashing methods. However, a pre-4.1 client that attempts to connect to a 4.1 or newer server may run into difficulties. For example, a 4.0 `mysql` client may fail with the following error message:

```
shell> mysql -h localhost -u root
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

This phenomenon also occurs for attempts to use the older PHP `mysql` extension after upgrading to MySQL 4.1 or newer. (See Common Problems with MySQL and PHP.)

The following discussion describes the differences between the pre-4.1 and 4.1 hashing methods, and what you should do if you upgrade your server but need to maintain backward compatibility with pre-4.1 clients. (However, permitting connections by old clients is not recommended and should be avoided if possible.) Additional information can be found in Section B.5.2.4, "Client does not support authentication protocol". This information is of particular importance to PHP programmers migrating MySQL databases from versions older than 4.1 to 4.1 or higher.

The differences between short and long password hashes are relevant both for how the server uses passwords during authentication and for how it generates password hashes for connected clients that perform password-changing operations.

The way in which the server uses password hashes during authentication is affected by the width of the `Password` column:

- If the column is short, only short-hash authentication is used.

- If the column is long, it can hold either short or long hashes, and the server can use either format:

  - Pre-4.1 clients can connect, but because they know only about the pre-4.1 hashing method, they can authenticate only using accounts that have short hashes.

  - 4.1 and later clients can authenticate using accounts that have short or long hashes.

Even for short-hash accounts, the authentication process is actually a bit more secure for 4.1 and later clients than for older clients. In terms of security, the gradient from least to most secure is:

- Pre-4.1 client authenticating with short password hash

- 4.1 or later client authenticating with short password hash

- 4.1 or later client authenticating with long password hash

The way in which the server generates password hashes for connected clients is affected by the width of the `Password` column and by the `old_passwords` system variable. A 4.1 or later server generates long hashes only if certain conditions are met: The `Password` column must be wide enough to hold long values and `old_passwords` must not be set to 1.

Those conditions apply as follows:

- The `Password` column must be wide enough to hold long hashes (41 bytes). If the column has not been updated and still has the pre-4.1 width of 16 bytes, the server notices that long hashes cannot fit into it and generates only short hashes when a client performs password-changing operations using the `PASSWORD()` function or a password-generating statement. This is the behavior that occurs if you have upgraded from a version of MySQL older than 4.1 to 4.1 or later but have not yet run the `mysql_upgrade` program to widen the `Password` column.

- If the `Password` column is wide, it can store either short or long password hashes. In this case, the `PASSWORD()` function and password-generating statements generate long hashes unless the server was started with the `old_passwords` system variable set to 1 to force the server to generate short password hashes instead.

The purpose of the `old_passwords` system variable is to permit backward compatibility with pre-4.1 clients under circumstances where the server would otherwise generate long password hashes. The option does not affect authentication (4.1 and later clients can still use accounts that have long password hashes), but it does prevent creation of a long password hash in the `user` table as the result of a password-changing operation. Were that permitted to occur, the account could no longer be used by pre-4.1 clients. With `old_passwords` disabled, the following undesirable scenario is possible:

- An old pre-4.1 client connects to an account that has a short password hash.

- The client changes its own password. With `old_passwords` disabled, this results in the account having a long password hash.

- The next time the old client attempts to connect to the account, it cannot, because the account has a long password hash that requires the 4.1 hashing method during authentication. (Once an account has a long password hash in the user table, only 4.1 and later clients can authenticate for it because pre-4.1 clients do not understand long hashes.)

This scenario illustrates that, if you must support older pre-4.1 clients, it is problematic to run a 4.1 or newer server without `old_passwords` set to 1. By running the server with `old_passwords=1`, password-changing operations do not generate long password hashes and thus do not cause accounts to become inaccessible to older clients. (Those clients cannot inadvertently lock themselves out by changing their password and ending up with a long password hash.)

The downside of `old_passwords=1` is that any passwords created or changed use short hashes, even for 4.1 or later clients. Thus, you lose the additional security provided by long password hashes. To create an account that has a long hash (for example, for use by 4.1 clients) or to change an existing account to use a long password hash, an administrator can set the session value of `old_passwords` set to 0 while leaving the global value set to 1:

```
mysql> SET @@session.old_passwords = 0;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@session.old_passwords, @@global.old_passwords;
+-------------------------+------------------------+
| @@session.old_passwords | @@global.old_passwords |
+-------------------------+------------------------+
|                       0 |                      1 |
+-------------------------+------------------------+
1 row in set (0.00 sec)

mysql> CREATE USER 'newuser'@'localhost' IDENTIFIED BY 'newpass';
Query OK, 0 rows affected (0.03 sec)

mysql> SET PASSWORD FOR 'existinguser'@'localhost' = PASSWORD('existingpass');
Query OK, 0 rows affected (0.00 sec)
```

The following scenarios are possible in MySQL 4.1 or later. The factors are whether the `Password` column is short or long, and, if long, whether the server is started with `old_passwords` enabled or disabled.

Scenario 1: Short `Password` column in user table:

- Only short hashes can be stored in the `Password` column.

- The server uses only short hashes during client authentication.

- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.

- The value of `old_passwords` is irrelevant because with a short `Password` column, the server generates only short password hashes anyway.

This scenario occurs when a pre-4.1 MySQL installation has been upgraded to 4.1 or later but `mysql_upgrade` has not been run to upgrade the system tables in the `mysql` database. (This is not a recommended configuration because it does not permit use of more secure 4.1 password hashing.)

Scenario 2: Long `Password` column; server started with `old_passwords=1`:

- Short or long hashes can be stored in the `Password` column.

- 4.1 and later clients can authenticate for accounts that have short or long hashes.

- Pre-4.1 clients can authenticate only for accounts that have short hashes.

- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.

In this scenario, newly created accounts have short password hashes because `old_passwords=1` prevents generation of long hashes. Also, if you create an account with a long hash before setting `old_passwords` to 1, changing the account's password while `old_passwords=1` results in the account being given a short password, causing it to lose the security benefits of a longer hash.

To create a new account that has a long password hash, or to change the password of any existing account to use a long hash, first set the session value of `old_passwords` set to 0 while leaving the global value set to 1, as described previously.

In this scenario, the server has an up to date `Password` column, but is running with the default password hashing method set to generate pre-4.1 hash values. This is not a recommended configuration but may be useful during a transitional period in which pre-4.1 clients and passwords are upgraded to 4.1 or later. When that has been done, it is preferable to run the server with `old_passwords=0` and `secure_auth=1`.

Scenario 3: Long `Password` column; server started with `old_passwords=0`:

- Short or long hashes can be stored in the `Password` column.

- 4.1 and later clients can authenticate using accounts that have short or long hashes.

- Pre-4.1 clients can authenticate only using accounts that have short hashes.

- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use long hashes exclusively. A change to an account's password results in that account having a long password hash.

As indicated earlier, a danger in this scenario is that it is possible for accounts that have a short password hash to become inaccessible to pre-4.1 clients. A change to such an account's password made using the `PASSWORD()` function or a password-generating statement results in the account being given a long password hash. From that point on, no pre-4.1 client can connect to the server using that account. The client must upgrade to 4.1 or later.

If this is a problem, you can change a password in a special way. For example, normally you use `SET PASSWORD` as follows to change an account password:

```
SET PASSWORD FOR 'some_user'@'some_host' = PASSWORD('mypass');
```

To change the password but create a short hash, use the `OLD_PASSWORD()` function instead:

```
SET PASSWORD FOR 'some_user'@'some_host' = OLD_PASSWORD('mypass');
```

`OLD_PASSWORD()` is useful for situations in which you explicitly want to generate a short hash.

The disadvantages for each of the preceding scenarios may be summarized as follows:

In scenario 1, you cannot take advantage of longer hashes that provide more secure authentication.

In scenario 2, `old_passwords=1` prevents accounts with short hashes from becoming inaccessible, but password-changing operations cause accounts with long hashes to revert to short hashes unless you take care to change the session value of `old_passwords` to 0 first.

In scenario 3, accounts with short hashes become inaccessible to pre-4.1 clients if you change their passwords without explicitly using `OLD_PASSWORD()`.

The best way to avoid compatibility problems related to short password hashes is to not use them:

- Upgrade all client programs to MySQL 4.1 or later.

- Run the server with `old_passwords=0`.

- Reset the password for any account with a short password hash to use a long password hash.

- For additional security, run the server with `secure_auth=1`.

6.1.2.5 Implications of Password Hashing Changes in MySQL 4.1 for Application Programs

An upgrade to MySQL version 4.1 or later can cause compatibility issues for applications that use `PASSWORD()` to generate passwords for their own purposes. Applications really should not do this, because `PASSWORD()` should be used only to manage passwords for MySQL accounts. But some applications use `PASSWORD()` for their own purposes anyway.

If you upgrade to 4.1 or later from a pre-4.1 version of MySQL and run the server under conditions where it generates long password hashes, an application using `PASSWORD()` for its own passwords breaks. The recommended course of action in such cases is to modify the application to use another function, such as `SHA1()` or `MD5()`, to produce hashed values. If that is not possible, you can use the `OLD_PASSWORD()` function, which is provided for generate short hashes in the old format. However, you should note that `OLD_PASSWORD()` may one day no longer be supported.

If the server is running with `old_passwords=1`, it generates short hashes and `OLD_PASSWORD()` is equivalent to `PASSWORD()`.

PHP programmers migrating their MySQL databases from version 4.0 or lower to version 4.1 or higher should see MySQL and PHP.

6.1.3 Making MySQL Secure Against Attackers

When you connect to a MySQL server, you should use a password. The password is not transmitted in clear text over the connection. Password handling during the client connection sequence was upgraded in MySQL 4.1.1 to be very secure. If you are still using pre-4.1.1-style passwords, the encryption algorithm is not as strong as the newer algorithm. With some effort, a clever attacker who can sniff the traffic between

the client and the server can crack the password. (See Section 6.1.2.4, "Password Hashing in MySQL", for a discussion of the different password handling methods.)

All other information is transferred as text, and can be read by anyone who is able to watch the connection. If the connection between the client and the server goes through an untrusted network, and you are concerned about this, you can use the compressed protocol to make traffic much more difficult to decipher. You can also use MySQL's internal SSL support to make the connection even more secure. See Section 6.4, "Using Secure Connections". Alternatively, use SSH to get an encrypted TCP/IP connection between a MySQL server and a MySQL client. You can find an Open Source SSH client at http://www.openssh.org/, and a comparison of both Open Source and Commercial SSH clients at http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.

To make a MySQL system secure, you should strongly consider the following suggestions:

- Require all MySQL accounts to have a password. A client program does not necessarily know the identity of the person running it. It is common for client/server applications that the user can specify any user name to the client program. For example, anyone can use the `mysql` program to connect as any other person simply by invoking it as `mysql -u other_user db_name` if `other_user` has no password. If all accounts have a password, connecting using another user's account becomes much more difficult.

  For a discussion of methods for setting passwords, see Section 6.3.5, "Assigning Account Passwords".

- Make sure that the only Unix user account with read or write privileges in the database directories is the account that is used for running `mysqld`.

- Never run the MySQL server as the Unix `root` user. This is extremely dangerous, because any user with the `FILE` privilege is able to cause the server to create files as `root` (for example, `~root/.bashrc`). To prevent this, `mysqld` refuses to run as `root` unless that is specified explicitly using the `--user=root` option.

  `mysqld` can (and should) be run as an ordinary, unprivileged user instead. You can create a separate Unix account named `mysql` to make everything even more secure. Use this account only for administering MySQL. To start `mysqld` as a different Unix user, add a `user` option that specifies the user name in the `[mysqld]` group of the `my.cnf` option file where you specify server options. For example:

```
[mysqld]
user=mysql
```

  This causes the server to start as the designated user whether you start it manually or by using `mysqld_safe` or `mysql.server`. For more details, see Section 6.1.5, "How to Run MySQL as a Normal User".

  Running `mysqld` as a Unix user other than `root` does not mean that you need to change the `root` user name in the `user` table. *User names for MySQL accounts have nothing to do with user names for Unix accounts.*

- Do not grant the `FILE` privilege to nonadministrative users. Any user that has this privilege can write a file anywhere in the file system with the privileges of the `mysqld` daemon. This includes the server's data directory containing the files that implement the privilege tables. To make `FILE`-privilege operations a bit safer, files generated with `SELECT ... INTO OUTFILE` do not overwrite existing files and are writable by everyone.

  The `FILE` privilege may also be used to read any file that is world-readable or accessible to the Unix user that the server runs as. With this privilege, you can read any file into a database table. This could

be abused, for example, by using `LOAD DATA` to load `/etc/passwd` into a table, which then can be displayed with `SELECT`.

To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Section 5.1.4, "Server System Variables".

- Do not grant the `PROCESS` or `SUPER` privilege to nonadministrative users. The output of `mysqladmin processlist` and `SHOW PROCESSLIST` shows the text of any statements currently being executed, so any user who is permitted to see the server process list might be able to see statements issued by other users such as `UPDATE user SET password=PASSWORD('not_secure')`.

    `mysqld` reserves an extra connection for users who have the `SUPER` privilege, so that a MySQL `root` user can log in and check server activity even if all normal connections are in use.

    The `SUPER` privilege can be used to terminate client connections, change server operation by changing the value of system variables, and control replication servers.

- Do not permit the use of symlinks to tables. (This capability can be disabled with the `--skip-symbolic-links` option.) This is especially important if you run `mysqld` as `root`, because anyone that has write access to the server's data directory then could delete any file in the system! See Section 8.12.4.2, "Using Symbolic Links for MyISAM Tables on Unix".

- Stored programs and views should be written using the security guidelines discussed in Section 19.6, "Access Control for Stored Programs and Views".

- If you do not trust your DNS, you should use IP addresses rather than host names in the grant tables. In any case, you should be very careful about creating grant table entries using host name values that contain wildcards.

- If you want to restrict the number of connections permitted to a single account, you can do so by setting the `max_user_connections` variable in `mysqld`. The `GRANT` statement also supports resource control options for limiting the extent of server use permitted to an account. See Section 13.7.1.3, "GRANT Syntax".

- If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `--secure-file-priv` to a directory where `SELECT` writes can be made safely.

6.1.4 Security-Related mysqld Options and Variables

The following table shows `mysqld` options and system variables that affect security. For descriptions of each of these, see Section 5.1.3, "Server Command Options", and Section 5.1.4, "Server System Variables".

Table 6.1 Security Option/Variable Summary

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
allow-suspicious-udfs	Yes	Yes				
automatic_sp_privileges			Yes		Global	Yes
chroot	Yes	Yes				
des-key-file	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
local_infile			Yes		Global	Yes
old_passwords			Yes		Both	Yes
safe-show-database	Yes	Yes				
safe-user-create	Yes	Yes				
secure-auth	Yes	Yes			Global	Yes
- *Variable*: secure_auth			Yes		Global	Yes
secure-file-priv	Yes	Yes			Global	No
- *Variable*: secure_file_priv			Yes		Global	No
skip-grant-tables	Yes	Yes				
skip-name-resolve	Yes	Yes			Global	No
- *Variable*: skip_name_resolve			Yes		Global	No
skip-networking	Yes	Yes			Global	No
- *Variable*: skip_networking			Yes		Global	No
skip-show-database	Yes	Yes			Global	No
- *Variable*: skip_show_database			Yes		Global	No

6.1.5 How to Run MySQL as a Normal User

On Windows, you can run the server as a Windows service using a normal user account.

On Unix, the MySQL server `mysqld` can be started and run by any user. However, you should avoid running the server as the Unix `root` user for security reasons. To change `mysqld` to run as a normal unprivileged Unix user `user_name`, you must do the following:

1. Stop the server if it is running (use `mysqladmin shutdown`).

2. Change the database directories and files so that `user_name` has privileges to read and write files in them (you might need to do this as the Unix `root` user):

```
shell> chown -R user_name /path/to/mysql/datadir
```

   If you do not do this, the server will not be able to access databases or tables when it runs as `user_name`.

   If directories or files within the MySQL data directory are symbolic links, `chown -R` might not follow symbolic links for you. If it does not, you will also need to follow those links and change the directories and files they point to.

3. Start the server as user `user_name`. Another alternative is to start `mysqld` as the Unix `root` user and use the `--user=user_name` option. `mysqld` starts up, then switches to run as the Unix user `user_name` before accepting any connections.

4. To start the server as the given user automatically at system startup time, specify the user name by adding a `user` option to the `[mysqld]` group of the `/etc/my.cnf` option file or the `my.cnf` option file in the server's data directory. For example:

```
[mysqld]
user=user_name
```

If your Unix machine itself is not secured, you should assign passwords to the MySQL `root` accounts in the grant tables. Otherwise, any user with a login account on that machine can run the `mysql` client with a `--user=root` option and perform any operation. (It is a good idea to assign passwords to MySQL accounts in any case, but especially so when other login accounts exist on the server host.) See Section 2.12.4, "Securing the Initial MySQL Accounts".

6.1.6 Security Issues with LOAD DATA LOCAL

The `LOAD DATA` statement can load a file that is located on the server host, or it can load a file that is located on the client host when the `LOCAL` keyword is specified.

There are two potential security issues with supporting the `LOCAL` version of `LOAD DATA` statements:

- The transfer of the file from the client host to the server host is initiated by the MySQL server. In theory, a patched server could be built that would tell the client program to transfer a file of the server's choosing rather than the file named by the client in the `LOAD DATA` statement. Such a server could access any file on the client host to which the client user has read access.

- In a Web environment where the clients are connecting from a Web server, a user could use `LOAD DATA LOCAL` to read any files that the Web server process has read access to (assuming that a user could run any command against the SQL server). In this environment, the client with respect to the MySQL server actually is the Web server, not the remote program being run by the user who connects to the Web server.

To deal with these problems, `LOAD DATA LOCAL` works like this:

- By default, all MySQL clients and libraries in binary distributions are compiled with the `--enable-local-infile` option.

- If you build MySQL from source but do not invoke `configure` with the `--enable-local-infile` option, `LOAD DATA LOCAL` cannot be used by any client unless it is written explicitly to invoke `mysql_options(... MYSQL_OPT_LOCAL_INFILE, 0)`. See Section 21.8.7.49, "mysql_options()".

- You can disable all `LOAD DATA LOCAL` statements from the server side by starting `mysqld` with the `--local-infile=0` option.

- For the `mysql` command-line client, enable `LOAD DATA LOCAL` by specifying the `--local-infile[=1]` option, or disable it with the `--local-infile=0` option. For `mysqlimport`, local data file loading is off by default; enable it with the `--local` or `-L` option. In any case, successful use of a local load operation requires that the server permits it.

- If you use `LOAD DATA LOCAL` in Perl scripts or other programs that read the `[client]` group from option files, you can add the `local-infile=1` option to that group. However, to keep this from causing problems for programs that do not understand `local-infile`, specify it using the `loose-` prefix:

```
[client]
loose-local-infile=1
```

- If `LOAD DATA LOCAL` is disabled, either in the server or the client, a client that attempts to issue such a statement receives the following error message:

```
ERROR 1148: The used command is not allowed with this MySQL version
```

6.1.7 Client Programming Security Guidelines

Applications that access MySQL should not trust any data entered by users, who can try to trick your code by entering special or escaped character sequences in Web forms, URLs, or whatever application you have built. Be sure that your application remains secure if a user enters something like "`; DROP DATABASE mysql;`". This is an extreme example, but large security leaks and data loss might occur as a result of hackers using similar techniques, if you do not prepare for them.

A common mistake is to protect only string data values. Remember to check numeric data as well. If an application generates a query such as `SELECT * FROM table WHERE ID=234` when a user enters the value `234`, the user can enter the value `234 OR 1=1` to cause the application to generate the query `SELECT * FROM table WHERE ID=234 OR 1=1`. As a result, the server retrieves every row in the table. This exposes every row and causes excessive server load. The simplest way to protect from this type of attack is to use single quotation marks around the numeric constants: `SELECT * FROM table WHERE ID='234'`. If the user enters extra information, it all becomes part of the string. In a numeric context, MySQL automatically converts this string to a number and strips any trailing nonnumeric characters from it.

Sometimes people think that if a database contains only publicly available data, it need not be protected. This is incorrect. Even if it is permissible to display any row in the database, you should still protect against denial of service attacks (for example, those that are based on the technique in the preceding paragraph that causes the server to waste resources). Otherwise, your server becomes unresponsive to legitimate users.

Checklist:

- Enable strict SQL mode to tell the server to be more restrictive of what data values it accepts. See Section 5.1.7, "Server SQL Modes".

- Try to enter single and double quotation marks ("`'`" and "`"`") in all of your Web forms. If you get any kind of MySQL error, investigate the problem right away.

- Try to modify dynamic URLs by adding `%22` ("`"`"), `%23` ("`#`"), and `%27` ("`'`") to them.

- Try to modify data types in dynamic URLs from numeric to character types using the characters shown in the previous examples. Your application should be safe against these and similar attacks.

- Try to enter characters, spaces, and special symbols rather than numbers in numeric fields. Your application should remove them before passing them to MySQL or else generate an error. Passing unchecked values to MySQL is very dangerous!

- Check the size of data before passing it to MySQL.

- Have your application connect to the database using a user name different from the one you use for administrative purposes. Do not give your applications any access privileges they do not need.

Many application programming interfaces provide a means of escaping special characters in data values. Properly used, this prevents application users from entering values that cause the application to generate statements that have a different effect than you intend:

- MySQL C API: Use the `mysql_real_escape_string()` API call.

- MySQL++: Use the `escape` and `quote` modifiers for query streams.

- PHP: Use either the `mysqli` or `pdo_mysql` extensions, and not the older `ext/mysql` extension. The preferred API's support the improved MySQL authentication protocol and passwords, as well as prepared statements with placeholders. See also Choosing an API.

  If the older `ext/mysql` extension must be used, then for escaping use the `mysql_real_escape_string()` function and not `mysql_escape_string()` or `addslashes()` because only `mysql_real_escape_string()` is character set-aware; the other functions can be "bypassed" when using (invalid) multibyte character sets.

- Perl DBI: Use placeholders or the `quote()` method.

- Ruby DBI: Use placeholders or the `quote()` method.

- Java JDBC: Use a `PreparedStatement` object and placeholders.

Other programming interfaces might have similar capabilities.

6.2 The MySQL Access Privilege System

The primary function of the MySQL privilege system is to authenticate a user who connects from a given host and to associate that user with privileges on a database such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. Additional functionality includes the ability to have anonymous users and to grant privileges for MySQL-specific functions such as `LOAD DATA INFILE` and administrative operations.

There are some things that you cannot do with the MySQL privilege system:

- You cannot explicitly specify that a given user should be denied access. That is, you cannot explicitly match a user and then refuse the connection.

- You cannot specify that a user has privileges to create or drop tables in a database but not to create or drop the database itself.

- A password applies globally to an account. You cannot associate a password with a specific object such as a database, table, or routine.

The user interface to the MySQL privilege system consists of SQL statements such as `CREATE USER`, `GRANT`, and `REVOKE`. See Section 13.7.1, "Account Management Statements".

Internally, the server stores privilege information in the grant tables of the `mysql` database (that is, in the database named `mysql`). The MySQL server reads the contents of these tables into memory when it starts and bases access-control decisions on the in-memory copies of the grant tables.

The MySQL privilege system ensures that all users may perform only the operations permitted to them. As a user, when you connect to a MySQL server, your identity is determined by *the host from which you connect* and *the user name you specify*. When you issue requests after connecting, the system grants privileges according to your identity and *what you want to do*.

MySQL considers both your host name and user name in identifying you because there is no reason to assume that a given user name belongs to the same person on all hosts. For example, the user `joe` who connects from `office.example.com` need not be the same person as the user `joe` who connects from `home.example.com`. MySQL handles this by enabling you to distinguish users on different hosts that happen to have the same name: You can grant one set of privileges for connections by `joe` from `office.example.com`, and a different set of privileges for connections by `joe` from `home.example.com`. To see what privileges a given account has, use the `SHOW GRANTS` statement. For example:

```
SHOW GRANTS FOR 'joe'@'office.example.com';
SHOW GRANTS FOR 'joe'@'home.example.com';
```

MySQL access control involves two stages when you run a client program that connects to the server:

Stage 1: The server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password.

Stage 2: Assuming that you can connect, the server checks each statement you issue to determine whether you have sufficient privileges to perform it. For example, if you try to select rows from a table in a database or drop a table from the database, the server verifies that you have the `SELECT` privilege for the table or the `DROP` privilege for the database.

For a more detailed description of what happens during each stage, see Section 6.2.4, "Access Control, Stage 1: Connection Verification", and Section 6.2.5, "Access Control, Stage 2: Request Verification".

If your privileges are changed (either by yourself or someone else) while you are connected, those changes do not necessarily take effect immediately for the next statement that you issue. For details about the conditions under which the server reloads the grant tables, see Section 6.2.6, "When Privilege Changes Take Effect".

For general security-related advice, see Section 6.1, "General Security Issues". For help in diagnosing privilege-related problems, see Section 6.2.7, "Troubleshooting Problems Connecting to MySQL".

6.2.1 Privileges Provided by MySQL

MySQL provides privileges that apply in different contexts and at different levels of operation:

- Administrative privileges enable users to manage operation of the MySQL server. These privileges are global because they are not specific to a particular database.

- Database privileges apply to a database and to all objects within it. These privileges can be granted for specific databases, or globally so that they apply to all databases.

- Privileges for database objects such as tables, indexes, views, and stored routines can be granted for specific objects within a database, for all objects of a given type within a database (for example, all tables in a database), or globally for all objects of a given type in all databases).

Information about account privileges is stored in the `user`, `db`, `host`, `tables_priv`, `columns_priv`, and `procs_priv` tables in the `mysql` database (see Section 6.2.2, "Grant Tables"). The MySQL server reads the contents of these tables into memory when it starts and reloads them under the circumstances indicated in Section 6.2.6, "When Privilege Changes Take Effect". Access-control decisions are based on the in-memory copies of the grant tables.

Some releases of MySQL introduce changes to the structure of the grant tables to add new privileges or features. To make sure that you can take advantage of any new capabilities, update your grant tables to have the current structure whenever you update to a new version of MySQL. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

The following table shows the privilege names used at the SQL level in the `GRANT` and `REVOKE` statements, along with the column name associated with each privilege in the grant tables and the context in which the privilege applies.

Table 6.2 Permissible Privileges for GRANT and REVOKE

Privilege	Column	Context
CREATE	Create_priv	databases, tables, or indexes
DROP	Drop_priv	databases, tables, or views
GRANT OPTION	Grant_priv	databases, tables, or stored routines

Privilege	Column	Context
`LOCK TABLES`	`Lock_tables_priv`	databases
`REFERENCES`	`References_priv`	databases or tables
`EVENT`	`Event_priv`	databases
`ALTER`	`Alter_priv`	tables
`DELETE`	`Delete_priv`	tables
`INDEX`	`Index_priv`	tables
`INSERT`	`Insert_priv`	tables or columns
`SELECT`	`Select_priv`	tables or columns
`UPDATE`	`Update_priv`	tables or columns
`CREATE TEMPORARY TABLES`	`Create_tmp_table_priv`	tables
`TRIGGER`	`Trigger_priv`	tables
`CREATE VIEW`	`Create_view_priv`	views
`SHOW VIEW`	`Show_view_priv`	views
`ALTER ROUTINE`	`Alter_routine_priv`	stored routines
`CREATE ROUTINE`	`Create_routine_priv`	stored routines
`EXECUTE`	`Execute_priv`	stored routines
`FILE`	`File_priv`	file access on server host
`CREATE USER`	`Create_user_priv`	server administration
`PROCESS`	`Process_priv`	server administration
`RELOAD`	`Reload_priv`	server administration
`REPLICATION CLIENT`	`Repl_client_priv`	server administration
`REPLICATION SLAVE`	`Repl_slave_priv`	server administration
`SHOW DATABASES`	`Show_db_priv`	server administration
`SHUTDOWN`	`Shutdown_priv`	server administration
`SUPER`	`Super_priv`	server administration
`ALL [PRIVILEGES]`		server administration
`USAGE`		server administration

The following list provides a general description of each privilege available in MySQL. Particular SQL statements might have more specific privilege requirements than indicated here. If so, the description for the statement in question provides the details.

- The `ALL` or `ALL PRIVILEGES` privilege specifier is shorthand. It stands for "all privileges available at a given privilege level" (except `GRANT OPTION`). For example, granting `ALL` at the global or table level grants all global privileges or all table-level privileges.

- The `ALTER` privilege enables use of `ALTER TABLE` to change the structure of tables. `ALTER TABLE` also requires the `CREATE` and `INSERT` privileges. Renaming a table requires `ALTER` and `DROP` on the old table, `CREATE`, and `INSERT` on the new table.

- The `ALTER ROUTINE` privilege is needed to alter or drop stored routines (procedures and functions).

- The `CREATE` privilege enables creation of new databases and tables.

- The `CREATE ROUTINE` privilege is needed to create stored routines (procedures and functions).

- The `CREATE TEMPORARY TABLES` privilege enables the creation of temporary tables using the `CREATE TEMPORARY TABLE` statement.

  However, other operations on a temporary table, such as `INSERT`, `UPDATE`, or `SELECT`, require additional privileges for those operations for the database containing the temporary table, or for the nontemporary table of the same name.

  To keep privileges for temporary and nontemporary tables separate, a common workaround for this situation is to create a database dedicated to the use of temporary tables. Then for that database, a user can be granted the `CREATE TEMPORARY TABLES` privilege, along with any other privileges required for temporary table operations done by that user.

- The `CREATE USER` privilege enables use of `CREATE USER`, `DROP USER`, `RENAME USER`, and `REVOKE ALL PRIVILEGES`.

- The `CREATE VIEW` privilege enables use of `CREATE VIEW`.

- The `DELETE` privilege enables rows to be deleted from tables in a database.

- The `DROP` privilege enables you to drop (remove) existing databases, tables, and views. Beginning with MySQL 5.1.10, the `DROP` privilege is also required to use the statement `ALTER TABLE ... DROP PARTITION` on a partitioned table. Beginning with MySQL 5.1.16, the `DROP` privilege is required for `TRUNCATE TABLE` (before that, `TRUNCATE TABLE` requires the `DELETE` privilege). *If you grant the `DROP` privilege for the `mysql` database to a user, that user can drop the database in which the MySQL access privileges are stored.*

- The `EVENT` privilege is required to create, alter, drop, or see events for the Event Scheduler. This privilege was added in MySQL 5.1.6.

- The `EXECUTE` privilege is required to execute stored routines (procedures and functions).

- The `FILE` privilege gives you permission to read and write files on the server host using the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. A user who has the `FILE` privilege can read any file on the server host that is either world-readable or readable by the MySQL server. (This implies the user can read any file in any database directory, because the server can access any of those files.) The `FILE` privilege also enables the user to create new files in any directory where the MySQL server has write access. This includes the server's data directory containing the files that implement the privilege tables. As a security measure, the server will not overwrite existing files.

  To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Section 5.1.4, "Server System Variables".

- The `GRANT OPTION` privilege enables you to give to other users or remove from other users those privileges that you yourself possess.

- The `INDEX` privilege enables you to create or drop (remove) indexes. `INDEX` applies to existing tables. If you have the `CREATE` privilege for a table, you can include index definitions in the `CREATE TABLE` statement.

- The `INSERT` privilege enables rows to be inserted into tables in a database. `INSERT` is also required for the `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` table-maintenance statements.

- The `LOCK TABLES` privilege enables the use of explicit `LOCK TABLES` statements to lock tables for which you have the `SELECT` privilege. This includes the use of write locks, which prevents other sessions from reading the locked table.

- The `PROCESS` privilege pertains to display of information about the threads executing within the server (that is, information about the statements being executed by sessions). The privilege enables use of `SHOW PROCESSLIST` or `mysqladmin processlist` to see threads belonging to other accounts; you can always see your own threads. The `PROCESS` privilege also enables use of `SHOW ENGINE`.

- The `REFERENCES` privilege is unused.

- The `RELOAD` privilege enables use of the `FLUSH` statement. It also enables `mysqladmin` commands that are equivalent to `FLUSH` operations: `flush-hosts`, `flush-logs`, `flush-privileges`, `flush-status`, `flush-tables`, `flush-threads`, `refresh`, and `reload`.

  The `reload` command tells the server to reload the grant tables into memory. `flush-privileges` is a synonym for `reload`. The `refresh` command closes and reopens the log files and flushes all tables. The other `flush-xxx` commands perform functions similar to `refresh`, but are more specific and may be preferable in some instances. For example, if you want to flush just the log files, `flush-logs` is a better choice than `refresh`.

- The `REPLICATION CLIENT` privilege enables the use of `SHOW MASTER STATUS` and `SHOW SLAVE STATUS`. In MySQL 5.1.64 and later, it also enables the use of the `SHOW BINARY LOGS` statement.

- The `REPLICATION SLAVE` privilege should be granted to accounts that are used by slave servers to connect to the current server as their master. Without this privilege, the slave cannot request updates that have been made to databases on the master server.

- The `SELECT` privilege enables you to select rows from tables in a database. `SELECT` statements require the `SELECT` privilege only if they actually retrieve rows from a table. Some `SELECT` statements do not access tables and can be executed without permission for any database. For example, you can use `SELECT` as a simple calculator to evaluate expressions that make no reference to tables:

```
SELECT 1+1;
SELECT PI()*2;
```

  The `SELECT` privilege is also needed for other statements that read column values. For example, `SELECT` is needed for columns referenced on the right hand side of `col_name=expr` assignment in `UPDATE` statements or for columns named in the `WHERE` clause of `DELETE` or `UPDATE` statements.

- The `SHOW DATABASES` privilege enables the account to see database names by issuing the `SHOW DATABASE` statement. Accounts that do not have this privilege see only databases for which they have some privileges, and cannot use the statement at all if the server was started with the `--skip-show-database` option. Note that *any* global privilege is a privilege for the database.

- The `SHOW VIEW` privilege enables use of `SHOW CREATE VIEW`.

- The `SHUTDOWN` privilege enables use of the `mysqladmin shutdown` command and the `mysql_shutdown()` C API function. There is no corresponding SQL statement.

- The `SUPER` privilege enables an account to use `CHANGE MASTER TO`, `KILL` or `mysqladmin kill` to kill threads belonging to other accounts (you can always kill your own threads), `PURGE BINARY LOGS`, configuration changes using `SET GLOBAL` to modify global system variables, the `mysqladmin debug` command, enabling or disabling logging, performing updates even if the `read_only` system variable is enabled, starting and stopping replication on slave servers, specification of any account in the `DEFINER` attribute of stored programs and views, and enables you to connect (once) even if the connection limit controlled by the `max_connections` system variable is reached.

  To create or alter stored functions if binary logging is enabled, you may also need the `SUPER` privilege, as described in Section 19.7, "Binary Logging of Stored Programs".

- The `TRIGGER` privilege enables trigger operations. You must have this privilege for a table to create, drop, execute, or display triggers for that table. This privilege was added in MySQL 5.1.6. (Prior to MySQL 5.1.6, trigger operations required the `SUPER` privilege.)

- The `UPDATE` privilege enables rows to be updated in tables in a database.

- The `USAGE` privilege specifier stands for "no privileges." It is used at the global level with `GRANT` to modify account attributes such as resource limits or SSL characteristics without affecting existing account privileges.

It is a good idea to grant to an account only those privileges that it needs. You should exercise particular caution in granting the `FILE` and administrative privileges:

- The `FILE` privilege can be abused to read into a database table any files that the MySQL server can read on the server host. This includes all world-readable files and files in the server's data directory. The table can then be accessed using `SELECT` to transfer its contents to the client host.

  When a trigger is activated (by a user who has privileges to execute `INSERT`, `UPDATE`, or `DELETE` statements for the table associated with the trigger), trigger execution requires that the user who defined the trigger still have the `TRIGGER` privilege.

- The `GRANT OPTION` privilege enables users to give their privileges to other users. Two users that have different privileges and with the `GRANT OPTION` privilege are able to combine privileges.

- The `ALTER` privilege may be used to subvert the privilege system by renaming tables.

- The `SHUTDOWN` privilege can be abused to deny service to other users entirely by terminating the server.

- The `PROCESS` privilege can be used to view the plain text of currently executing statements, including statements that set or change passwords.

- The `SUPER` privilege can be used to terminate other sessions or change how the server operates.

- Privileges granted for the `mysql` database itself can be used to change passwords and other access privilege information. Passwords are stored encrypted, so a malicious user cannot simply read them to know the plain text password. However, a user with write access to the `user` table `Password` column can change an account's password, and then connect to the MySQL server using that account.

6.2.2 Grant Tables

The `mysql` system database includes several grant tables that contain information about user accounts and the privileges held by them. This section describes those tables. For information about other tables in the system database, see Section 5.3, "The mysql System Database".

Normally, to manipulate the contents of grant tables, you modify them indirectly by using account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to set up accounts and control the privileges available to each one. See Section 13.7.1, "Account Management Statements". The discussion here describes the underlying structure of the grant tables and how the server uses their contents when interacting with clients.

> **Note**
>
> Direct modification of grant tables using statements such as `INSERT`, `UPDATE`, or `DELETE` is discouraged and done at your own risk. The server is free to ignore rows that become malformed as a result of such modifications.

These `mysql` database tables contain grant information:

- `user`: User accounts, global privileges, and other non-privilege columns.

- `db`: Database-level privileges.

- `host`: Obsolete.

- `tables_priv`: Table-level privileges.

- `columns_priv`: Column-level privileges.

- `procs_priv`: Stored procedure and function privileges.

Each grant table contains scope columns and privilege columns:

- Scope columns determine the scope of each row in the tables; that is, the context in which the row applies. For example, a `user` table row with `Host` and `User` values of `'thomas.loc.gov'` and `'bob'` applies to authenticating connections made to the server from the host `thomas.loc.gov` by a client that specifies a user name of `bob`. Similarly, a `db` table row with `Host`, `User`, and `Db` column values of `'thomas.loc.gov'`, `'bob'` and `'reports'` applies when `bob` connects from the host `thomas.loc.gov` to access the `reports` database. The `tables_priv` and `columns_priv` tables contain scope columns indicating tables or table/column combinations to which each row applies. The `procs_priv` scope columns indicate the stored routine to which each row applies.

- Privilege columns indicate which privileges a table row grants; that is, which operations it permits to be performed. The server combines the information in the various grant tables to form a complete description of a user's privileges. Section 6.2.5, "Access Control, Stage 2: Request Verification", describes the rules for this.

The server uses the grant tables in the following manner:

- The `user` table scope columns determine whether to reject or permit incoming connections. For permitted connections, any privileges granted in the `user` table indicate the user's global privileges. Any privileges granted in this table apply to *all* databases on the server.

  > **Caution**
  >
  > Because any global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with `SHOW DATABASES` or by examining the `SCHEMATA` table of `INFORMATION_SCHEMA`.

- The `db` table scope columns determine which users can access which databases from which hosts. The privilege columns determine the permitted operations. A privilege granted at the database level applies to the database and to all objects in the database, such as tables and stored programs.

- The `host` table is used in conjunction with the `db` table when you want a given `db` table row to apply to several hosts. For example, if you want a user to be able to use a database from several hosts in your network, leave the `Host` value empty in the user's `db` table row, then populate the `host` table with a row for each of those hosts. This mechanism is described more detail in Section 6.2.5, "Access Control, Stage 2: Request Verification".

  > **Note**
  >
  > The `host` table must be modified directly with statements such as `INSERT`, `UPDATE`, and `DELETE`. It is not affected by statements such as `GRANT` and `REVOKE` that modify the grant tables indirectly. Most MySQL installations need not use this table at all.

- The `tables_priv` and `columns_priv` tables are similar to the `db` table, but are more fine-grained: They apply at the table and column levels rather than at the database level. A privilege granted at the

table level applies to the table and to all its columns. A privilege granted at the column level applies only to a specific column.

- The `procs_priv` table applies to stored routines (procedures and functions). A privilege granted at the routine level applies only to a single procedure or function.

The server uses the `user`, `db`, and `host` tables in the `mysql` database at both the first and second stages of access control (see Section 6.2, "The MySQL Access Privilege System"). The columns in the `user` and `db` tables are shown here. The `host` table is similar to the `db` table but has a specialized use as described in Section 6.2.5, "Access Control, Stage 2: Request Verification".

Table 6.3 user and db Table Columns

Table Name	user	db
Scope columns	Host	Host
	User	Db
	Password	User
Privilege columns	Select_priv	Select_priv
	Insert_priv	Insert_priv
	Update_priv	Update_priv
	Delete_priv	Delete_priv
	Index_priv	Index_priv
	Alter_priv	Alter_priv
	Create_priv	Create_priv
	Drop_priv	Drop_priv
	Grant_priv	Grant_priv
	Create_view_priv	Create_view_priv
	Show_view_priv	Show_view_priv
	Create_routine_priv	Create_routine_priv
	Alter_routine_priv	Alter_routine_priv
	Execute_priv	Execute_priv
	Trigger_priv	Trigger_priv
	Event_priv	Event_priv
	Create_tmp_table_priv	Create_tmp_table_priv
	Lock_tables_priv	Lock_tables_priv
	References_priv	References_priv
	Reload_priv	
	Shutdown_priv	
	Process_priv	
	File_priv	
	Show_db_priv	
	Super_priv	
	Repl_slave_priv	

Table Name	**user**	**db**
	`Repl_client_priv`	
	`Create_user_priv`	
Security columns	`ssl_type`	
	`ssl_cipher`	
	`x509_issuer`	
	`x509_subject`	
Resource control columns	`max_questions`	
	`max_updates`	
	`max_connections`	
	`max_user_connections`	

The `Event_priv` and `Trigger_priv` columns were added in MySQL 5.1.6.

During the second stage of access control, the server performs request verification to ensure that each client has sufficient privileges for each request that it issues. In addition to the `user`, `db`, and `host` grant tables, the server may also consult the `tables_priv` and `columns_priv` tables for requests that involve tables. The latter tables provide finer privilege control at the table and column levels. They have the columns shown in the following table.

Table 6.4 tables_priv and columns_priv Table Columns

Table Name	**tables_priv**	**columns_priv**
Scope columns	`Host`	`Host`
	`Db`	`Db`
	`User`	`User`
	`Table_name`	`Table_name`
		`Column_name`
Privilege columns	`Table_priv`	`Column_priv`
	`Column_priv`	
Other columns	`Timestamp`	`Timestamp`
	`Grantor`	

The `Timestamp` and `Grantor` columns are unused.

For verification of requests that involve stored routines, the server may consult the `procs_priv` table, which has the columns shown in the following table.

Table 6.5 procs_priv Table Columns

Table Name	**procs_priv**
Scope columns	`Host`
	`Db`
	`User`
	`Routine_name`
	`Routine_type`

Table Name	**procs_priv**
Privilege columns	Proc_priv
Other columns	Timestamp
	Grantor

The Routine_type column is an ENUM column with values of 'FUNCTION' or 'PROCEDURE' to indicate the type of routine the row refers to. This column enables privileges to be granted separately for a function and a procedure with the same name.

The Timestamp and Grantor columns are set to the current timestamp and the CURRENT_USER value, respectively, but are otherwise unused.

Scope columns in the grant tables contain strings. The default value for each is the empty string. The following table shows the number of characters permitted in each column.

Table 6.6 Grant Table Scope Column Lengths

Column Name	Maximum Permitted Characters
Host	60
User	16
Password	41
Db	64
Table_name	64
Column_name	64
Routine_name	64

For access-checking purposes, comparisons of User, Password, Db, and Table_name values are case sensitive. Comparisons of Host, Column_name, and Routine_name values are not case sensitive.

The user, db, and host tables list each privilege in a separate column that is declared as ENUM('N','Y') DEFAULT 'N'. In other words, each privilege can be disabled or enabled, with the default being disabled.

The tables_priv, columns_priv, and procs_priv tables declare the privilege columns as SET columns. Values in these columns can contain any combination of the privileges controlled by the table. Only those privileges listed in the column value are enabled.

Table 6.7 Set-Type Privilege Column Values

Table Name	Column Name	Possible Set Elements
tables_priv	Table_priv	'Select', 'Insert', 'Update', 'Delete', 'Create', 'Drop', 'Grant', 'References', 'Index', 'Alter', 'Create View', 'Show view', 'Trigger'
tables_priv	Column_priv	'Select', 'Insert', 'Update', 'References'
columns_priv	Column_priv	'Select', 'Insert', 'Update', 'References'

Table Name	Column Name	Possible Set Elements
`procs_priv`	`Proc_priv`	`'Execute', 'Alter Routine', 'Grant'`

Only the `user` table specifies administrative privileges, such as `RELOAD` and `SHUTDOWN`. Administrative operations are operations on the server itself and are not database-specific, so there is no reason to list these privileges in the other grant tables. Consequently, the server need consult only the `user` table to determine whether a user can perform an administrative operation.

The `FILE` privilege also is specified only in the `user` table. It is not an administrative privilege as such, but a user's ability to read or write files on the server host is independent of the database being accessed.

The server reads the contents of the grant tables into memory when it starts. You can tell it to reload the tables by issuing a `FLUSH PRIVILEGES` statement or executing a `mysqladmin flush-privileges` or `mysqladmin reload` command. Changes to the grant tables take effect as indicated in Section 6.2.6, "When Privilege Changes Take Effect".

When you modify an account, it is a good idea to verify that your changes have the intended effect. To check the privileges for a given account, use the `SHOW GRANTS` statement. For example, to determine the privileges that are granted to an account with user name and host name values of `bob` and `pc84.example.com`, use this statement:

```
SHOW GRANTS FOR 'bob'@'pc84.example.com';
```

6.2.3 Specifying Account Names

MySQL account names consist of a user name and a host name. This enables creation of accounts for users with the same name who can connect from different hosts. This section describes how to write account names, including special values and wildcard rules.

In SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, write account names using the following rules:

- Syntax for account names is `'user_name'@'host_name'`.

- An account name consisting only of a user name is equivalent to `'user_name'@'%'`. For example, `'me'` is equivalent to `'me'@'%'`.

- The user name and host name need not be quoted if they are legal as unquoted identifiers. Quotes are necessary to specify a `user_name` string containing special characters (such as `-`), or a `host_name` string containing special characters or wildcard characters (such as `.` or `%`); for example, `'test-user'@'%.com'`.

- Quote user names and host names as identifiers or as strings, using either backticks (`` ` ``), single quotation marks (`'`), or double quotation marks (`"`).

- The user name and host name parts, if quoted, must be quoted separately. That is, write `'me'@'localhost'`, not `'me@localhost'`; the latter is actually equivalent to `'me@localhost'@'%'`.

- A reference to the `CURRENT_USER` or `CURRENT_USER()` function is equivalent to specifying the current client's user name and host name literally.

MySQL stores account names in grant tables in the `mysql` system database using separate columns for the user name and host name parts:

- The `user` table contains one row for each account. The `User` and `Host` columns store the user name and host name. This table also indicates which global privileges the account has.

- Other grant tables indicate privileges an account has for databases and objects within databases. These tables have `User` and `Host` columns to store the account name. Each row in these tables associates with the account in the `user` table that has the same `User` and `Host` values.

For additional detail about grant table structure, see Section 6.2.2, "Grant Tables".

User names and host names have certain special values or wildcard conventions, as described following.

A user name is either a nonblank value that literally matches the user name for incoming connection attempts, or a blank value (empty string) that matches any user name. An account with a blank user name is an anonymous user. To specify an anonymous user in SQL statements, use a quoted empty user name part, such as `''@'localhost'`.

The host name part of an account name can take many forms, and wildcards are permitted:

- A host value can be a host name or an IP address. The name `'localhost'` indicates the local host. The IP address `'127.0.0.1'` indicates the loopback interface.

- You can use the wildcard characters `%` and `_` in host name or IP address values. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. For example, a host value of `'%'` matches any host name, whereas a value of `'%.mysql.com'` matches any host in the `mysql.com` domain. `'192.168.1.%'` matches any host in the 192.168.1 class C network.

  Because you can use IP wildcard values in host values (for example, `'192.168.1.%'` to match every host on a subnet), someone could try to exploit this capability by naming a host `192.168.1.somewhere.com`. To foil such attempts, MySQL disallows matching on host names that start with digits and a dot. Thus, if you have a host named something like `1.2.example.com`, its name never matches the host part of account names. An IP wildcard value can match only IP addresses, not host names.

- For a host value specified as an IP address, you can specify a netmask indicating how many address bits to use for the network number. The syntax is `host_ip/netmask`. For example:

```
CREATE USER 'david'@'192.58.197.0/255.255.255.0';
```

This enables `david` to connect from any client host having an IP address `client_ip` for which the following condition is true:

```
client_ip & netmask = host_ip
```

That is, for the `CREATE USER` statement just shown:

```
client_ip & 255.255.255.0 = 192.58.197.0
```

IP addresses that satisfy this condition and can connect to the MySQL server are those in the range from `192.58.197.0` to `192.58.197.255`.

A netmask typically begins with bits set to 1, followed by bits set to 0. Examples:

- `192.0.0.0/255.0.0.0`: Any host on the 192 class A network

- `192.168.0.0/255.255.0.0`: Any host on the 192.168 class B network

- `192.168.1.0/255.255.255.0`: Any host on the 192.168.1 class C network

- `192.168.1.1`: Only the host with this specific IP address

The server performs matching of host values in account names against the client host using the value returned by the system DNS resolver for the client host name or IP address. Except in the case that the account host value is specified using netmask notation, this comparison is performed as a string match, even for an account host value given as an IP address. This means that you should specify account host values in the same format used by DNS. Here are examples of problems to watch out for:

- Suppose that a host on the local network has a fully qualified name of `host1.example.com`. If DNS returns name lookups for this host as `host1.example.com`, use that name in account host values. But if DNS returns just `host1`, use `host1` instead.

- If DNS returns the IP address for a given host as `192.168.1.2`, that will match an account host value of `192.168.1.2` but not `192.168.01.2`. Similarly, it will match an account host pattern like `192.168.1.%` but not `192.168.01.%`.

To avoid problems like this, it is advisable to check the format in which your DNS returns host names and addresses, and use values in the same format in MySQL account names.

6.2.4 Access Control, Stage 1: Connection Verification

When you attempt to connect to a MySQL server, the server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password. If not, the server denies access to you completely. Otherwise, the server accepts the connection, and then enters Stage 2 and waits for requests.

Credential checking is performed using the three `user` table scope columns (`Host`, `User`, and `Password`). The server accepts the connection only if the `Host` and `User` columns in some `user` table row match the client host name and user name and the client supplies the password specified in that row. The rules for permissible `Host` and `User` values are given in Section 6.2.3, "Specifying Account Names".

Your identity is based on two pieces of information:

- The client host from which you connect

- Your MySQL user name

If the `User` column value is nonblank, the user name in an incoming connection must match exactly. If the `User` value is blank, it matches any user name. If the `user` table row that matches an incoming connection has a blank user name, the user is considered to be an anonymous user with no name, not a user with the name that the client actually specified. This means that a blank user name is used for all further access checking for the duration of the connection (that is, during Stage 2).

The `Password` column can be blank. This is not a wildcard and does not mean that any password matches. It means that the user must connect without specifying a password.

Nonblank `Password` values in the `user` table represent encrypted passwords. MySQL does not store passwords in cleartext form for anyone to see. Rather, the password supplied by a user who is attempting to connect is encrypted (using the `PASSWORD()` function). The encrypted password then is used during the connection process when checking whether the password is correct. This is done without the encrypted password ever traveling over the connection. See Section 6.3.1, "User Names and Passwords".

From MySQL's point of view, the encrypted password is the *real* password, so you should never give anyone access to it. In particular, *do not give nonadministrative users read access to tables in the* `mysql` *database*.

The following table shows how various combinations of `User` and `Host` values in the `user` table apply to incoming connections.

`User` Value	`Host` Value	Permissible Connections
`'fred'`	`'thomas.loc.gov'`	`fred`, connecting from `thomas.loc.gov`
`''`	`'thomas.loc.gov'`	Any user, connecting from `thomas.loc.gov`
`'fred'`	`'%'`	`fred`, connecting from any host
`''`	`'%'`	Any user, connecting from any host
`'fred'`	`'%.loc.gov'`	`fred`, connecting from any host in the `loc.gov` domain
`'fred'`	`'x.y.%'`	`fred`, connecting from `x.y.net`, `x.y.com`, `x.y.edu`, and so on; this is probably not useful
`'fred'`	`'192.168.10.177'`	`fred`, connecting from the host with IP address `192.168.10.177`
`'fred'`	`'192.168.10.%'`	`fred`, connecting from any host in the `192.168.10` class C subnet
`'fred'`	`'192.168.10.0/255.255.255.0'`	Same as previous example

It is possible for the client host name and user name of an incoming connection to match more than one row in the `user` table. The preceding set of examples demonstrates this: Several of the entries shown match a connection from `thomas.loc.gov` by `fred`.

When multiple matches are possible, the server must determine which of them to use. It resolves this issue as follows:

- Whenever the server reads the `user` table into memory, it sorts the rows.

- When a client attempts to connect, the server looks through the rows in sorted order.

- The server uses the first row that matches the client host name and user name.

The server uses sorting rules that order rows with the most-specific `Host` values first. Literal host names and IP addresses are the most specific. (The specificity of a literal IP address is not affected by whether it has a netmask, so `192.168.1.13` and `192.168.1.0/255.255.255.0` are considered equally specific.) The pattern `'%'` means "any host" and is least specific. The empty string `''` also means "any host" but sorts after `'%'`. Rows with the same `Host` value are ordered with the most-specific `User` values first (a blank `User` value means "any user" and is least specific). For rows with equally-specific `Host` and `User` values, the order is indeterminate.

To see how this works, suppose that the `user` table looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| %         | root     | ...
| %         | jeffrey  | ...
| localhost | root     | ...
| localhost |          | ...
+-----------+----------+-
```

When the server reads the table into memory, it sorts the rows using the rules just described. The result after sorting looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| localhost | root     | ...
| localhost |          | ...
| %         | jeffrey  | ...
| %         | root     | ...
+-----------+----------+-
```

When a client attempts to connect, the server looks through the sorted rows and uses the first match found. For a connection from `localhost` by `jeffrey`, two of the rows from the table match: the one with `Host` and `User` values of `'localhost'` and `''`, and the one with values of `'%'` and `'jeffrey'`. The `'localhost'` row appears first in sorted order, so that is the one the server uses.

Here is another example. Suppose that the `user` table looks like this:

```
+----------------+----------+-
| Host           | User     | ...
+----------------+----------+-
| %              | jeffrey  | ...
| thomas.loc.gov |          | ...
+----------------+----------+-
```

The sorted table looks like this:

```
+----------------+----------+-
| Host           | User     | ...
+----------------+----------+-
| thomas.loc.gov |          | ...
| %              | jeffrey  | ...
+----------------+----------+-
```

A connection by `jeffrey` from `thomas.loc.gov` is matched by the first row, whereas a connection by `jeffrey` from any host is matched by the second.

Note

It is a common misconception to think that, for a given user name, all rows that explicitly name that user are used first when the server attempts to find a match for the connection. This is not true. The preceding example illustrates this, where a connection from `thomas.loc.gov` by `jeffrey` is first matched not by the row containing `'jeffrey'` as the `User` column value, but by the row with no user name. As a result, `jeffrey` is authenticated as an anonymous user, even though he specified a user name when connecting.

If you are able to connect to the server, but your privileges are not what you expect, you probably are being authenticated as some other account. To find out what account the server used to authenticate you, use the `CURRENT_USER()` function. (See Section 12.14, "Information Functions".) It returns a value in *user_name@host_name* format that indicates the `User` and `Host` values from the matching `user` table row. Suppose that `jeffrey` connects and issues the following query:

```
mysql> SELECT CURRENT_USER();
+----------------+
| CURRENT_USER() |
```

```
+----------------+
| @localhost     |
+----------------+
```

The result shown here indicates that the matching `user` table row had a blank `User` column value. In other words, the server is treating `jeffrey` as an anonymous user.

Another way to diagnose authentication problems is to print out the `user` table and sort it by hand to see where the first match is being made.

6.2.5 Access Control, Stage 2: Request Verification

After you establish a connection, the server enters Stage 2 of access control. For each request that you issue through that connection, the server determines what operation you want to perform, then checks whether you have sufficient privileges to do so. This is where the privilege columns in the grant tables come into play. These privileges can come from any of the `user`, `db`, `host`, `tables_priv`, `columns_priv`, or `procs_priv` tables. (You may find it helpful to refer to Section 6.2.2, "Grant Tables", which lists the columns present in each of the grant tables.)

The `user` table grants privileges that are assigned to you on a global basis and that apply no matter what the default database is. For example, if the `user` table grants you the `DELETE` privilege, you can delete rows from any table in any database on the server host! It is wise to grant privileges in the `user` table only to people who need them, such as database administrators. For other users, you should leave all privileges in the `user` table set to `'N'` and grant privileges at more specific levels only. You can grant privileges for particular databases, tables, columns, or routines.

The `db` and `host` tables grant database-specific privileges. Values in the scope columns of these tables can take the following forms:

- A blank `User` value in the `db` table matches the anonymous user. A nonblank value matches literally; there are no wildcards in user names.

- The wildcard characters `%` and `_` can be used in the `Host` and `Db` columns of either table. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. If you want to use either character literally when granting privileges, you must escape it with a backslash. For example, to include the underscore character (`_`) as part of a database name, specify it as `\_` in the `GRANT` statement.

- A `'%'` `Host` value in the `db` table means "any host." A blank `Host` value in the `db` table means "consult the `host` table for further information" (a process that is described later in this section).

- A `'%'` or blank `Host` value in the `host` table means "any host."

- A `'%'` or blank `Db` value in either table means "any database."

The server reads the `db` and `host` tables into memory and sorts them at the same time that it reads the `user` table. The server sorts the `db` table based on the `Host`, `Db`, and `User` scope columns, and sorts the `host` table based on the `Host` and `Db` scope columns. As with the `user` table, sorting puts the most-specific values first and least-specific values last, and when the server looks for matching rows, it uses the first match that it finds.

The `tables_priv`, `columns_priv`, and `procs_priv` tables grant table-specific, column-specific, and routine-specific privileges. Values in the scope columns of these tables can take the following forms:

- The wildcard characters `%` and `_` can be used in the `Host` column. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator.

- A `'%'` or blank `Host` value means "any host."

- The `Db`, `Table_name`, `Column_name`, and `Routine_name` columns cannot contain wildcards or be blank.

The server sorts the `tables_priv`, `columns_priv`, and `procs_priv` tables based on the `Host`, `Db`, and `User` columns. This is similar to `db` table sorting, but simpler because only the `Host` column can contain wildcards.

The server uses the sorted tables to verify each request that it receives. For requests that require administrative privileges such as `SHUTDOWN` or `RELOAD`, the server checks only the `user` table row because that is the only table that specifies administrative privileges. The server grants access if the row permits the requested operation and denies access otherwise. For example, if you want to execute `mysqladmin shutdown` but your `user` table row does not grant the `SHUTDOWN` privilege to you, the server denies access without even checking the `db` or `host` tables. (They contain no `Shutdown_priv` column, so there is no need to do so.)

For database-related requests (`INSERT`, `UPDATE`, and so on), the server first checks the user's global privileges by looking in the `user` table row. If the row permits the requested operation, access is granted. If the global privileges in the `user` table are insufficient, the server determines the user's database-specific privileges by checking the `db` and `host` tables:

1. The server looks in the `db` table for a match on the `Host`, `Db`, and `User` columns. The `Host` and `User` columns are matched to the connecting user's host name and MySQL user name. The `Db` column is matched to the database that the user wants to access. If there is no row for the `Host` and `User`, access is denied.

2. If there is a matching `db` table row and its `Host` column is not blank, that row defines the user's database-specific privileges.

3. If the matching `db` table row's `Host` column is blank, it signifies that the `host` table enumerates which hosts should be permitted access to the database. In this case, a further lookup is done in the `host` table to find a match on the `Host` and `Db` columns. If no `host` table row matches, access is denied. If there is a match, the user's database-specific privileges are computed as the intersection (*not* the union!) of the privileges in the `db` and `host` table rows; that is, the privileges that are `'Y'` in both rows. (This way you can grant general privileges in the `db` table row and then selectively restrict them on a host-by-host basis using the `host` table rows.)

After determining the database-specific privileges granted by the `db` and `host` table rows, the server adds them to the global privileges granted by the `user` table. If the result permits the requested operation, access is granted. Otherwise, the server successively checks the user's table and column privileges in the `tables_priv` and `columns_priv` tables, adds those to the user's privileges, and permits or denies access based on the result. For stored-routine operations, the server uses the `procs_priv` table rather than `tables_priv` and `columns_priv`.

Expressed in boolean terms, the preceding description of how a user's privileges are calculated may be summarized like this:

```
global privileges
OR (database privileges AND host privileges)
OR table privileges
OR column privileges
OR routine privileges
```

It may not be apparent why, if the global `user` row privileges are initially found to be insufficient for the requested operation, the server adds those privileges to the database, table, and column privileges later.

The reason is that a request might require more than one type of privilege. For example, if you execute an `INSERT INTO ... SELECT` statement, you need both the `INSERT` and the `SELECT` privileges. Your privileges might be such that the `user` table row grants one privilege and the `db` table row grants the other. In this case, you have the necessary privileges to perform the request, but the server cannot tell that from either table by itself; the privileges granted by the rows in both tables must be combined.

The `host` table is not affected by the `GRANT` or `REVOKE` statements, so it is unused in most MySQL installations. If you modify it directly, you can use it for some specialized purposes, such as to maintain a list of secure servers on the local network that are granted all privileges.

You can also use the `host` table to indicate hosts that are *not* secure. Suppose that you have a machine `public.your.domain` that is located in a public area that you do not consider secure. You can enable access to all hosts on your network except that machine by using `host` table rows like this:

```
+--------------------+----+-
| Host               | Db | ...
+--------------------+----+-
| public.your.domain | %  | ... (all privileges set to 'N')
| %.your.domain      | %  | ... (all privileges set to 'Y')
+--------------------+----+-
```

6.2.6 When Privilege Changes Take Effect

When `mysqld` starts, it reads all grant table contents into memory. The in-memory tables become effective for access control at that point.

If you modify the grant tables indirectly using account-management statements such as `GRANT`, `REVOKE`, `SET PASSWORD`, or `RENAME USER`, the server notices these changes and loads the grant tables into memory again immediately.

If you modify the grant tables directly using statements such as `INSERT`, `UPDATE`, or `DELETE`, your changes have no effect on privilege checking until you either restart the server or tell it to reload the tables. If you change the grant tables directly but forget to reload them, your changes have *no effect* until you restart the server. This may leave you wondering why your changes seem to make no difference!

To tell the server to reload the grant tables, perform a flush-privileges operation. This can be done by issuing a `FLUSH PRIVILEGES` statement or by executing a `mysqladmin flush-privileges` or `mysqladmin reload` command.

A grant table reload affects privileges for each existing client connection as follows:

- Table and column privilege changes take effect with the client's next request.

- Database privilege changes take effect the next time the client executes a `USE` *db_name* statement.

> **Note**
>
> Client applications may cache the database name; thus, this effect may not be visible to them without actually changing to a different database or flushing the privileges.

- Global privileges and passwords are unaffected for a connected client. These changes take effect only for subsequent connections.

If the server is started with the `--skip-grant-tables` option, it does not read the grant tables or implement any access control. Anyone can connect and do anything, *which is insecure.* To cause a server thus started to read the tables and enable access checking, flush the privileges.

6.2.7 Troubleshooting Problems Connecting to MySQL

If you encounter problems when you try to connect to the MySQL server, the following items describe some courses of action you can take to correct the problem.

- Make sure that the server is running. If it is not, clients cannot connect to it. For example, if an attempt to connect to the server fails with a message such as one of those following, one cause might be that the server is not running:

```
shell> mysql
ERROR 2003: Can't connect to MySQL server on 'host_name' (111)
shell> mysql
ERROR 2002: Can't connect to local MySQL server through socket
'/tmp/mysql.sock' (111)
```

- It might be that the server is running, but you are trying to connect using a TCP/IP port, named pipe, or Unix socket file different from the one on which the server is listening. To correct this when you invoke a client program, specify a `--port` option to indicate the proper port number, or a `--socket` option to indicate the proper named pipe or Unix socket file. To find out where the socket file is, you can use this command:

```
shell> netstat -ln | grep mysql
```

- Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with `--skip-networking`, it will not accept TCP/IP connections at all. If the server was started with `--bind-address=127.0.0.1`, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.

- Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or the Windows XP personal firewall may need to be configured not to block the MySQL port.

- The grant tables must be properly set up so that the server can use them for access control. For some distribution types (such as binary distributions on Windows, or RPM distributions on Linux), the installation process initializes the MySQL data directory, including the `mysql` database containing the grant tables. For distributions that do not do this, you must initialize the data directory manually. For details, see Section 2.12, "Postinstallation Setup and Testing".

  To determine whether you need to initialize the grant tables, look for a `mysql` directory under the data directory. (The data directory normally is named `data` or `var` and is located under your MySQL installation directory.) Make sure that you have a file named `user.MYD` in the `mysql` database directory. If not, initialize the data directory. After doing so and starting the server, test the initial privileges by executing this command:

```
shell> mysql -u root
```

  The server should let you connect without error.

- After a fresh installation, you should connect to the server and set up your users and their access permissions:

```
shell> mysql -u root mysql
```

The server should let you connect because the MySQL `root` user has no password initially. That is also a security risk, so setting the password for the `root` accounts is something you should do while you're setting up your other MySQL accounts. For instructions on setting the initial passwords, see Section 2.12.4, "Securing the Initial MySQL Accounts".

- If you have updated an existing MySQL installation to a newer version, did you run the `mysql_upgrade` script? If not, do so. The structure of the grant tables changes occasionally when new capabilities are added, so after an upgrade you should always make sure that your tables have the current structure. For instructions, see Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

- If a client program receives the following error message when it tries to connect, it means that the server expects passwords in a newer format than the client is capable of generating:

```
shell> mysql
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

For information on how to deal with this, see Section 6.1.2.4, "Password Hashing in MySQL", and Section B.5.2.4, "Client does not support authentication protocol".

- Remember that client programs use connection parameters specified in option files or environment variables. If a client program seems to be sending incorrect default connection parameters when you have not specified them on the command line, check any applicable option files and your environment. For example, if you get `Access denied` when you run a client without any options, make sure that you have not specified an old password in any of your option files!

  You can suppress the use of option files by a client program by invoking it with the `--no-defaults` option. For example:

```
shell> mysqladmin --no-defaults -u root version
```

  The option files that clients use are listed in Section 4.2.6, "Using Option Files". Environment variables are listed in Section 2.14, "Environment Variables".

- If you get the following error, it means that you are using an incorrect `root` password:

```
shell> mysqladmin -u root -pxxxx ver
Access denied for user 'root'@'localhost' (using password: YES)
```

  If the preceding error occurs even when you have not specified a password, it means that you have an incorrect password listed in some option file. Try the `--no-defaults` option as described in the previous item.

  For information on changing passwords, see Section 6.3.5, "Assigning Account Passwords".

  If you have lost or forgotten the `root` password, see Section B.5.3.2, "How to Reset the Root Password".

- If you change a password by using `SET PASSWORD`, `INSERT`, or `UPDATE`, you must encrypt the password using the `PASSWORD()` function. If you do not use `PASSWORD()` for these statements, the password will not work. For example, the following statement assigns a password, but fails to encrypt it, so the user is not able to connect afterward:

```
SET PASSWORD FOR 'abe'@'host_name' = 'eagle';
```

Instead, set the password like this:

```
SET PASSWORD FOR 'abe'@'host_name' = PASSWORD('eagle');
```

The `PASSWORD()` function is unnecessary when you specify a password using the `CREATE USER` or `GRANT` statements or the `mysqladmin password` command. Each of those automatically uses `PASSWORD()` to encrypt the password. See Section 6.3.5, "Assigning Account Passwords", and Section 13.7.1.1, "CREATE USER Syntax".

- `localhost` is a synonym for your local host name, and is also the default host to which clients try to connect if you specify no host explicitly.

  You can use a `--host=127.0.0.1` option to name the server host explicitly. This will make a TCP/IP connection to the local `mysqld` server. You can also use TCP/IP by specifying a `--host` option that uses the actual host name of the local host. In this case, the host name must be specified in a `user` table row on the server host, even though you are running the client program on the same host as the server.

- The `Access denied` error message tells you who you are trying to log in as, the client host from which you are trying to connect, and whether you were using a password. Normally, you should have one row in the `user` table that exactly matches the host name and user name that were given in the error message. For example, if you get an error message that contains `using password: NO`, it means that you tried to log in without a password.

- If you get an `Access denied` error when trying to connect to the database with `mysql -u user_name`, you may have a problem with the `user` table. Check this by executing `mysql -u root mysql` and issuing this SQL statement:

```
SELECT * FROM user;
```

The result should include a row with the `Host` and `User` columns matching your client's host name and your MySQL user name.

- If the following error occurs when you try to connect from a host other than the one on which the MySQL server is running, it means that there is no row in the `user` table with a `Host` value that matches the client host:

```
Host ... is not allowed to connect to this MySQL server
```

You can fix this by setting up an account for the combination of client host name and user name that you are using when trying to connect.

If you do not know the IP address or host name of the machine from which you are connecting, you should put a row with `'%'` as the `Host` column value in the `user` table. After trying to connect from the client machine, use a `SELECT USER()` query to see how you really did connect. Then change the `'%'` in the `user` table row to the actual host name that shows up in the log. Otherwise, your system is left insecure because it permits connections from any host for the given user name.

On Linux, another reason that this error might occur is that you are using a binary MySQL version that is compiled with a different version of the `glibc` library than the one you are using. In this case, you should either upgrade your operating system or `glibc`, or download a source distribution of MySQL version and compile it yourself. A source RPM is normally trivial to compile and install, so this is not a big problem.

- If you specify a host name when trying to connect, but get an error message where the host name is not shown or is an IP address, it means that the MySQL server got an error when trying to resolve the IP address of the client host to a name:

```
shell> mysqladmin -u root -pxxxx -h some_hostname ver
Access denied for user 'root'@'' (using password: YES)
```

If you try to connect as `root` and get the following error, it means that you do not have a row in the `user` table with a `User` column value of `'root'` and that `mysqld` cannot resolve the host name for your client:

```
Access denied for user ''@'unknown'
```

These errors indicate a DNS problem. To fix it, execute `mysqladmin flush-hosts` to reset the internal DNS host cache. See Section 8.12.6.2, "DNS Lookup Optimization and the Host Cache".

Some permanent solutions are:

- Determine what is wrong with your DNS server and fix it.

- Specify IP addresses rather than host names in the MySQL grant tables.

- Put an entry for the client machine name in `/etc/hosts` on Unix or `\windows\hosts` on Windows.

- Start `mysqld` with the `--skip-name-resolve` option.

- Start `mysqld` with the `--skip-host-cache` option.

- On Unix, if you are running the server and the client on the same machine, connect to `localhost`. For connections to `localhost`, MySQL programs attempt to connect to the local server by using a Unix socket file, unless there are connection parameters specified to ensure that the client makes a TCP/IP connection. For more information, see Section 4.2.2, "Connecting to the MySQL Server".

- On Windows, if you are running the server and the client on the same machine and the server supports named pipe connections, connect to the host name `.` (period). Connections to `.` use a named pipe rather than TCP/IP.

- If `mysql -u root` works but `mysql -h your_hostname -u root` results in `Access denied` (where `your_hostname` is the actual host name of the local host), you may not have the correct name for your host in the `user` table. A common problem here is that the `Host` value in the `user` table row specifies an unqualified host name, but your system's name resolution routines return a fully qualified domain name (or vice versa). For example, if you have a row with host `'pluto'` in the `user` table, but your DNS tells MySQL that your host name is `'pluto.example.com'`, the row does not work. Try adding a row to the `user` table that contains the IP address of your host as the `Host` column value. (Alternatively, you could add a row to the `user` table with a `Host` value that contains a wildcard; for example, `'pluto.%'`. However, use of `Host` values ending with `%` is *insecure* and is *not* recommended!)

- If `mysql -u user_name` works but `mysql -u user_name some_db` does not, you have not granted access to the given user for the database named *some_db*.

- If `mysql -u user_name` works when executed on the server host, but `mysql -h host_name -u user_name` does not work when executed on a remote client host, you have not enabled access to the server for the given user name from the remote host.

- If you cannot figure out why you get `Access denied`, remove from the `user` table all rows that have `Host` values containing wildcards (rows that contain `'%'` or `'_'` characters). A very common error is to insert a new row with `Host='%'` and `User='some_user'`, thinking that this enables you to specify `localhost` to connect from the same machine. The reason that this does not work is that the default privileges include a row with `Host='localhost'` and `User=''`. Because that row has a `Host` value `'localhost'` that is more specific than `'%'`, it is used in preference to the new row when connecting from `localhost`! The correct procedure is to insert a second row with `Host='localhost'` and `User='some_user'`, or to delete the row with `Host='localhost'` and `User=''`. After deleting the row, remember to issue a `FLUSH PRIVILEGES` statement to reload the grant tables. See also Section 6.2.4, "Access Control, Stage 1: Connection Verification".

- If you are able to connect to the MySQL server, but get an `Access denied` message whenever you issue a `SELECT ... INTO OUTFILE` or `LOAD DATA INFILE` statement, your row in the `user` table does not have the `FILE` privilege enabled.

- If you change the grant tables directly (for example, by using `INSERT`, `UPDATE`, or `DELETE` statements) and your changes seem to be ignored, remember that you must execute a `FLUSH PRIVILEGES` statement or a `mysqladmin flush-privileges` command to cause the server to reload the privilege tables. Otherwise, your changes have no effect until the next time the server is restarted. Remember that after you change the `root` password with an `UPDATE` statement, you will not need to specify the new password until after you flush the privileges, because the server will not know you've changed the password yet!

- If your privileges seem to have changed in the middle of a session, it may be that a MySQL administrator has changed them. Reloading the grant tables affects new client connections, but it also affects existing connections as indicated in Section 6.2.6, "When Privilege Changes Take Effect".

- If you have access problems with a Perl, PHP, Python, or ODBC program, try to connect to the server with `mysql -u user_name db_name` or `mysql -u user_name -pyour_pass db_name`. If you are able to connect using the `mysql` client, the problem lies with your program, not with the access privileges. (There is no space between `-p` and the password; you can also use the `--password=your_pass` syntax to specify the password. If you use the `-p` or `--password` option with no password value, MySQL prompts you for the password.)

- For testing purposes, start the `mysqld` server with the `--skip-grant-tables` option. Then you can change the MySQL grant tables and use the `mysqlaccess` script to check whether your modifications have the desired effect. When you are satisfied with your changes, execute `mysqladmin flush-privileges` to tell the `mysqld` server to reload the privileges. This enables you to begin using the new grant table contents without stopping and restarting the server.

- If you get the following error, you may have a problem with the `db` or `host` table:

```
Access to database denied
```

If the row selected from the `db` table has an empty value in the `Host` column, make sure that there are one or more corresponding rows in the `host` table specifying which hosts the `db` table row applies to. This problem occurs infrequently because the `host` table is rarely used.

- If everything else fails, start the `mysqld` server with a debugging option (for example, `--debug=d,general,query`). This prints host and user information about attempted connections, as well as information about each command issued. See Section 22.4.3, "The DBUG Package".

- If you have any other problems with the MySQL grant tables and feel you must post the problem to the mailing list, always provide a dump of the MySQL grant tables. You can dump the tables with the `mysqldump mysql` command. To file a bug report, see the instructions at Section 1.7, "How to Report

Bugs or Problems". In some cases, you may need to restart `mysqld` with `--skip-grant-tables` to run `mysqldump`.

6.3 MySQL User Account Management

This section describes how to set up accounts for clients of your MySQL server. It discusses the following topics:

- The meaning of account names and passwords as used in MySQL and how that compares to names and passwords used by your operating system

- How to set up new accounts and remove existing accounts

- How to change passwords

- Guidelines for using passwords securely

See also Section 13.7.1, "Account Management Statements", which describes the syntax and use for all user-management SQL statements.

6.3.1 User Names and Passwords

MySQL stores accounts in the `user` table of the `mysql` system database. An account is defined in terms of a user name and the client host or hosts from which the user can connect to the server. The account may also have a password. For information about account representation in the `user` table, see Section 6.2.2, "Grant Tables".

There are several distinctions between the way user names and passwords are used by MySQL and your operating system:

- User names, as used by MySQL for authentication purposes, have nothing to do with user names (login names) as used by Windows or Unix. On Unix, most MySQL clients by default try to log in using the current Unix user name as the MySQL user name, but that is for convenience only. The default can be overridden easily, because client programs permit any user name to be specified with a `-u` or `--user` option. This means that anyone can attempt to connect to the server using any user name, so you cannot make a database secure in any way unless all MySQL accounts have passwords. Anyone who specifies a user name for an account that has no password is able to connect successfully to the server.

- MySQL user names can be up to 16 characters long. Operating system user names may be of a different maximum length. For example, Unix user names typically are limited to eight characters.

  > **Warning**
  >
  > The limit on MySQL user name length is hardcoded in MySQL servers and clients, and trying to circumvent it by modifying the definitions of the tables in the `mysql` database *does not work*.
  >
  > You should never alter the structure of tables in the `mysql` database in any manner whatsoever except by means of the procedure that is described in Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables". Attempting to redefine MySQL's system tables in any other fashion results in undefined (and unsupported!) behavior. The server is free to ignore rows that become malformed as a result of such modifications.

- To authenticate client connections that use MySQL built-in authentication, the server uses MySQL passwords stored in the `user` table. These passwords are distinct from passwords for logging in to your

operating system. There is no necessary connection between the "external" password you use to log in to a Windows or Unix machine and the password you use to access the MySQL server on that machine.

- MySQL encrypts passwords stored in the `user` table using its own algorithm. This encryption is the same as that implemented by the `PASSWORD()` SQL function but differs from that used during the Unix login process. Unix password encryption is the same as that implemented by the `ENCRYPT()` SQL function. See the descriptions of the `PASSWORD()` and `ENCRYPT()` functions in Section 12.13, "Encryption and Compression Functions".

  From version 4.1 on, MySQL employs a stronger authentication method that has better password protection during the connection process than in earlier versions. It is secure even if TCP/IP packets are sniffed or the `mysql` database is captured. (In earlier versions, even though passwords are stored in encrypted form in the `user` table, knowledge of the encrypted password value could be used to connect to the MySQL server.) Section 6.1.2.4, "Password Hashing in MySQL", discusses password encryption further.

- If the user name and password contain only ASCII characters, it is possible to connect to the server regardless of character set settings. To connect when the user name or password contain non-ASCII characters, the client should call the `mysql_options()` C API function with the `MYSQL_SET_CHARSET_NAME` option and appropriate character set name as arguments. This causes authentication to take place using the specified character set. Otherwise, authentication will fail unless the server default character set is the same as the encoding in the authentication defaults.

  Standard MySQL client programs support a `--default-character-set` option that causes `mysql_options()` to be called as just described. For programs that use a connector that is not based on the C API, the connector may provide an equivalent to `mysql_options()` that can be used instead. Check the connector documentation.

  The preceding notes do not apply for `ucs2`, which is not permitted as a client character set.

The MySQL installation process populates the grant tables with an initial account or accounts. The names and access privileges for these accounts are described in Section 2.12.4, "Securing the Initial MySQL Accounts", which also discusses how to assign passwords to them. Thereafter, you normally set up, modify, and remove MySQL accounts using statements such as `CREATE USER`, `DROP USER`, `GRANT`, and `REVOKE`. See Section 13.7.1, "Account Management Statements".

To connect to a MySQL server with a command-line client, specify user name and password options as necessary for the account that you want to use:

```
shell> mysql --user=monty --password db_name
```

If you prefer short options, the command looks like this:

```
shell> mysql -u monty -p db_name
```

If you omit the password value following the `--password` or `-p` option on the command line (as just shown), the client prompts for one. Alternatively, the password can be specified on the command line:

```
shell> mysql --user=monty --password=password db_name
shell> mysql -u monty -ppassword db_name
```

If you use the `-p` option, there must be *no space* between `-p` and the following password value.

Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line. See Section 4.2.6, "Using Option Files".

For additional information about specifying user names, passwords, and other connection parameters, see Section 4.2.2, "Connecting to the MySQL Server".

6.3.2 Adding User Accounts

You can create MySQL accounts two ways:

- By using account-management statements intended for creating accounts and establishing their privileges, such as `CREATE USER` and `GRANT`. These statements cause the server to make appropriate modifications to the underlying grant tables.

- By manipulating the MySQL grant tables directly with statements such as `INSERT`, `UPDATE`, or `DELETE`.

The preferred method is to use account-management statements because they are more concise and less error-prone than manipulating the grant tables directly. All such statements are described in Section 13.7.1, "Account Management Statements". Direct grant table manipulation is discouraged, and is not described here. The server is free to ignore rows that become malformed as a result of such modifications.

Another option for creating accounts is to use the GUI tool MySQL Workbench. Also, several third-party programs offer capabilities for MySQL account administration. `phpMyAdmin` is one such program.

The following examples show how to use the `mysql` client program to set up new accounts. These examples assume that privileges have been set up according to the defaults described in Section 2.12.4, "Securing the Initial MySQL Accounts". This means that to make changes, you must connect to the MySQL server as the MySQL `root` user, which has the `CREATE USER` privilege.

First, use the `mysql` program to connect to the server as the MySQL `root` user:

```
shell> mysql --user=root mysql
```

If you have assigned a password to the `root` account, you must also supply a `--password` or `-p` option.

After connecting to the server as `root`, you can add new accounts. The following example uses `CREATE USER` and `GRANT` statements to set up four accounts:

```
mysql> CREATE USER 'monty'@'localhost' IDENTIFIED BY 'some_pass';
mysql> GRANT ALL PRIVILEGES ON *.* TO 'monty'@'localhost'
    ->     WITH GRANT OPTION;
mysql> CREATE USER 'monty'@'%' IDENTIFIED BY 'some_pass';
mysql> GRANT ALL PRIVILEGES ON *.* TO 'monty'@'%'
    ->     WITH GRANT OPTION;
mysql> CREATE USER 'admin'@'localhost' IDENTIFIED BY 'admin_pass';
mysql> GRANT RELOAD,PROCESS ON *.* TO 'admin'@'localhost';
mysql> CREATE USER 'dummy'@'localhost';
```

The accounts created by those statements have the following properties:

- Two accounts have a user name of `monty` and a password of `some_pass`. Both are superuser accounts with full privileges to do anything. The `'monty'@'localhost'` account can be used only when connecting from the local host. The `'monty'@'%'` account uses the `'%'` wildcard for the host part, so it can be used to connect from any host.

  The `'monty'@'localhost'` account is necessary if there is an anonymous-user account for `localhost`. Without the `'monty'@'localhost'` account, that anonymous-user account takes precedence when `monty` connects from the local host and `monty` is treated as an anonymous user. The reason for this is that the anonymous-user account has a more specific `Host` column value than the `'monty'@'%'` account and thus comes earlier in the `user` table sort order. (`user` table sorting is discussed in Section 6.2.4, "Access Control, Stage 1: Connection Verification".)

- The `'admin'@'localhost'` account has a password of `admin_pass`. This account can be used only by `admin` to connect from the local host. It is granted the `RELOAD` and `PROCESS` administrative privileges. These privileges enable the `admin` user to execute the `mysqladmin reload`, `mysqladmin refresh`, and `mysqladmin flush-xxx` commands, as well as `mysqladmin processlist`. No privileges are granted for accessing any databases. You could add such privileges using `GRANT` statements.

- The `'dummy'@'localhost'` account has no password (which is insecure and not recommended). This account can be used only to connect from the local host. No privileges are granted. It is assumed that you will grant specific privileges to the account using `GRANT` statements.

To see the privileges for an account, use `SHOW GRANTS`:

```
mysql> SHOW GRANTS FOR 'admin'@'localhost';
+-----------------------------------------------------+
| Grants for admin@localhost                          |
+-----------------------------------------------------+
| GRANT RELOAD, PROCESS ON *.* TO 'admin'@'localhost' |
+-----------------------------------------------------+
```

The next examples create three accounts and grant them access to specific databases. Each of them has a user name of `custom` and password of `obscure`:

```
mysql> CREATE USER 'custom'@'localhost' IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON bankaccount.*
    ->     TO 'custom'@'localhost';
mysql> CREATE USER 'custom'@'host47.example.com' IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON expenses.*
    ->     TO 'custom'@'host47.example.com';
mysql> CREATE USER 'custom'@'%.example.com' IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON customer.*
    ->     TO 'custom'@'%.example.com';
```

The three accounts can be used as follows:

- The first account can access the `bankaccount` database, but only from the local host.

- The second account can access the `expenses` database, but only from the host `host47.example.com`.

- The third account can access the `customer` database, from any host in the `example.com` domain. This account has access from all machines in the domain due to use of the "`%`" wildcard character in the host part of the account name.

6.3.3 Removing User Accounts

To remove an account, use the `DROP USER` statement, which is described in Section 13.7.1.2, "DROP USER Syntax". For example:

```
mysql> DROP USER 'jeffrey'@'localhost';
```

6.3.4 Setting Account Resource Limits

One means of restricting client use of MySQL server resources is to set the global `max_user_connections` system variable to a nonzero value. This limits the number of simultaneous

connections that can be made by any given account, but places no limits on what a client can do once connected. In addition, setting `max_user_connections` does not enable management of individual accounts. Both types of control are of interest to MySQL administrators.

To address such concerns, MySQL permits limits for individual accounts on use of these server resources:

- The number of queries an account can issue per hour

- The number of updates an account can issue per hour

- The number of times an account can connect to the server per hour

- The number of simultaneous connections to the server by an account

Any statement that a client can issue counts against the query limit, unless its results are served from the query cache. Only statements that modify databases or tables count against the update limit.

An "account" in this context corresponds to a row in the `mysql.user` table. That is, a connection is assessed against the `User` and `Host` values in the `user` table row that applies to the connection. For example, an account `'usera'@'%.example.com'` corresponds to a row in the `user` table that has `User` and `Host` values of `usera` and `%.example.com`, to permit `usera` to connect from any host in the `example.com` domain. In this case, the server applies resource limits in this row collectively to all connections by `usera` from any host in the `example.com` domain because all such connections use the same account.

Before MySQL 5.0.3, an "account" was assessed against the actual host from which a user connects. This older method of accounting may be selected by starting the server with the `--old-style-user-limits` option. In this case, if `usera` connects simultaneously from `host1.example.com` and `host2.example.com`, the server applies the account resource limits separately to each connection. If `usera` connects again from `host1.example.com`, the server applies the limits for that connection together with the existing connection from that host.

To establish resource limits for an account, use the `GRANT` statement (see Section 13.7.1.3, "GRANT Syntax"). Provide a `WITH` clause that names each resource to be limited. The default value for each limit is zero (no limit). For example, to create a new account that can access the `customer` database, but only in a limited fashion, issue these statements:

```
mysql> CREATE USER 'francis'@'localhost' IDENTIFIED BY 'frank';
mysql> GRANT ALL ON customer.* TO 'francis'@'localhost'
    ->     WITH MAX_QUERIES_PER_HOUR 20
    ->          MAX_UPDATES_PER_HOUR 10
    ->          MAX_CONNECTIONS_PER_HOUR 5
    ->          MAX_USER_CONNECTIONS 2;
```

The limit types need not all be named in the `WITH` clause, but those named can be present in any order. The value for each per-hour limit should be an integer representing a count per hour. For `MAX_USER_CONNECTIONS`, the limit is an integer representing the maximum number of simultaneous connections by the account. If this limit is set to zero, the global `max_user_connections` system variable value determines the number of simultaneous connections. If `max_user_connections` is also zero, there is no limit for the account.

To modify limits for an existing account, use a `GRANT USAGE` statement at the global level (`ON *.*`). The following statement changes the query limit for `francis` to 100:

```
mysql> GRANT USAGE ON *.* TO 'francis'@'localhost'
    ->     WITH MAX_QUERIES_PER_HOUR 100;
```

The statement modifies only the limit value specified and leaves the account otherwise unchanged.

To remove a limit, set its value to zero. For example, to remove the limit on how many times per hour `francis` can connect, use this statement:

```
mysql> GRANT USAGE ON *.* TO 'francis'@'localhost'
    ->     WITH MAX_CONNECTIONS_PER_HOUR 0;
```

As mentioned previously, the simultaneous-connection limit for an account is determined from the `MAX_USER_CONNECTIONS` limit and the `max_user_connections` system variable. Suppose that the global `max_user_connections` value is 10 and three accounts have individual resource limits specified as follows:

```
GRANT ... TO 'user1'@'localhost' WITH MAX_USER_CONNECTIONS 0;
GRANT ... TO 'user2'@'localhost' WITH MAX_USER_CONNECTIONS 5;
GRANT ... TO 'user3'@'localhost' WITH MAX_USER_CONNECTIONS 20;
```

`user1` has a connection limit of 10 (the global `max_user_connections` value) because it has a `MAX_USER_CONNECTIONS` limit of zero. `user2` and `user3` have connection limits of 5 and 20, respectively, because they have nonzero `MAX_USER_CONNECTIONS` limits.

The server stores resource limits for an account in the `user` table row corresponding to the account. The `max_questions`, `max_updates`, and `max_connections` columns store the per-hour limits, and the `max_user_connections` column stores the `MAX_USER_CONNECTIONS` limit. (See Section 6.2.2, "Grant Tables".) If your `user` table does not have these columns, it must be upgraded; see Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

Resource-use counting takes place when any account has a nonzero limit placed on its use of any of the resources.

As the server runs, it counts the number of times each account uses resources. If an account reaches its limit on number of connections within the last hour, the server rejects further connections for the account until that hour is up. Similarly, if the account reaches its limit on the number of queries or updates, the server rejects further queries or updates until the hour is up. In all such cases, the server issues appropriate error messages.

Resource counting occurs per account, not per client. For example, if your account has a query limit of 50, you cannot increase your limit to 100 by making two simultaneous client connections to the server. Queries issued on both connections are counted together.

The current per-hour resource-use counts can be reset globally for all accounts, or individually for a given account:

- To reset the current counts to zero for all accounts, issue a `FLUSH USER_RESOURCES` statement. The counts also can be reset by reloading the grant tables (for example, with a `FLUSH PRIVILEGES` statement or a `mysqladmin reload` command).

- The counts for an individual account can be reset to zero by setting any of its limits again. Specify a limit value equal to the value currently assigned to the account.

Per-hour counter resets do not affect the `MAX_USER_CONNECTIONS` limit.

All counts begin at zero when the server starts. Counts do not carry over through server restarts.

For the `MAX_USER_CONNECTIONS` limit, an edge case can occur if the account currently has open the maximum number of connections permitted to it: A disconnect followed quickly by a connect can result in an error (`ER_TOO_MANY_USER_CONNECTIONS` or `ER_USER_LIMIT_REACHED`) if the server has not fully

processed the disconnect by the time the connect occurs. When the server finishes disconnect processing, another connection will once more be permitted.

6.3.5 Assigning Account Passwords

Required credentials for clients that connect to the MySQL server can include a password. This section describes how to assign passwords for MySQL accounts.

MySQL stores passwords in the `user` table in the `mysql` system database. Operations that assign or modify passwords are permitted only to users with the `CREATE USER` privilege, or, alternatively, privileges for the `mysql` database (`INSERT` privilege to create new accounts, `UPDATE` privilege to modify existing accounts). If the `read_only` system variable is enabled, use of account-modification statements such as `CREATE USER` or `SET PASSWORD` additionally requires the `SUPER` privilege.

The discussion here summarizes syntax only for the most common password-assignment statements. For complete details on other possibilities, see Section 13.7.1.1, "CREATE USER Syntax", Section 13.7.1.3, "GRANT Syntax", and Section 13.7.1.6, "SET PASSWORD Syntax".

MySQL hashes passwords stored in the `mysql.user` table to obfuscate them. For most statements described here, MySQL automatically hashes the password specified. An exception is `SET PASSWORD ... = PASSWORD('`*`auth_string`*`')`, for which you use the `PASSWORD()` function explicitly to hash the password. There are also syntaxes for `CREATE USER`, `GRANT`, and `SET PASSWORD` that permit hashed values to be specified literally; for details, see the descriptions of those statements.

To assign a password when you create a new account, use `CREATE USER` and include an `IDENTIFIED BY` clause:

```
mysql> CREATE USER 'jeffrey'@'localhost'
    -> IDENTIFIED BY 'mypass';
```

For this `CREATE USER` syntax, MySQL automatically hashes the password before storing it in the `mysql.user` table.

To assign or change a password for an existing account, use one of the following methods:

- Use `SET PASSWORD` with the `PASSWORD()` function:

```
mysql> SET PASSWORD FOR
    -> 'jeffrey'@'localhost' = PASSWORD('mypass');
```

If you are not connected as an anonymous user, you can change your own password by omitting the `FOR` clause:

```
mysql> SET PASSWORD = PASSWORD('mypass');
```

The `PASSWORD()` function hashes the password using the hashing method determined by the value of the `old_passwords` system variable value. If `SET PASSWORD` rejects the hashed password value returned by `PASSWORD()` as not being in the correct format, it may be necessary to change `old_passwords` to change the hashing method. For descriptions of the permitted values, see Section 5.1.4, "Server System Variables".

- You can also use a `GRANT USAGE` statement at the global level (`ON *.*`) to assign a password to an account without affecting the account's current privileges:

```
mysql> GRANT USAGE ON *.* TO 'jeffrey'@'localhost'
```

```
    -> IDENTIFIED BY 'mypass';
```

For this `GRANT` syntax, MySQL automatically hashes the password before storing it in the `mysql.user` table.

- To change an account password from the command line, use the `mysqladmin` command:

```
shell> mysqladmin -u user_name -h host_name password "new_password"
```

The account for which this command sets the password is the one with a `mysql.user` table row that matches *user_name* in the `User` column and the client host *from which you connect* in the `Host` column.

For password changes made using `mysqladmin`, MySQL automatically hashes the password before storing it in the `mysql.user` table.

6.3.6 SQL-Based MySQL Account Activity Auditing

Applications can use the following guidelines to perform SQL-based auditing that ties database activity to MySQL accounts.

MySQL accounts correspond to rows in the `mysql.user` table. When a client connects successfully, the server authenticates the client to a particular row in this table. The `User` and `Host` column values in this row uniquely identify the account and correspond to the `'user_name'@'host_name'` format in which account names are written in SQL statements.

The account used to authenticate a client determines which privileges the client has. Normally, the `CURRENT_USER()` function can be invoked to determine which account this is for the client user. Its value is constructed from the `User` and `Host` columns of the `user` table row for the account.

However, there are circumstances under which the `CURRENT_USER()` value corresponds not to the client user but to a different account. This occurs in contexts when privilege checking is not based the client's account:

- Stored routines (procedures and functions) defined with the `SQL SECURITY DEFINER` characteristic

- Views defined with the `SQL SECURITY DEFINER` characteristic (as of MySQL 5.1.12)

- Triggers and events

In those contexts, privilege checking is done against the `DEFINER` account and `CURRENT_USER()` refers to that account, not to the account for the client who invoked the stored routine or view or who caused the trigger to activate. To determine the invoking user, you can call the `USER()` function, which returns a value indicating the actual user name provided by the client and the host from which the client connected. However, this value does not necessarily correspond directly to an account in the `user` table, because the `USER()` value never contains wildcards, whereas account values (as returned by `CURRENT_USER()`) may contain user name and host name wildcards.

For example, a blank user name matches any user, so an account of `''@'localhost'` enables clients to connect as an anonymous user from the local host with any user name. In this case, if a client connects as `user1` from the local host, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+----------------+----------------+
| USER()         | CURRENT_USER() |
+----------------+----------------+
```

```
| user1@localhost | @localhost     |
+-----------------+----------------+
```

The host name part of an account can contain wildcards, too. If the host name contains a `'%'` or `'_'` pattern character or uses netmask notation, the account can be used for clients connecting from multiple hosts and the `CURRENT_USER()` value will not indicate which one. For example, the account `'user2'@'%.example.com'` can be used by `user2` to connect from any host in the `example.com` domain. If `user2` connects from `remote.example.com`, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+------------------------+--------------------+
| USER()                 | CURRENT_USER()     |
+------------------------+--------------------+
| user2@remote.example.com | user2@%.example.com |
+------------------------+--------------------+
```

If an application must invoke `USER()` for user auditing (for example, if it does auditing from within triggers) but must also be able to associate the `USER()` value with an account in the `user` table, it is necessary to avoid accounts that contain wildcards in the `User` or `Host` column. Specifically, do not permit `User` to be empty (which creates an anonymous-user account), and do not permit pattern characters or netmask notation in `Host` values. All accounts must have a nonempty `User` value and literal `Host` value.

With respect to the previous examples, the `''@'localhost'` and `'user2'@'%.example.com'` accounts should be changed not to use wildcards:

```
RENAME USER ''@'localhost' TO 'user1'@'localhost';
RENAME USER 'user2'@'%.example.com' TO 'user2'@'remote.example.com';
```

If `user2` must be able to connect from several hosts in the `example.com` domain, there should be a separate account for each host.

To extract the user name or host name part from a `CURRENT_USER()` or `USER()` value, use the `SUBSTRING_INDEX()` function:

```
mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',1);
+--------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',1) |
+--------------------------------------+
| user1                                |
+--------------------------------------+

mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',-1);
+--------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',-1) |
+--------------------------------------+
| localhost                            |
+--------------------------------------+
```

6.4 Using Secure Connections

With an unencrypted connection between the MySQL client and the server, someone with access to the network could watch all your traffic and inspect the data being sent or received between client and server.

When you must move information over a network in a secure fashion, an unencrypted connection is unacceptable. To make any kind of data unreadable, use encryption. Encryption algorithms must include security elements to resist many kinds of known attacks such as changing the order of encrypted messages or replaying data twice.

MySQL supports secure (encrypted) connections between clients and the server using the TLS (Transport Layer Security) protocol. TLS is sometimes referred to as SSL (Secure Sockets Layer).

TLS uses encryption algorithms to ensure that data received over a public network can be trusted. It has mechanisms to detect data change, loss, or replay. TLS also incorporates algorithms that provide identity verification using the X509 standard.

X509 makes it possible to identify someone on the Internet. In basic terms, there should be some entity called a "Certificate Authority" (or CA) that assigns electronic certificates to anyone who needs them. Certificates rely on asymmetric encryption algorithms that have two encryption keys (a public key and a secret key). A certificate owner can present the certificate to another party as proof of identity. A certificate consists of its owner's public key. Any data encrypted using this public key can be decrypted only using the corresponding secret key, which is held by the owner of the certificate.

For more information about TLS, SSL, X509, encryption, or public-key cryptography, perform an Internet search for the keywords in which you are interested.

MySQL can be compiled for secure-connection support using OpenSSL or yaSSL. For a comparison of the two packages, see Section 6.4.1, "OpenSSL Versus yaSSL" For information about the encryption protocols and ciphers each package supports, see Section 6.4.3, "Secure Connection Protocols and Ciphers".

MySQL performs encryption on a per-connection basis, and use of encryption can be optional or mandatory. This enables you to choose an encrypted or unencrypted connection according to the requirements of individual applications. For information on how to require users to use encrypted connections, see the discussion of the `REQUIRE` clause of the `GRANT` statement in Section 13.7.1.3, "GRANT Syntax".

Encrypted connections are not used by default. For applications that require the security provided by encrypted connections, the extra computation to encrypt the data is worthwhile.

Secure connections are available through the MySQL C API using the `mysql_ssl_set()` and `mysql_options()` functions. See Section 21.8.7.67, "mysql_ssl_set()", and Section 21.8.7.49, "mysql_options()".

Replication uses the C API, so secure connections can be used between master and slave servers. See Section 16.3.7, "Setting Up Replication to Use Secure Connections".

It is also possible to connect securely from within an SSH connection to the MySQL server host. For an example, see Section 6.4.7, "Connecting to MySQL Remotely from Windows with SSH".

6.4.1 OpenSSL Versus yaSSL

MySQL can be compiled using OpenSSL or yaSSL, both of which enable secure conections based on the OpenSSL API.

OpenSSL and yaSSL offer the same basic functionality, but additional features are available in MySQL distributions compiled using OpenSSL: OpenSSL supports a wider range of encryption ciphers from which to choose for the `--ssl-cipher` option, and supports the `--ssl-capath` option. See Section 6.4.5, "Command Options for Secure Connections".

6.4.2 Building MySQL with Support for Secure Connections

To use SSL connections between the MySQL server and client programs, your system must support either OpenSSL or yaSSL, and your version of MySQL must be built with SSL support. To make it easier to use secure connections, MySQL is bundled with yaSSL, which uses the same licensing model as MySQL.

(OpenSSL uses an Apache-style license.) yaSSL support is available on all MySQL platforms supported by Oracle Corporation.

To get secure connections to work with MySQL and SSL, you must do the following:

1. If you are not using a binary (precompiled) version of MySQL that has been built with SSL support, and you are going to use OpenSSL rather than the bundled yaSSL library, install OpenSSL if it has not already been installed. We have tested MySQL with OpenSSL 0.9.6. To obtain OpenSSL, visit http:// www.openssl.org.

   Building MySQL using OpenSSL requires a shared OpenSSL library, otherwise linker errors occur. Alternatively, build MySQL using yaSSL.

2. If you are not using a binary (precompiled) version of MySQL that has been built with SSL support, configure a MySQL source distribution to use SSL. When you configure MySQL, invoke the `configure` script like this:

   ```
   shell> ./configure --with-ssl
   ```

   That command configures the distribution to use the bundled yaSSL library. To use OpenSSL instead, specify the `--with-ssl` option with the path to the directory where the OpenSSL header files and libraries are located:

   ```
   shell> ./configure --with-ssl=path
   ```

   > **Note**
   >
   > On some platforms the full determination of the You may also need to explicitly add the SSL library and header directories. You can do this by setting the `LDFLAGS`, `CFLAGS`, `CPPFLAGS` and `CXXFLAGS` with the full directories. For example:
   >
   > ```
   > shell> LDFLAGS="-L/usr/local/ssl/lib" CFLAGS="-I/usr/local/ssl/include" \
   > CPPFLAGS="-I/usr/local/ssl/include" CXXFLAGS="-I/usr/local/ssl/include" \
   > configure --with-ssl=/usr/local/ssl
   > ```

   Before MySQL 5.1.11, you must use the appropriate option to select the SSL library that you want to use.

   For yaSSL:

   ```
   shell> ./configure --with-yassl
   ```

   For OpenSSL:

   ```
   shell> ./configure --with-openssl
   ```

   Then compile and install the distribution.

   On Unix platforms, yaSSL retrieves true random numbers from either `/dev/urandom` or `/dev/ random`. Bug#13164 lists workarounds for some very old platforms which do not support these devices.

3. To check whether a `mysqld` server supports secure connections, examine the value of the `have_ssl` system variable:

```
mysql> SHOW VARIABLES LIKE 'have_ssl';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| have_ssl      | YES   |
+---------------+-------+
```

If the value is YES, the server supports secure connections. If the value is DISABLED, the server is capable of supporting secure connections but was not started with the appropriate `--ssl-xxx` options to enable secure connections to be used; see Section 6.4.4, "Configuring MySQL to Use Secure Connections".

6.4.3 Secure Connection Protocols and Ciphers

To determine which encryption protocol and cipher are in use for an encrypted connection, use the following statements to check the values of the Ssl_version and Ssl_cipher status variables:

```
mysql> SHOW SESSION STATUS LIKE 'Ssl_version';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Ssl_version   | TLSv1 |
+---------------+-------+
mysql> SHOW SESSION STATUS LIKE 'Ssl_cipher';
+---------------+-------------------+
| Variable_name | Value             |
+---------------+-------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+---------------+-------------------+
```

If the connection is not encrypted, both variables have an empty value.

MySQL supports encrypted connections using the TLSv1 protocol.

To determine which ciphers a given server supports, use the following statement to check the value of the Ssl_cipher_list status variable:

```
SHOW SESSION STATUS LIKE 'Ssl_cipher_list';
```

The set of available ciphers depends on your MySQL version and whether MySQL was compiled using OpenSSL or yaSSL, and (for OpenSSL) the library version used to compile MySQL.

MySQL passes this cipher list to OpenSSL:

```
AES256-GCM-SHA384
AES256-SHA
AES256-SHA256
CAMELLIA256-SHA
DES-CBC3-SHA
DHE-DSS-AES256-GCM-SHA384
DHE-DSS-AES256-SHA
DHE-DSS-AES256-SHA256
DHE-DSS-CAMELLIA256-SHA
DHE-RSA-AES256-GCM-SHA384
DHE-RSA-AES256-SHA
DHE-RSA-AES256-SHA256
DHE-RSA-CAMELLIA256-SHA
ECDH-ECDSA-AES256-GCM-SHA384
ECDH-ECDSA-AES256-SHA
ECDH-ECDSA-AES256-SHA384
ECDH-ECDSA-DES-CBC3-SHA
ECDH-RSA-AES256-GCM-SHA384
```

```
ECDH-RSA-AES256-SHA
ECDH-RSA-AES256-SHA384
ECDH-RSA-DES-CBC3-SHA
ECDHE-ECDSA-AES128-GCM-SHA256
ECDHE-ECDSA-AES128-SHA
ECDHE-ECDSA-AES128-SHA256
ECDHE-ECDSA-AES256-GCM-SHA384
ECDHE-ECDSA-AES256-SHA
ECDHE-ECDSA-AES256-SHA384
ECDHE-ECDSA-DES-CBC3-SHA
ECDHE-RSA-AES128-GCM-SHA256
ECDHE-RSA-AES128-SHA
ECDHE-RSA-AES128-SHA256
ECDHE-RSA-AES256-GCM-SHA384
ECDHE-RSA-AES256-SHA
ECDHE-RSA-AES256-SHA384
ECDHE-RSA-DES-CBC3-SHA
EDH-DSS-DES-CBC3-SHA
EDH-RSA-DES-CBC3-SHA
PSK-3DES-EDE-CBC-SHA
PSK-AES256-CBC-SHA
SRP-DSS-3DES-EDE-CBC-SHA
SRP-DSS-AES-128-CBC-SHA
SRP-DSS-AES-256-CBC-SHA
SRP-RSA-3DES-EDE-CBC-SHA
SRP-RSA-AES-128-CBC-S
SRP-RSA-AES-256-CBC-SHA
```

MySQL passes this cipher list to yaSSL:

```
AES128-RMD
AES128-SHA
AES256-RMD
AES256-SHA
DES-CBC-SHA
DES-CBC3-RMD
DES-CBC3-SHA
DHE-RSA-AES128-RMD
DHE-RSA-AES128-SHA
DHE-RSA-AES256-RMD
DHE-RSA-AES256-SHA
DHE-RSA-DES-CBC3-RMD
EDH-RSA-DES-CBC-SHA
EDH-RSA-DES-CBC3-SHA
RC4-MD5
RC4-SHA
```

6.4.4 Configuring MySQL to Use Secure Connections

To enable secure connections, your MySQL distribution must be built with SSL support, as described in Section 6.4.2, "Building MySQL with Support for Secure Connections". In addition, the proper options must be used to specify the appropriate certificate and key files. For a complete list of options related to establishment of secure connections, see Section 6.4.5, "Command Options for Secure Connections".

If you need to create the required SSL files, see Section 6.4.6, "Creating SSL Certificates and Keys Using openssl".

Server-Side Configuration for Secure Connections

To start the MySQL server so that it permits clients to connect securely, use options that identify the certificate and key files the server uses when establishing a secure connection:

- `--ssl-ca` identifies the Certificate Authority (CA) certificate.

- `--ssl-cert` identifies the server public key certificate. This can be sent to the client and authenticated against the CA certificate that it has.

- `--ssl-key` identifies the server private key.

For example, start the server with these lines in the `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=ca.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

Each option names a file in PEM format. If you have a MySQL source distribution, you can test your setup using the demonstration certificate and key files in its `mysql-test/std_data` directory.

Client-Side Configuration for Secure Connections

For client programs, options for secure connections are similar to those used on the server side, but `--ssl-cert` and `--ssl-key` identify the client public and private key:

- `--ssl-ca` identifies the Certificate Authority (CA) certificate. This option, if used, must specify the same certificate used by the server.

- `--ssl-cert` identifies the client public key certificate.

- `--ssl-key` identifies the client private key.

To connect securely to a MySQL server that supports secure connections, the options that a client must specify depend on the encryption requirements of the MySQL account used by the client. (See the discussion of the `REQUIRE` clause in Section 13.7.1.3, "GRANT Syntax".)

Suppose that you want to connect using an account that has no special encryption requirements or was created using a `GRANT` statement that includes the `REQUIRE SSL` option. As a recommended set of secure-connection options, start the server with at least `--ssl-cert` and `--ssl-key`, and invoke the client with `--ssl-ca`. A client can connect securely like this:

```
shell> mysql --ssl-ca=ca.pem
```

To require that a client certificate also be specified, create the account using the `REQUIRE X509` option. Then the client must also specify the proper client key and certificate files or the server will reject the connection:

```
shell> mysql --ssl-ca=ca.pem \
       --ssl-cert=client-cert.pem \
       --ssl-key=client-key.pem
```

To prevent use of encryption and override other `--ssl-xxx` options, invoke the client program with `--ssl=0` or a synonym (`--skip-ssl`, `--disable-ssl`):

```
shell> mysql --ssl=0
```

A client can determine whether the current connection with the server uses encryption by checking the value of the `Ssl_cipher` status variable. If the value is empty, the connection is not encrypted. Otherwise, the connection is encrypted and the value indicates the encryption cipher. For example:

```
mysql> SHOW STATUS LIKE 'Ssl_cipher';
+---------------+--------------------+
```

```
| Variable_name | Value              |
+---------------+--------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+---------------+--------------------+
```

For the `mysql` client, an alternative is to use the `STATUS` or `\s` command and check the `SSL` line:

```
mysql> \s
...
SSL: Cipher in use is DHE-RSA-AES256-SHA
...
```

Or:

```
mysql> \s
...
SSL: Not in use
...
```

C API Configuration for Secure Connections

The C API enables application programs to use secure connections:

- To establish a secure connection, use the `mysql_ssl_set()` C API function to set the appropriate certificate options before calling `mysql_real_connect()`. See Section 21.8.7.67, "mysql_ssl_set()".

- To determine whether encryption is in use after the connection is established, use `mysql_get_ssl_cipher()`. A non-`NULL` return value indicates an encrypted connection and names the cipher used for encryption. A `NULL` return value indicates that encryption is not being used. See Section 21.8.7.33, "mysql_get_ssl_cipher()".

Replication uses the C API, so secure connections can be used between master and slave servers. See Section 16.3.7, "Setting Up Replication to Use Secure Connections".

6.4.5 Command Options for Secure Connections

This section describes options that specify whether to use secure connections and the names of certificate and key files. These options can be given on the command line or in an option file. They are not available unless MySQL has been built with SSL support. See Section 6.4.2, "Building MySQL with Support for Secure Connections". For examples of suggested use and how to check whether a connection is secure, see Section 6.4.4, "Configuring MySQL to Use Secure Connections". (There are also `--master-ssl*` options that can be used for setting up a secure connection from a slave replication server to a master server; see Section 16.1.3, "Replication and Binary Logging Options and Variables".)

Table 6.8 Secure-Connection Option Summary

Format	Description	Introduced
--skip-ssl	Do not use secure connection	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	5.1.11
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	5.1.11
--ssl-cert	Path of file that contains X509 certificate in PEM format	5.1.11
--ssl-cipher	List of permitted ciphers to use for connection encryption	5.1.11
--ssl-key	Path of file that contains X509 key in PEM format	5.1.11

Format	Description	Introduced
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	5.1.11

- `--ssl`

  For the MySQL server, this option specifies that the server permits but does not require secure connections.

  For MySQL client programs, this option permits but does not require the client to connect to the server using encryption. Therefore, this option is not sufficient in itself to cause a secure connection to be used. For example, if you specify this option for a client program but the server has not been configured to support secure connections, the client falls back to an unencrypted connection.

  As a recommended set of options to enable secure connections, use at least `--ssl-cert` and `--ssl-key` on the server side and `--ssl-ca` on the client side. See Section 6.4.4, "Configuring MySQL to Use Secure Connections".

  `--ssl` may be implied by other `--ssl-xxx` options, as indicated in the descriptions for those options.

  The `--ssl` option in negated form overrides other `--ssl-xxx` options and indicates that encryption should *not* be used. To do this, specify the option as `--ssl=0` or a synonym (`--skip-ssl`, `--disable-ssl`). For example, you might have options specified in the `[client]` group of your option file to use secure connections by default when you invoke MySQL client programs. To use an unencrypted connection instead, invoke the client program with `--ssl=0` on the command line to override the options in the option file.

  To require use of secure connections for a MySQL account, use a `GRANT` statement for the account that includes at least a `REQUIRE SSL` clause. Connections for the account will be rejected unless MySQL supports secure connections and the server and client have been started with the proper secure-connection options.

  The `REQUIRE` clause permits other encryption-related options, which can be used to enforce stricter requirements than `REQUIRE SSL`. For additional details about which command options may or must be specified by clients that connect using accounts configured using the various `REQUIRE` options, see the description of `REQUIRE` in Section 13.7.1.3, "GRANT Syntax".

- `--ssl-ca=file_name`

  The path to a file in PEM format that contains a list of trusted SSL certificate authorities. This option implies `--ssl`.

  As of MySQL 5.1.18, if you use encryption when establishing a client connection, to tell the client not to authenticate the server certificate, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified at server startup.

- `--ssl-capath=dir_name`

  The path to a directory that contains trusted SSL certificate authority certificates in PEM format. This option implies `--ssl`.

  As of MySQL 5.1.18, if you use encryption when establishing a client connection, to tell the client not to authenticate the server certificate, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified at server startup.

MySQL distributions compiled using OpenSSL support the `--ssl-capath` option (see Section 6.4.1, "OpenSSL Versus yaSSL"). Distributions compiled using yaSSL do not because yaSSL does not look in any directory and does not follow a chained certificate tree. yaSSL requires that all components of the CA certificate tree be contained within a single CA certificate tree and that each certificate in the file has a unique SubjectName value. To work around this yaSSL limitation, concatenate the individual certificate files comprising the certificate tree into a new file and specify that file as the value of the `--ssl-ca` option.

- `--ssl-cert=file_name`

  The name of the SSL certificate file in PEM format to use for establishing a secure connection. This option implies `--ssl`.

- `--ssl-cipher=cipher_list`

  A list of permissible ciphers to use for connection encryption. If no cipher in the list is supported, encrypted connections will not work. This option implies `--ssl`.

  For greatest portability, `cipher_list` should be a list of one or more cipher names, separated by colons. This format is understood both by OpenSSL and yaSSL. Examples:

  ```
  --ssl-cipher=AES128-SHA
  --ssl-cipher=DHE-RSA-AES256-SHA:AES128-SHA
  ```

  OpenSSL supports a more flexible syntax for specifying ciphers, as described in the OpenSSL documentation at http://www.openssl.org/docs/apps/ciphers.html. However, yaSSL does not, so attempts to use that extended syntax fail for a MySQL distribution compiled using yaSSL.

  For information about which encryption ciphers MySQL supports, see Section 6.4.3, "Secure Connection Protocols and Ciphers".

- `--ssl-key=file_name`

  The name of the SSL key file in PEM format to use for establishing a secure connection. This option implies `--ssl`.

  If the MySQL distribution was compiled using OpenSSL and the key file is protected by a passphrase, the program prompts the user for the passphrase. The password must be given interactively; it cannot be stored in a file. If the passphrase is incorrect, the program continues as if it could not read the key. If the MySQL distribution was built using yaSSL and the key file is protected by a passphrase, an error occurs.

- `--ssl-verify-server-cert`

  This option is available only for client programs, not the server. It causes the client to check the server's Common Name value in the certificate that the server sends to the client. The client verifies that name against the host name the client uses for connecting to the server, and the connection fails if there is a mismatch. For encrypted connections, this option helps prevent man-in-the-middle attacks. Verification is disabled by default. This option was added in MySQL 5.1.11.

6.4.6 Creating SSL Certificates and Keys Using openssl

This section describes how to use the `openssl` command to set up SSL certificate and key files for use by MySQL servers and clients. The first example shows a simplified procedure such as you might use from the command line. The second shows a script that contains more detail. The first two examples are

intended for use on Unix and both use the `openssl` command that is part of OpenSSL. The third example describes how to set up SSL files on Windows.

> **Important**
>
> Whatever method you use to generate the certificate and key files, the Common Name value used for the server and client certificates/keys must each differ from the Common Name value used for the CA certificate. Otherwise, the certificate and key files will not work for servers compiled using OpenSSL. A typical error in this case is:
>
> ```
> ERROR 2026 (HY000): SSL connection error:
> error:00000001:lib(0):func(0):reason(1)
> ```

Example 1: Creating SSL Files from the Command Line on Unix

The following example shows a set of commands to create MySQL server and client certificate and key files. You will need to respond to several prompts by the `openssl` commands. To generate test files, you can press Enter to all prompts. To generate files for production use, you should provide nonempty responses.

```
# Create clean environment
shell> rm -rf newcerts
shell> mkdir newcerts && cd newcerts

# Create CA certificate
shell> openssl genrsa 2048 > ca-key.pem
shell> openssl req -new -x509 -nodes -days 3600 \
         -key ca-key.pem -out ca.pem

# Create server certificate, remove passphrase, and sign it
# server-cert.pem = public key, server-key.pem = private key
shell> openssl req -newkey rsa:2048 -days 3600 \
         -nodes -keyout server-key.pem -out server-req.pem
shell> openssl rsa -in server-key.pem -out server-key.pem
shell> openssl x509 -req -in server-req.pem -days 3600 \
         -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out server-cert.pem

# Create client certificate, remove passphrase, and sign it
# client-cert.pem = public key, client-key.pem = private key
shell> openssl req -newkey rsa:2048 -days 3600 \
         -nodes -keyout client-key.pem -out client-req.pem
shell> openssl rsa -in client-key.pem -out client-key.pem
shell> openssl x509 -req -in client-req.pem -days 3600 \
         -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out client-cert.pem
```

After generating the certificates, verify them:

```
shell> openssl verify -CAfile ca.pem server-cert.pem client-cert.pem
server-cert.pem: OK
client-cert.pem: OK
```

Now you have a set of files that can be used as follows:

- `ca.pem`: Use this as the argument to `--ssl-ca` on the server and client sides. (The CA certificate, if used, must be the same on both sides.)

- `server-cert.pem`, `server-key.pem`: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the server side.

- `client-cert.pem`, `client-key.pem`: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the client side.

To use the files for SSL connections, see Section 6.4.4, "Configuring MySQL to Use Secure Connections".

Example 2: Creating SSL Files Using a Script on Unix

Here is an example script that shows how to set up SSL certificate and key files for MySQL. After executing the script, use the files for SSL connections as described in Section 6.4.4, "Configuring MySQL to Use Secure Connections".

```
DIR=`pwd`/openssl
PRIV=$DIR/private

mkdir $DIR $PRIV $DIR/newcerts
cp /usr/share/ssl/openssl.cnf $DIR
replace ./demoCA $DIR -- $DIR/openssl.cnf

# Create necessary files: $database, $serial and $new_certs_dir
# directory (optional)

touch $DIR/index.txt
echo "01" > $DIR/serial

#
# Generation of Certificate Authority(CA)
#

openssl req -new -x509 -keyout $PRIV/cakey.pem -out $DIR/ca.pem \
    -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ................++++++
# .........++++++
# writing new private key to '/home/monty/openssl/private/cakey.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL admin
# Email Address []:

#
# Create server request and key
#
openssl req -new -keyout $DIR/server-key.pem -out \
    $DIR/server-req.pem -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
```

```
# ..++++++
# ..........++++++
# writing new private key to '/home/monty/openssl/server-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL server
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:

#
# Remove the passphrase from the key
#
openssl rsa -in $DIR/server-key.pem -out $DIR/server-key.pem

#
# Sign server cert
#
openssl ca -cert $DIR/ca.pem -policy policy_anything \
    -out $DIR/server-cert.pem -config $DIR/openssl.cnf \
    -infiles $DIR/server-req.pem

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL admin'
# Certificate is to be certified until Sep 13 14:22:46 2003 GMT
# (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

#
# Create client request and key
#
openssl req -new -keyout $DIR/client-key.pem -out \
    $DIR/client-req.pem -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ...................................++++++
```

```
# ...........................................++++++
# writing new private key to '/home/monty/openssl/client-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL user
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:

#
# Remove the passphrase from the key
#
openssl rsa -in $DIR/client-key.pem -out $DIR/client-key.pem

#
# Sign client cert
#

openssl ca -cert $DIR/ca.pem -policy policy_anything \
    -out $DIR/client-cert.pem -config $DIR/openssl.cnf \
    -infiles $DIR/client-req.pem

# Sample output:
# Using configuration from /home/monty/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL user'
# Certificate is to be certified until Sep 13 16:45:17 2003 GMT
# (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

#
# Create a my.cnf file that you can use to test the certificates
#

cat <<EOF > $DIR/my.cnf
[client]
ssl-ca=$DIR/ca.pem
ssl-cert=$DIR/client-cert.pem
ssl-key=$DIR/client-key.pem
[mysqld]
```

```
ssl-ca=$DIR/ca.pem
ssl-cert=$DIR/server-cert.pem
ssl-key=$DIR/server-key.pem
EOF
```

Example 3: Creating SSL Files on Windows

Download OpenSSL for Windows if it is not installed on your system. An overview of available packages can be seen here:

```
http://www.slproweb.com/products/Win32OpenSSL.html
```

Choose the Win32 OpenSSL Light or Win64 OpenSSL Light package, depending on your architecture (32-bit or 64-bit). The default installation location will be `C:\OpenSSL-Win32` or `C:\OpenSSL-Win64`, depending on which package you downloaded. The following instructions assume a default location of `C:\OpenSSL-Win32`. Modify this as necessary if you are using the 64-bit package.

If a message occurs during setup indicating `'...critical component is missing: Microsoft Visual C++ 2008 Redistributables'`, cancel the setup and download one of the following packages as well, again depending on your architecture (32-bit or 64-bit):

• Visual C++ 2008 Redistributables (x86), available at:

```
http://www.microsoft.com/downloads/details.aspx?familyid=9B2DA534-3E03-4391-8A4D-074B9F2BC1BF
```

• Visual C++ 2008 Redistributables (x64), available at:

```
http://www.microsoft.com/downloads/details.aspx?familyid=bd2a6171-e2d6-4230-b809-9a8d7548c1b6
```

After installing the additional package, restart the OpenSSL setup procedure.

During installation, leave the default `C:\OpenSSL-Win32` as the install path, and also leave the default option `'Copy OpenSSL DLL files to the Windows system directory'` selected.

When the installation has finished, add `C:\OpenSSL-Win32\bin` to the Windows System Path variable of your server:

1. On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.

2. Select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.

3. Under **System Variables**, select **Path**, then click the **Edit** button. The **Edit System Variable** dialogue should appear.

4. Add `';C:\OpenSSL-Win32\bin'` to the end (notice the semicolon).

5. Press OK 3 times.

6. Check that OpenSSL was correctly integrated into the Path variable by opening a new command console (`Start>Run>cmd.exe`) and verifying that OpenSSL is available:

```
Microsoft Windows [Version ...]
Copyright (c) 2006 Microsoft Corporation. All rights reserved.

C:\Windows\system32>cd \
```

```
C:\>openssl
OpenSSL> exit <<< If you see the OpenSSL prompt, installation was successful.

C:\>
```

Depending on your version of Windows, the preceding path-setting instructions might differ slightly.

After OpenSSL has been installed, use instructions similar to those from Example 1 (shown earlier in this section), with the following changes:

- Change the following Unix commands:

```
# Create clean environment
shell> rm -rf newcerts
shell> mkdir newcerts && cd newcerts
```

  On Windows, use these commands instead:

```
# Create clean environment
C:\> md c:\newcerts
C:\> cd c:\newcerts
```

- When a `'\'` character is shown at the end of a command line, this `'\'` character must be removed and the command lines entered all on a single line.

After generating the certificate and key files, to use them for SSL connections, see Section 6.4.4, "Configuring MySQL to Use Secure Connections".

6.4.7 Connecting to MySQL Remotely from Windows with SSH

This section describes how to get a secure connection to a remote MySQL server with SSH. The information was provided by David Carlson `<dcarlson@mplcomm.com>`.

1. Install an SSH client on your Windows machine. For a comparison of SSH clients, see http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.

2. Start your Windows SSH client. Set `Host_Name = yourmysqlserver_URL_or_IP`. Set `userid=your_userid` to log in to your server. This `userid` value might not be the same as the user name of your MySQL account.

3. Set up port forwarding. Either do a remote forward (Set `local_port: 3306`, `remote_host: yourmysqlservername_or_ip`, `remote_port: 3306`) or a local forward (Set `port: 3306`, `host: localhost`, `remote port: 3306`).

4. Save everything, otherwise you will have to redo it the next time.

5. Log in to your server with the SSH session you just created.

6. On your Windows machine, start some ODBC application (such as Access).

7. Create a new file in Windows and link to MySQL using the ODBC driver the same way you normally do, except type in `localhost` for the MySQL host server, not `yourmysqlservername`.

At this point, you should have an ODBC connection to MySQL, encrypted using SSH.

Chapter 7 Backup and Recovery

Table of Contents

It is important to back up your databases so that you can recover your data and be up and running again in case problems occur, such as system crashes, hardware failures, or users deleting data by mistake. Backups are also essential as a safeguard before upgrading a MySQL installation, and they can be used to transfer a MySQL installation to another system or to set up replication slave servers.

MySQL offers a variety of backup strategies from which you can choose the methods that best suit the requirements for your installation. This chapter discusses several backup and recovery topics with which you should be familiar:

- Types of backups: Logical versus physical, full versus incremental, and so forth.

- Methods for creating backups.

- Recovery methods, including point-in-time recovery.

- Backup scheduling, compression, and encryption.

- Table maintenance, to enable recovery of corrupt tables.

Additional Resources

Resources related to backup or to maintaining data availability include the following:

- Customers of MySQL Enterprise Edition can use the MySQL Enterprise Backup product for backups. For an overview of the MySQL Enterprise Backup product, see Section 23.2, "MySQL Enterprise Backup Overview".

- A forum dedicated to backup issues is available at http://forums.mysql.com/list.php?28.

- Details for `mysqldump`, `mysqlhotcopy`, and other MySQL backup programs can be found in Chapter 4, *MySQL Programs*.

- The syntax of the SQL statements described here is given in Chapter 13, *SQL Statement Syntax*.

- For additional information about `InnoDB` backup procedures, see Section 14.6.10, "InnoDB Backup and Recovery".

- Replication enables you to maintain identical data on multiple servers. This has several benefits, such as enabling client query load to be distributed over servers, availability of data even if a given server is taken offline or fails, and the ability to make backups with no impact on the master by using a slave server. See Chapter 16, *Replication*.

- MySQL Cluster provides a high-availability, high-redundancy version of MySQL adapted for the distributed computing environment. See Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*. For information specifically about MySQL Cluster backup, see Section 17.5.3, "Online Backup of MySQL Cluster".

- Distributed Replicated Block Device (DRBD) is another high-availability solution. It works by replicating a block device from a primary server to a secondary server at the block level. See Chapter 15, *High Availability and Scalability*

7.1 Backup and Recovery Types

This section describes the characteristics of different types of backups.

Physical (Raw) Versus Logical Backups

Physical backups consist of raw copies of the directories and files that store database contents. This type of backup is suitable for large, important databases that need to be recovered quickly when problems occur.

Logical backups save information represented as logical database structure (`CREATE DATABASE`, `CREATE TABLE` statements) and content (`INSERT` statements or delimited-text files). This type of backup is suitable for smaller amounts of data where you might edit the data values or table structure, or recreate the data on a different machine architecture.

Logical backup methods have these characteristics:

- The backup is done by querying the MySQL server to obtain database structure and content information.

- Backup is slower than physical methods because the server must access database information and convert it to logical format. If the output is written on the client side, the server must also send it to the backup program.

- Output is larger than for physical backup, particularly when saved in text format.

- Backup and restore granularity is available at the server level (all databases), database level (all tables in a particular database), or table level. This is true regardless of storage engine.

- The backup does not include log or configuration files, or other database-related files that are not part of databases.

- Backups stored in logical format are machine independent and highly portable.

- Logical backups are performed with the MySQL server running. The server is not taken offline.

- Logical backup tools include the `mysqldump` program and the `SELECT ... INTO OUTFILE` statement. These work for any storage engine, even `MEMORY`.

- To restore logical backups, SQL-format dump files can be processed using the `mysql` client. To load delimited-text files, use the `LOAD DATA INFILE` statement or the `mysqlimport` client.

Physical backup methods have these characteristics:

- The backup consists of exact copies of database directories and files. Typically this is a copy of all or part of the MySQL data directory. Data from `MEMORY` tables cannot be backed up this way because their contents are not stored on disk.

- Physical backup methods are faster than logical because they involve only file copying without conversion.

- Output is more compact than for logical backup.

- Backup and restore granularity ranges from the level of the entire data directory down to the level of individual files. This may or may not provide for table-level granularity, depending on storage engine. (Each `MyISAM` table corresponds uniquely to a set of files, but an `InnoDB` table shares file storage with other `InnoDB` tables.)

- In addition to databases, the backup can include any related files such as log or configuration files.

- Backups are portable only to other machines that have identical or similar hardware characteristics.

- Backups can be performed while the MySQL server is not running. If the server is running, it is necessary to perform appropriate locking so that the server does not change database contents during the backup.

- Physical backup tools include file system-level commands (such as `cp`, `scp`, `tar`, `rsync`), `mysqlhotcopy` for `MyISAM` tables, `ibbackup` for `InnoDB` tables, or `START BACKUP` for `NDB` tables.

- For restore, files copied at the file system level or with `mysqlhotcopy` can be copied back to their original locations with file system commands; `ibbackup` restores `InnoDB` tables, and `ndb_restore` restores `NDB` tables.

Online Versus Offline Backups

Online backups take place while the MySQL server is running so that the database information can be obtained from the server. Offline backups take place while the server is stopped. This distinction can also be described as "hot" versus "cold" backups; a "warm" backup is one where the server remains running but locked against modifying data while you access database files externally.

Online backup methods have these characteristics:

- The backup is less intrusive to other clients, which can connect to the MySQL server during the backup and may be able to access data depending on what operations they need to perform.

- Care must be taken to impose appropriate locking so that data modifications do not take place that would compromise backup integrity. The MySQL Enterprise Backup product does such locking automatically.

Offline backup methods have these characteristics:

- Clients can be affected adversely because the server is unavailable during backup. For that reason, such backups are often taken from a replication slave server that can be taken offline without harming availability.

- The backup procedure is simpler because there is no possibility of interference from client activity.

A similar distinction between online and offline applies for recovery operations, and similar characteristics apply. However, it is more likely that clients will be affected for online recovery than for online backup because recovery requires stronger locking. During backup, clients might be able to read data while it is being backed up. Recovery modifies data and does not just read it, so clients must be prevented from accessing data while it is being restored.

Local Versus Remote Backups

A local backup is performed on the same host where the MySQL server runs, whereas a remote backup is done from a different host. For some types of backups, the backup can be initiated from a remote host even if the output is written locally on the server. host.

- `mysqldump` can connect to local or remote servers. For SQL output (`CREATE` and `INSERT` statements), local or remote dumps can be done and generate output on the client. For delimited-text output (with the `--tab` option), data files are created on the server host.

- `mysqlhotcopy` performs only local backups: It connects to the server to lock it against data modifications and then copies local table files.

- `SELECT ... INTO OUTFILE` can be initiated from a local or remote client host, but the output file is created on the server host.

- Physical backup methods typically are initiated locally on the MySQL server host so that the server can be taken offline, although the destination for copied files might be remote.

Snapshot Backups

Some file system implementations enable "snapshots" to be taken. These provide logical copies of the file system at a given point in time, without requiring a physical copy of the entire file system. (For example, the implementation may use copy-on-write techniques so that only parts of the file system modified after the snapshot time need be copied.) MySQL itself does not provide the capability for taking file system snapshots. It is available through third-party solutions such as Veritas, LVM, or ZFS.

Full Versus Incremental Backups

A full backup includes all data managed by a MySQL server at a given point in time. An incremental backup consists of the changes made to the data during a given time span (from one point in time to another). MySQL has different ways to perform full backups, such as those described earlier in this section. Incremental backups are made possible by enabling the server's binary log, which the server uses to record data changes.

Full Versus Point-in-Time (Incremental) Recovery

A full recovery restores all data from a full backup. This restores the server instance to the state that it had when the backup was made. If that state is not sufficiently current, a full recovery can be followed by recovery of incremental backups made since the full backup, to bring the server to a more up-to-date state.

Incremental recovery is recovery of changes made during a given time span. This is also called point-in-time recovery because it makes a server's state current up to a given time. Point-in-time recovery is based on the binary log and typically follows a full recovery from the backup files that restores the server to its state when the backup was made. Then the data changes written in the binary log files are applied as incremental recovery to redo data modifications and bring the server up to the desired point in time.

Table Maintenance

Data integrity can be compromised if tables become corrupt. For `InnoDB` tables, this is not a typical issue. For programs to check `MyISAM` tables and repair them if problems are found, see Section 7.6, "MyISAM Table Maintenance and Crash Recovery".

Backup Scheduling, Compression, and Encryption

Backup scheduling is valuable for automating backup procedures. Compression of backup output reduces space requirements, and encryption of the output provides better security against unauthorized access of backed-up data. MySQL itself does not provide these capabilities. The MySQL Enterprise Backup product can compress `InnoDB` backups, and compression or encryption of backup output can be achieved using file system utilities. Other third-party solutions may be available.

7.2 Database Backup Methods

This section summarizes some general methods for making backups.

Making a Hot Backup with MySQL Enterprise Backup

Customers of MySQL Enterprise Edition can use the MySQL Enterprise Backup product to do physical backups of entire instances or selected databases, tables, or both. This product includes features for incremental and compressed backups. Backing up the physical database files makes restore much faster than logical techniques such as the `mysqldump` command. `InnoDB` tables are copied using a hot backup mechanism. (Ideally, the `InnoDB` tables should represent a substantial majority of the data.) Tables from other storage engines are copied using a warm backup mechanism. For an overview of the MySQL Enterprise Backup product, see Section 23.2, "MySQL Enterprise Backup Overview".

Making Backups with mysqldump or mysqlhotcopy

The `mysqldump` program and the `mysqlhotcopy` script can make backups. `mysqldump` is more general because it can back up all kinds of tables. `mysqlhotcopy` works only with some storage engines. (See Section 7.4, "Using mysqldump for Backups", and Section 4.6.9, "`mysqlhotcopy` — A Database Backup Program".)

For `InnoDB` tables, it is possible to perform an online backup that takes no locks on tables using the `--single-transaction` option to `mysqldump`. See Section 7.3.1, "Establishing a Backup Policy".

Making Backups by Copying Table Files

For storage engines that represent each table using its own files, tables can be backed up by copying those files. For example, `MyISAM` tables are stored as files, so it is easy to do a backup by copying files (`*.frm`, `*.MYD`, and `*.MYI` files). To get a consistent backup, stop the server or lock and flush the relevant tables:

```
LOCK TABLES tbl_list READ;
FLUSH TABLES tbl_list;
```

You need only a read lock; this enables other clients to continue to query the tables while you are making a copy of the files in the database directory. The `FLUSH TABLES` statement is needed to ensure that the all active index pages are written to disk before you start the backup. See Section 13.3.5, "LOCK TABLES and UNLOCK TABLES Syntax", and Section 13.7.6.3, "FLUSH Syntax".

You can also create a binary backup simply by copying all table files, as long as the server isn't updating anything. The `mysqlhotcopy` script uses this method. (But note that table file copying methods do not work if your database contains `InnoDB` tables. `mysqlhotcopy` does not work for `InnoDB` tables because `InnoDB` does not necessarily store table contents in database directories. Also, even if the server is not actively updating data, `InnoDB` may still have modified data cached in memory and not flushed to disk.)

Making Delimited-Text File Backups

To create a text file containing a table's data, you can use `SELECT * INTO OUTFILE 'file_name' FROM tbl_name`. The file is created on the MySQL server host, not the client host. For this statement, the output file cannot already exist because permitting files to be overwritten constitutes a security risk. See Section 13.2.8, "SELECT Syntax". This method works for any kind of data file, but saves only table data, not the table structure.

Another way to create text data files (along with files containing `CREATE TABLE` statements for the backed up tables) is to use `mysqldump` with the `--tab` option. See Section 7.4.3, "Dumping Data in Delimited-Text Format with mysqldump".

To reload a delimited-text data file, use `LOAD DATA INFILE` or `mysqlimport`.

Making Incremental Backups by Enabling the Binary Log

MySQL supports incremental backups: You must start the server with the `--log-bin` option to enable binary logging; see Section 5.4.4, "The Binary Log". The binary log files provide you with the information you need to replicate changes to the database that are made subsequent to the point at which you performed a backup. At the moment you want to make an incremental backup (containing all changes that happened since the last full or incremental backup), you should rotate the binary log by using `FLUSH LOGS`. This done, you need to copy to the backup location all binary logs which range from the one of the moment of the last full or incremental backup to the last but one. These binary logs are the incremental backup; at restore time, you apply them as explained in Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log". The next time you do a full backup, you should also rotate the binary log using `FLUSH LOGS`, `mysqldump --flush-logs`, or `mysqlhotcopy --flushlog`. See Section 4.5.4, "`mysqldump` — A Database Backup Program", and Section 4.6.9, "`mysqlhotcopy` — A Database Backup Program".

Making Backups Using Replication Slaves

If you have performance problems with your master server while making backups, one strategy that can help is to set up replication and perform backups on the slave rather than on the master. See Section 16.3.1, "Using Replication for Backups".

If you are backing up a slave replication server, you should back up its `master.info` and `relay-log.info` files when you back up the slave's databases, regardless of the backup method you choose. These information files are always needed to resume replication after you restore the slave's data. If your slave is replicating `LOAD DATA INFILE` statements, you should also back up any `SQL_LOAD-*` files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA INFILE` operations. The location of this directory is the value of the `--slave-load-tmpdir` option. If the server was not started with that option, the directory location is the value of the `tmpdir` system variable.

Recovering Corrupt Tables

If you have to restore `MyISAM` tables that have become corrupt, try to recover them using `REPAIR TABLE` or `myisamchk -r` first. That should work in 99.9% of all cases. If `myisamchk` fails, see Section 7.6, "MyISAM Table Maintenance and Crash Recovery".

Making Backups Using a File System Snapshot

If you are using a Veritas file system, you can make a backup like this:

1. From a client program, execute `FLUSH TABLES WITH READ LOCK`.

2. From another shell, execute `mount vxfs snapshot`.

3. From the first client, execute `UNLOCK TABLES`.

4. Copy files from the snapshot.

5. Unmount the snapshot.

Similar snapshot capabilities may be available in other file systems, such as LVM or ZFS.

7.3 Example Backup and Recovery Strategy

This section discusses a procedure for performing backups that enables you to recover data after several types of crashes:

- Operating system crash

- Power failure

- File system crash

- Hardware problem (hard drive, motherboard, and so forth)

The example commands do not include options such as `--user` and `--password` for the `mysqldump` and `mysql` client programs. You should include such options as necessary to enable client programs to connect to the MySQL server.

Assume that data is stored in the `InnoDB` storage engine, which has support for transactions and automatic crash recovery. Assume also that the MySQL server is under load at the time of the crash. If it were not, no recovery would ever be needed.

For cases of operating system crashes or power failures, we can assume that MySQL's disk data is available after a restart. The `InnoDB` data files might not contain consistent data due to the crash, but `InnoDB` reads its logs and finds in them the list of pending committed and noncommitted transactions that have not been flushed to the data files. `InnoDB` automatically rolls back those transactions that were not committed, and flushes to its data files those that were committed. Information about this recovery process is conveyed to the user through the MySQL error log. The following is an example log excerpt:

```
InnoDB: Database was not shut down normally.
InnoDB: Starting recovery from log files...
InnoDB: Starting log scan based on checkpoint at
InnoDB: log sequence number 0 13674004
InnoDB: Doing recovery: scanned up to log sequence number 0 13739520
InnoDB: Doing recovery: scanned up to log sequence number 0 13805056
InnoDB: Doing recovery: scanned up to log sequence number 0 13870592
InnoDB: Doing recovery: scanned up to log sequence number 0 13936128
...
InnoDB: Doing recovery: scanned up to log sequence number 0 20555264
InnoDB: Doing recovery: scanned up to log sequence number 0 20620800
InnoDB: Doing recovery: scanned up to log sequence number 0 20664692
InnoDB: 1 uncommitted transaction(s) which must be rolled back
InnoDB: Starting rollback of uncommitted transactions
InnoDB: Rolling back trx no 16745
```

```
InnoDB: Rolling back of trx no 16745 completed
InnoDB: Rollback of uncommitted transactions completed
InnoDB: Starting an apply batch of log records to the database...
InnoDB: Apply batch completed
InnoDB: Started
mysqld: ready for connections
```

For the cases of file system crashes or hardware problems, we can assume that the MySQL disk data is *not* available after a restart. This means that MySQL fails to start successfully because some blocks of disk data are no longer readable. In this case, it is necessary to reformat the disk, install a new one, or otherwise correct the underlying problem. Then it is necessary to recover our MySQL data from backups, which means that backups must already have been made. To make sure that is the case, design and implement a backup policy.

7.3.1 Establishing a Backup Policy

To be useful, backups must be scheduled regularly. A full backup (a snapshot of the data at a point in time) can be done in MySQL with several tools. For example, MySQL Enterprise Backup can perform a physical backup of an entire instance, with optimizations to minimize overhead and avoid disruption when backing up `InnoDB` data files; `mysqldump` provides online logical backup. This discussion uses `mysqldump`.

Assume that we make a full backup of all our `InnoDB` tables in all databases using the following command on Sunday at 1 p.m., when load is low:

```
shell> mysqldump --single-transaction --all-databases > backup_sunday_1_PM.sql
```

The resulting `.sql` file produced by `mysqldump` contains a set of SQL `INSERT` statements that can be used to reload the dumped tables at a later time.

This backup operation acquires a global read lock on all tables at the beginning of the dump (using `FLUSH TABLES WITH READ LOCK`). As soon as this lock has been acquired, the binary log coordinates are read and the lock is released. If long updating statements are running when the `FLUSH` statement is issued, the backup operation may stall until those statements finish. After that, the dump becomes lock-free and does not disturb reads and writes on the tables.

It was assumed earlier that the tables to back up are `InnoDB` tables, so `--single-transaction` uses a consistent read and guarantees that data seen by `mysqldump` does not change. (Changes made by other clients to `InnoDB` tables are not seen by the `mysqldump` process.) If the backup operation includes nontransactional tables, consistency requires that they do not change during the backup. For example, for the `MyISAM` tables in the `mysql` database, there must be no administrative changes to MySQL accounts during the backup.

Full backups are necessary, but it is not always convenient to create them. They produce large backup files and take time to generate. They are not optimal in the sense that each successive full backup includes all data, even that part that has not changed since the previous full backup. It is more efficient to make an initial full backup, and then to make incremental backups. The incremental backups are smaller and take less time to produce. The tradeoff is that, at recovery time, you cannot restore your data just by reloading the full backup. You must also process the incremental backups to recover the incremental changes.

To make incremental backups, we need to save the incremental changes. In MySQL, these changes are represented in the binary log, so the MySQL server should always be started with the `--log-bin` option to enable that log. With binary logging enabled, the server writes each data change into a file while it updates data. Looking at the data directory of a MySQL server that was started with the `--log-bin` option and that has been running for some days, we find these MySQL binary log files:

```
-rw-rw---- 1 guilhem  guilhem   1277324 Nov 10 23:59 gbichot2-bin.000001
```

```
-rw-rw---- 1 guilhem  guilhem         4 Nov 10 23:59 gbichot2-bin.000002
-rw-rw---- 1 guilhem  guilhem        79 Nov 11 11:06 gbichot2-bin.000003
-rw-rw---- 1 guilhem  guilhem       508 Nov 11 11:08 gbichot2-bin.000004
-rw-rw---- 1 guilhem  guilhem 220047446 Nov 12 16:47 gbichot2-bin.000005
-rw-rw---- 1 guilhem  guilhem    998412 Nov 14 10:08 gbichot2-bin.000006
-rw-rw---- 1 guilhem  guilhem       361 Nov 14 10:07 gbichot2-bin.index
```

Each time it restarts, the MySQL server creates a new binary log file using the next number in the sequence. While the server is running, you can also tell it to close the current binary log file and begin a new one manually by issuing a `FLUSH LOGS` SQL statement or with a `mysqladmin flush-logs` command. `mysqldump` also has an option to flush the logs. The `.index` file in the data directory contains the list of all MySQL binary logs in the directory.

The MySQL binary logs are important for recovery because they form the set of incremental backups. If you make sure to flush the logs when you make your full backup, the binary log files created afterward contain all the data changes made since the backup. Let's modify the previous `mysqldump` command a bit so that it flushes the MySQL binary logs at the moment of the full backup, and so that the dump file contains the name of the new current binary log:

```
shell> mysqldump --single-transaction --flush-logs --master-data=2 \
         --all-databases > backup_sunday_1_PM.sql
```

After executing this command, the data directory contains a new binary log file, `gbichot2-bin.000007`, because the `--flush-logs` option causes the server to flush its logs. The `--master-data` option causes `mysqldump` to write binary log information to its output, so the resulting `.sql` dump file includes these lines:

```
-- Position to start replication or point-in-time recovery from
-- CHANGE MASTER TO MASTER_LOG_FILE='gbichot2-bin.000007',MASTER_LOG_POS=4;
```

Because the `mysqldump` command made a full backup, those lines mean two things:

- The dump file contains all changes made before any changes written to the `gbichot2-bin.000007` binary log file or newer.

- All data changes logged after the backup are not present in the dump file, but are present in the `gbichot2-bin.000007` binary log file or newer.

On Monday at 1 p.m., we can create an incremental backup by flushing the logs to begin a new binary log file. For example, executing a `mysqladmin flush-logs` command creates `gbichot2-bin.000008`. All changes between the Sunday 1 p.m. full backup and Monday 1 p.m. will be in the `gbichot2-bin.000007` file. This incremental backup is important, so it is a good idea to copy it to a safe place. (For example, back it up on tape or DVD, or copy it to another machine.) On Tuesday at 1 p.m., execute another `mysqladmin flush-logs` command. All changes between Monday 1 p.m. and Tuesday 1 p.m. will be in the `gbichot2-bin.000008` file (which also should be copied somewhere safe).

The MySQL binary logs take up disk space. To free up space, purge them from time to time. One way to do this is by deleting the binary logs that are no longer needed, such as when we make a full backup:

```
shell> mysqldump --single-transaction --flush-logs --master-data=2 \
         --all-databases --delete-master-logs > backup_sunday_1_PM.sql
```

Note

Deleting the MySQL binary logs with `mysqldump --delete-master-logs` can be dangerous if your server is a replication master server, because slave servers might not yet fully have processed the contents of the binary log. The description

> for the `PURGE BINARY LOGS` statement explains what should be verified before deleting the MySQL binary logs. See Section 13.4.1.1, "PURGE BINARY LOGS Syntax".

7.3.2 Using Backups for Recovery

Now, suppose that we have a catastrophic crash on Wednesday at 8 a.m. that requires recovery from backups. To recover, first we restore the last full backup we have (the one from Sunday 1 p.m.). The full backup file is just a set of SQL statements, so restoring it is very easy:

```
shell> mysql < backup_sunday_1_PM.sql
```

At this point, the data is restored to its state as of Sunday 1 p.m.. To restore the changes made since then, we must use the incremental backups; that is, the `gbichot2-bin.000007` and `gbichot2-bin.000008` binary log files. Fetch the files if necessary from where they were backed up, and then process their contents like this:

```
shell> mysqlbinlog gbichot2-bin.000007 gbichot2-bin.000008 | mysql
```

We now have recovered the data to its state as of Tuesday 1 p.m., but still are missing the changes from that date to the date of the crash. To not lose them, we would have needed to have the MySQL server store its MySQL binary logs into a safe location (RAID disks, SAN, ...) different from the place where it stores its data files, so that these logs were not on the destroyed disk. (That is, we can start the server with a `--log-bin` option that specifies a location on a different physical device from the one on which the data directory resides. That way, the logs are safe even if the device containing the directory is lost.) If we had done this, we would have the `gbichot2-bin.000009` file (and any subsequent files) at hand, and we could apply them using `mysqlbinlog` and `mysql` to restore the most recent data changes with no loss up to the moment of the crash:

```
shell> mysqlbinlog gbichot2-bin.000009 ... | mysql
```

For more information about using `mysqlbinlog` to process binary log files, see Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log".

7.3.3 Backup Strategy Summary

In case of an operating system crash or power failure, `InnoDB` itself does all the job of recovering data. But to make sure that you can sleep well, observe the following guidelines:

- Always run the MySQL server with the `--log-bin` option, or even `--log-bin=log_name`, where the log file name is located on some safe media different from the drive on which the data directory is located. If you have such safe media, this technique can also be good for disk load balancing (which results in a performance improvement).

- Make periodic full backups, using the `mysqldump` command shown earlier in Section 7.3.1, "Establishing a Backup Policy", that makes an online, nonblocking backup.

- Make periodic incremental backups by flushing the logs with `FLUSH LOGS` or `mysqladmin flush-logs`.

7.4 Using mysqldump for Backups

This section describes how to use `mysqldump` to produce dump files, and how to reload dump files. A dump file can be used in several ways:

- As a backup to enable data recovery in case of data loss.

- As a source of data for setting up replication slaves.

- As a source of data for experimentation:

  - To make a copy of a database that you can use without changing the original data.

  - To test potential upgrade incompatibilities.

`mysqldump` produces two types of output, depending on whether the `--tab` option is given:

- Without `--tab`, `mysqldump` writes SQL statements to the standard output. This output consists of `CREATE` statements to create dumped objects (databases, tables, stored routines, and so forth), and `INSERT` statements to load data into tables. The output can be saved in a file and reloaded later using `mysql` to recreate the dumped objects. Options are available to modify the format of the SQL statements, and to control which objects are dumped.

- With `--tab`, `mysqldump` produces two output files for each dumped table. The server writes one file as tab-delimited text, one line per table row. This file is named `tbl_name.txt` in the output directory. The server also sends a `CREATE TABLE` statement for the table to `mysqldump`, which writes it as a file named `tbl_name.sql` in the output directory.

7.4.1 Dumping Data in SQL Format with mysqldump

This section describes how to use `mysqldump` to create SQL-format dump files. For information about reloading such dump files, see Section 7.4.2, "Reloading SQL-Format Backups".

By default, `mysqldump` writes information as SQL statements to the standard output. You can save the output in a file:

```
shell> mysqldump [arguments] > file_name
```

To dump all databases, invoke `mysqldump` with the `--all-databases` option:

```
shell> mysqldump --all-databases > dump.sql
```

To dump only specific databases, name them on the command line and use the `--databases` option:

```
shell> mysqldump --databases db1 db2 db3 > dump.sql
```

The `--databases` option causes all names on the command line to be treated as database names. Without this option, `mysqldump` treats the first name as a database name and those following as table names.

With `--all-databases` or `--databases`, `mysqldump` writes `CREATE DATABASE` and `USE` statements prior to the dump output for each database. This ensures that when the dump file is reloaded, it creates each database if it does not exist and makes it the default database so database contents are loaded into the same database from which they came. If you want to cause the dump file to force a drop of each database before recreating it, use the `--add-drop-database` option as well. In this case, `mysqldump` writes a `DROP DATABASE` statement preceding each `CREATE DATABASE` statement.

To dump a single database, name it on the command line:

```
shell> mysqldump --databases test > dump.sql
```

In the single-database case, it is permissible to omit the `--databases` option:

```
shell> mysqldump test > dump.sql
```

The difference between the two preceding commands is that without `--databases`, the dump output contains no `CREATE DATABASE` or `USE` statements. This has several implications:

- When you reload the dump file, you must specify a default database name so that the server knows which database to reload.

- For reloading, you can specify a database name different from the original name, which enables you to reload the data into a different database.

- If the database to be reloaded does not exist, you must create it first.

- Because the output will contain no `CREATE DATABASE` statement, the `--add-drop-database` option has no effect. If you use it, it produces no `DROP DATABASE` statement.

To dump only specific tables from a database, name them on the command line following the database name:

```
shell> mysqldump test t1 t3 t7 > dump.sql
```

7.4.2 Reloading SQL-Format Backups

To reload a dump file written by `mysqldump` that consists of SQL statements, use it as input to the `mysql` client. If the dump file was created by `mysqldump` with the `--all-databases` or `--databases` option, it contains `CREATE DATABASE` and `USE` statements and it is not necessary to specify a default database into which to load the data:

```
shell> mysql < dump.sql
```

Alternatively, from within `mysql`, use a `source` command:

```
mysql> source dump.sql
```

If the file is a single-database dump not containing `CREATE DATABASE` and `USE` statements, create the database first (if necessary):

```
shell> mysqladmin create db1
```

Then specify the database name when you load the dump file:

```
shell> mysql db1 < dump.sql
```

Alternatively, from within `mysql`, create the database, select it as the default database, and load the dump file:

```
mysql> CREATE DATABASE IF NOT EXISTS db1;
mysql> USE db1;
mysql> source dump.sql
```

7.4.3 Dumping Data in Delimited-Text Format with mysqldump

This section describes how to use `mysqldump` to create delimited-text dump files. For information about reloading such dump files, see Section 7.4.4, "Reloading Delimited-Text Format Backups".

If you invoke `mysqldump` with the `--tab=dir_name` option, it uses `dir_name` as the output directory and dumps tables individually in that directory using two files for each table. The table name is the base name for these files. For a table named `t1`, the files are named `t1.sql` and `t1.txt`. The `.sql` file contains a `CREATE TABLE` statement for the table. The `.txt` file contains the table data, one line per table row.

The following command dumps the contents of the `db1` database to files in the `/tmp` database:

```
shell> mysqldump --tab=/tmp db1
```

The `.txt` files containing table data are written by the server, so they are owned by the system account used for running the server. The server uses `SELECT ... INTO OUTFILE` to write the files, so you must have the `FILE` privilege to perform this operation, and an error occurs if a given `.txt` file already exists.

The server sends the `CREATE` definitions for dumped tables to `mysqldump`, which writes them to `.sql` files. These files therefore are owned by the user who executes `mysqldump`.

It is best that `--tab` be used only for dumping a local server. If you use it with a remote server, the `--tab` directory must exist on both the local and remote hosts, and the `.txt` files will be written by the server in the remote directory (on the server host), whereas the `.sql` files will be written by `mysqldump` in the local directory (on the client host).

For `mysqldump --tab`, the server by default writes table data to `.txt` files one line per row with tabs between column values, no quotation marks around column values, and newline as the line terminator. (These are the same defaults as for `SELECT ... INTO OUTFILE`.)

To enable data files to be written using a different format, `mysqldump` supports these options:

- `--fields-terminated-by=str`

  The string for separating column values (default: tab).

- `--fields-enclosed-by=char`

  The character within which to enclose column values (default: no character).

- `--fields-optionally-enclosed-by=char`

  The character within which to enclose non-numeric column values (default: no character).

- `--fields-escaped-by=char`

  The character for escaping special characters (default: no escaping).

- `--lines-terminated-by=str`

  The line-termination string (default: newline).

Depending on the value you specify for any of these options, it might be necessary on the command line to quote or escape the value appropriately for your command interpreter. Alternatively, specify the value using hex notation. Suppose that you want `mysqldump` to quote column values within double quotation marks. To do so, specify double quote as the value for the `--fields-enclosed-by` option. But this

character is often special to command interpreters and must be treated specially. For example, on Unix, you can quote the double quote like this:

```
--fields-enclosed-by='"'
```

On any platform, you can specify the value in hex:

```
--fields-enclosed-by=0x22
```

It is common to use several of the data-formatting options together. For example, to dump tables in comma-separated values format with lines terminated by carriage-return/newline pairs ($\r\n$), use this command (enter it on a single line):

```
shell> mysqldump --tab=/tmp --fields-terminated-by=,
         --fields-enclosed-by='"' --lines-terminated-by=0x0d0a db1
```

Should you use any of the data-formatting options to dump table data, you will need to specify the same format when you reload data files later, to ensure proper interpretation of the file contents.

7.4.4 Reloading Delimited-Text Format Backups

For backups produced with `mysqldump --tab`, each table is represented in the output directory by an `.sql` file containing the `CREATE TABLE` statement for the table, and a `.txt` file containing the table data. To reload a table, first change location into the output directory. Then process the `.sql` file with `mysql` to create an empty table and process the `.txt` file to load the data into the table:

```
shell> mysql db1 < t1.sql
shell> mysqlimport db1 t1.txt
```

An alternative to using `mysqlimport` to load the data file is to use the `LOAD DATA INFILE` statement from within the `mysql` client:

```
mysql> USE db1;
mysql> LOAD DATA INFILE 't1.txt' INTO TABLE t1;
```

If you used any data-formatting options with `mysqldump` when you initially dumped the table, you must use the same options with `mysqlimport` or `LOAD DATA INFILE` to ensure proper interpretation of the data file contents:

```
shell> mysqlimport --fields-terminated-by=,
         --fields-enclosed-by='"' --lines-terminated-by=0x0d0a db1 t1.txt
```

Or:

```
mysql> USE db1;
mysql> LOAD DATA INFILE 't1.txt' INTO TABLE t1
    -> FIELDS TERMINATED BY ',' FIELDS ENCLOSED BY '"'
    -> LINES TERMINATED BY '\r\n';
```

7.4.5 mysqldump Tips

This section surveys techniques that enable you to use `mysqldump` to solve specific problems:

• How to make a copy a database

- How to copy a database from one server to another

- How to dump stored programs (stored procedures and functions, triggers, and events)

- How to dump definitions and data separately

7.4.5.1 Making a Copy of a Database

```
shell> mysqldump db1 > dump.sql
shell> mysqladmin create db2
shell> mysql db2 < dump.sql
```

Do not use `--databases` on the `mysqldump` command line because that causes `USE db1` to be included in the dump file, which overrides the effect of naming `db2` on the `mysql` command line.

7.4.5.2 Copy a Database from one Server to Another

On Server 1:

```
shell> mysqldump --databases db1 > dump.sql
```

Copy the dump file from Server 1 to Server 2.

On Server 2:

```
shell> mysql < dump.sql
```

Use of `--databases` with the `mysqldump` command line causes the dump file to include `CREATE DATABASE` and `USE` statements that create the database if it does exist and make it the default database for the reloaded data.

Alternatively, you can omit `--databases` from the `mysqldump` command. Then you will need to create the database on Server 2 (if necessary) and specify it as the default database when you reload the dump file.

On Server 1:

```
shell> mysqldump db1 > dump.sql
```

On Server 2:

```
shell> mysqladmin create db1
shell> mysql db1 < dump.sql
```

You can specify a different database name in this case, so omitting `--databases` from the `mysqldump` command enables you to dump data from one database and load it into another.

7.4.5.3 Dumping Stored Programs

Several options control how `mysqldump` handles stored programs (stored procedures and functions, triggers, and events):

- `--events`: Dump Event Scheduler events

- `--routines`: Dump stored procedures and functions

- `--triggers`: Dump triggers for tables

The `--triggers` option is enabled by default so that when tables are dumped, they are accompanied by any triggers they have. The other options are disabled by default and must be specified explicitly to dump the corresponding objects. To disable any of these options explicitly, use its skip form: `--skip-events`, `--skip-routines`, or `--skip-triggers`.

7.4.5.4 Dumping Table Definitions and Content Separately

The `--no-data` option tells `mysqldump` not to dump table data, resulting in the dump file containing only statements to create the tables. Conversely, the `--no-create-info` option tells `mysqldump` to suppress `CREATE` statements from the output, so that the dump file contains only table data.

For example, to dump table definitions and data separately for the `test` database, use these commands:

```
shell> mysqldump --no-data test > dump-defs.sql
shell> mysqldump --no-create-info test > dump-data.sql
```

For a definition-only dump, add the `--routines` and `--events` options to also include stored routine and event definitions:

```
shell> mysqldump --no-data --routines --events test > dump-defs.sql
```

7.4.5.5 Using mysqldump to Test for Upgrade Incompatibilities

When contemplating a MySQL upgrade, it is prudent to install the newer version separately from your current production version. Then you can dump the database and database object definitions from the production server and load them into the new server to verify that they are handled properly. (This is also useful for testing downgrades.)

On the production server:

```
shell> mysqldump --all-databases --no-data --routines --events > dump-defs.sql
```

On the upgraded server:

```
shell> mysql < dump-defs.sql
```

Because the dump file does not contain table data, it can be processed quickly. This enables you to spot potential incompatibilities without waiting for lengthy data-loading operations. Look for warnings or errors while the dump file is being processed.

After you have verified that the definitions are handled properly, dump the data and try to load it into the upgraded server.

On the production server:

```
shell> mysqldump --all-databases --no-create-info > dump-data.sql
```

On the upgraded server:

```
shell> mysql < dump-data.sql
```

Now check the table contents and run some test queries.

7.5 Point-in-Time (Incremental) Recovery Using the Binary Log

Point-in-time recovery refers to recovery of data changes made since a given point in time. Typically, this type of recovery is performed after restoring a full backup that brings the server to its state as of the time the backup was made. (The full backup can be made in several ways, such as those listed in Section 7.2, "Database Backup Methods".) Point-in-time recovery then brings the server up to date incrementally from the time of the full backup to a more recent time.

Point-in-time recovery is based on these principles:

- The source of information for point-in-time recovery is the set of incremental backups represented by the binary log files generated subsequent to the full backup operation. Therefore, the server must be started with the `--log-bin` option to enable binary logging (see Section 5.4.4, "The Binary Log").

  To restore data from the binary log, you must know the name and location of the current binary log files. By default, the server creates binary log files in the data directory, but a path name can be specified with the `--log-bin` option to place the files in a different location. Section 5.4.4, "The Binary Log".

  To see a listing of all binary log files, use this statement:

  ```
  mysql> SHOW BINARY LOGS;
  ```

  To determine the name of the current binary log file, issue the following statement:

  ```
  mysql> SHOW MASTER STATUS;
  ```

- The `mysqlbinlog` utility converts the events in the binary log files from binary format to text so that they can be executed or viewed. `mysqlbinlog` has options for selecting sections of the binary log based on event times or position of events within the log. See Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files".

- Executing events from the binary log causes the data modifications they represent to be redone. This enables recovery of data changes for a given span of time. To execute events from the binary log, process `mysqlbinlog` output using the `mysql` client:

  ```
  shell> mysqlbinlog binlog_files | mysql -u root -p
  ```

- Viewing log contents can be useful when you need to determine event times or positions to select partial log contents prior to executing events. To view events from the log, send `mysqlbinlog` output into a paging program:

  ```
  shell> mysqlbinlog binlog_files | more
  ```

  Alternatively, save the output in a file and view the file in a text editor:

  ```
  shell> mysqlbinlog binlog_files > tmpfile
  shell> ... edit tmpfile ...
  ```

- Saving the output in a file is useful as a preliminary to executing the log contents with certain events removed, such as an accidental `DROP DATABASE`. You can delete from the file any statements not to be executed before executing its contents. After editing the file, execute the contents as follows:

  ```
  shell> mysql -u root -p < tmpfile
  ```

If you have more than one binary log to execute on the MySQL server, the safe method is to process them all using a single connection to the server. Here is an example that demonstrates what may be *unsafe*:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p # DANGER!!
shell> mysqlbinlog binlog.000002 | mysql -u root -p # DANGER!!
```

Processing binary logs this way using different connections to the server causes problems if the first log file contains a `CREATE TEMPORARY TABLE` statement and the second log contains a statement that uses the temporary table. When the first `mysql` process terminates, the server drops the temporary table. When the second `mysql` process attempts to use the table, the server reports "unknown table."

To avoid problems like this, use a *single* connection to execute the contents of all binary logs that you want to process. Here is one way to do so:

```
shell> mysqlbinlog binlog.000001 binlog.000002 | mysql -u root -p
```

Another approach is to write all the logs to a single file and then process the file:

```
shell> mysqlbinlog binlog.000001 >  /tmp/statements.sql
shell> mysqlbinlog binlog.000002 >> /tmp/statements.sql
shell> mysql -u root -p -e "source /tmp/statements.sql"
```

7.5.1 Point-in-Time Recovery Using Event Times

To indicate the start and end times for recovery, specify the `--start-datetime` and `--stop-datetime` options for `mysqlbinlog`, in `DATETIME` format. As an example, suppose that exactly at 10:00 a.m. on April 20, 2005 an SQL statement was executed that deleted a large table. To restore the table and data, you could restore the previous night's backup, and then execute the following command:

```
shell> mysqlbinlog --stop-datetime="2005-04-20 9:59:59" \
       /var/log/mysql/bin.123456 | mysql -u root -p
```

This command recovers all of the data up until the date and time given by the `--stop-datetime` option. If you did not detect the erroneous SQL statement that was entered until hours later, you will probably also want to recover the activity that occurred afterward. Based on this, you could run `mysqlbinlog` again with a start date and time, like so:

```
shell> mysqlbinlog --start-datetime="2005-04-20 10:01:00" \
       /var/log/mysql/bin.123456 | mysql -u root -p
```

In this command, the SQL statements logged from 10:01 a.m. on will be re-executed. The combination of restoring of the previous night's dump file and the two `mysqlbinlog` commands restores everything up until one second before 10:00 a.m. and everything from 10:01 a.m. on.

To use this method of point-in-time recovery, you should examine the log to be sure of the exact times to specify for the commands. To display the log file contents without executing them, use this command:

```
shell> mysqlbinlog /var/log/mysql/bin.123456 > /tmp/mysql_restore.sql
```

Then open the `/tmp/mysql_restore.sql` file with a text editor to examine it.

Excluding specific changes by specifying times for `mysqlbinlog` does not work well if multiple statements executed at the same time as the one to be excluded.

7.5.2 Point-in-Time Recovery Using Event Positions

Instead of specifying dates and times, the `--start-position` and `--stop-position` options for `mysqlbinlog` can be used for specifying log positions. They work the same as the start and stop date options, except that you specify log position numbers rather than dates. Using positions may enable you to be more precise about which part of the log to recover, especially if many transactions occurred around the same time as a damaging SQL statement. To determine the position numbers, run `mysqlbinlog` for a range of times near the time when the unwanted transaction was executed, but redirect the results to a text file for examination. This can be done like so:

```
shell> mysqlbinlog --start-datetime="2005-04-20 9:55:00" \
         --stop-datetime="2005-04-20 10:05:00" \
         /var/log/mysql/bin.123456 > /tmp/mysql_restore.sql
```

This command creates a small text file in the `/tmp` directory that contains the SQL statements around the time that the deleterious SQL statement was executed. Open this file with a text editor and look for the statement that you do not want to repeat. Determine the positions in the binary log for stopping and resuming the recovery and make note of them. Positions are labeled as `log_pos` followed by a number. After restoring the previous backup file, use the position numbers to process the binary log file. For example, you would use commands something like these:

```
shell> mysqlbinlog --stop-position=368312 /var/log/mysql/bin.123456 \
         | mysql -u root -p

shell> mysqlbinlog --start-position=368315 /var/log/mysql/bin.123456 \
         | mysql -u root -p
```

The first command recovers all the transactions up until the stop position given. The second command recovers all transactions from the starting position given until the end of the binary log. Because the output of `mysqlbinlog` includes `SET TIMESTAMP` statements before each SQL statement recorded, the recovered data and related MySQL logs will reflect the original times at which the transactions were executed.

7.6 MyISAM Table Maintenance and Crash Recovery

This section discusses how to use `myisamchk` to check or repair `MyISAM` tables (tables that have `.MYD` and `.MYI` files for storing data and indexes). For general `myisamchk` background, see Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility". Other table-repair information can be found at Section 2.13.4, "Rebuilding or Repairing Tables or Indexes".

You can use `myisamchk` to check, repair, or optimize database tables. The following sections describe how to perform these operations and how to set up a table maintenance schedule. For information about using `myisamchk` to get information about your tables, see Section 4.6.3.5, "Obtaining Table Information with myisamchk".

Even though table repair with `myisamchk` is quite secure, it is always a good idea to make a backup *before* doing a repair or any maintenance operation that could make a lot of changes to a table.

`myisamchk` operations that affect indexes can cause `FULLTEXT` indexes to be rebuilt with full-text parameters that are incompatible with the values used by the MySQL server. To avoid this problem, follow the guidelines in Section 4.6.3.1, "myisamchk General Options".

`MyISAM` table maintenance can also be done using the SQL statements that perform operations similar to what `myisamchk` can do:

- To check `MyISAM` tables, use `CHECK TABLE`.

- To repair `MyISAM` tables, use `REPAIR TABLE`.

- To optimize `MyISAM` tables, use `OPTIMIZE TABLE`.

- To analyze `MyISAM` tables, use `ANALYZE TABLE`.

For additional information about these statements, see Section 13.7.2, "Table Maintenance Statements".

These statements can be used directly or by means of the `mysqlcheck` client program. One advantage of these statements over `myisamchk` is that the server does all the work. With `myisamchk`, you must make sure that the server does not use the tables at the same time so that there is no unwanted interaction between `myisamchk` and the server.

7.6.1 Using myisamchk for Crash Recovery

This section describes how to check for and deal with data corruption in MySQL databases. If your tables become corrupted frequently, you should try to find the reason why. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

For an explanation of how `MyISAM` tables can become corrupted, see Section 14.5.4, "MyISAM Table Problems".

If you run `mysqld` with external locking disabled (which is the default), you cannot reliably use `myisamchk` to check a table when `mysqld` is using the same table. If you can be certain that no one will access the tables through `mysqld` while you run `myisamchk`, you only have to execute `mysqladmin flush-tables` before you start checking the tables. If you cannot guarantee this, you must stop `mysqld` while you check the tables. If you run `myisamchk` to check tables that `mysqld` is updating at the same time, you may get a warning that a table is corrupt even when it is not.

If the server is run with external locking enabled, you can use `myisamchk` to check tables at any time. In this case, if the server tries to update a table that `myisamchk` is using, the server will wait for `myisamchk` to finish before it continues.

If you use `myisamchk` to repair or optimize tables, you *must* always ensure that the `mysqld` server is not using the table (this also applies if external locking is disabled). If you do not stop `mysqld`, you should at least do a `mysqladmin flush-tables` before you run `myisamchk`. Your tables *may become corrupted* if the server and `myisamchk` access the tables simultaneously.

When performing crash recovery, it is important to understand that each `MyISAM` table *tbl_name* in a database corresponds to the three files in the database directory shown in the following table.

File	Purpose
tbl_name.frm	Definition (format) file
tbl_name.MYD	Data file
tbl_name.MYI	Index file

Each of these three file types is subject to corruption in various ways, but problems occur most often in data files and index files.

`myisamchk` works by creating a copy of the `.MYD` data file row by row. It ends the repair stage by removing the old `.MYD` file and renaming the new file to the original file name. If you use `--quick`, `myisamchk` does not create a temporary `.MYD` file, but instead assumes that the `.MYD` file is correct and generates only a new index file without touching the `.MYD` file. This is safe, because `myisamchk` automatically detects whether the `.MYD` file is corrupt and aborts the repair if it is. You can also specify the

`--quick` option twice to `myisamchk`. In this case, `myisamchk` does not abort on some errors (such as duplicate-key errors) but instead tries to resolve them by modifying the `.MYD` file. Normally the use of two `--quick` options is useful only if you have too little free disk space to perform a normal repair. In this case, you should at least make a backup of the table before running `myisamchk`.

7.6.2 How to Check MyISAM Tables for Errors

To check a `MyISAM` table, use the following commands:

- `myisamchk tbl_name`

  This finds 99.99% of all errors. What it cannot find is corruption that involves *only* the data file (which is very unusual). If you want to check a table, you should normally run `myisamchk` without options or with the `-s` (silent) option.

- `myisamchk -m tbl_name`

  This finds 99.999% of all errors. It first checks all index entries for errors and then reads through all rows. It calculates a checksum for all key values in the rows and verifies that the checksum matches the checksum for the keys in the index tree.

- `myisamchk -e tbl_name`

  This does a complete and thorough check of all data (`-e` means "extended check"). It does a check-read of every key for each row to verify that they indeed point to the correct row. This may take a long time for a large table that has many indexes. Normally, `myisamchk` stops after the first error it finds. If you want to obtain more information, you can add the `-v` (verbose) option. This causes `myisamchk` to keep going, up through a maximum of 20 errors.

- `myisamchk -e -i tbl_name`

  This is like the previous command, but the `-i` option tells `myisamchk` to print additional statistical information.

In most cases, a simple `myisamchk` command with no arguments other than the table name is sufficient to check a table.

7.6.3 How to Repair MyISAM Tables

The discussion in this section describes how to use `myisamchk` on `MyISAM` tables (extensions `.MYI` and `.MYD`).

You can also use the `CHECK TABLE` and `REPAIR TABLE` statements to check and repair `MyISAM` tables. See Section 13.7.2.3, "CHECK TABLE Syntax", and Section 13.7.2.6, "REPAIR TABLE Syntax".

Symptoms of corrupted tables include queries that abort unexpectedly and observable errors such as these:

- `tbl_name.frm` is locked against change

- Can't find file `tbl_name.MYI` (Errcode: `nnn`)

- Unexpected end of file

- Record file is crashed

- Got error `nnn` from table handler

To get more information about the error, run `perror nnn`, where *nnn* is the error number. The following example shows how to use `perror` to find the meanings for the most common error numbers that indicate a problem with a table:

```
shell> perror 126 127 132 134 135 136 141 144 145
MySQL error code 126 = Index file is crashed
MySQL error code 127 = Record-file is crashed
MySQL error code 132 = Old database file
MySQL error code 134 = Record was already deleted (or record file crashed)
MySQL error code 135 = No more room in record file
MySQL error code 136 = No more room in index file
MySQL error code 141 = Duplicate unique key or constraint on write or update
MySQL error code 144 = Table is crashed and last repair failed
MySQL error code 145 = Table was marked as crashed and should be repaired
```

Note that error 135 (no more room in record file) and error 136 (no more room in index file) are not errors that can be fixed by a simple repair. In this case, you must use `ALTER TABLE` to increase the `MAX_ROWS` and `AVG_ROW_LENGTH` table option values:

```
ALTER TABLE tbl_name MAX_ROWS=xxx AVG_ROW_LENGTH=yyy;
```

If you do not know the current table option values, use `SHOW CREATE TABLE`.

For the other errors, you must repair your tables. `myisamchk` can usually detect and fix most problems that occur.

The repair process involves up to four stages, described here. Before you begin, you should change location to the database directory and check the permissions of the table files. On Unix, make sure that they are readable by the user that `mysqld` runs as (and to you, because you need to access the files you are checking). If it turns out you need to modify files, they must also be writable by you.

This section is for the cases where a table check fails (such as those described in Section 7.6.2, "How to Check MyISAM Tables for Errors"), or you want to use the extended features that `myisamchk` provides.

The `myisamchk` options used for table maintenance with are described in Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility". `myisamchk` also has variables that you can set to control memory allocation that may improve performance. See Section 4.6.3.6, "myisamchk Memory Usage".

If you are going to repair a table from the command line, you must first stop the `mysqld` server. Note that when you do `mysqladmin shutdown` on a remote server, the `mysqld` server is still available for a while after `mysqladmin` returns, until all statement-processing has stopped and all index changes have been flushed to disk.

Stage 1: Checking your tables

Run `myisamchk *.MYI` or `myisamchk -e *.MYI` if you have more time. Use the `-s` (silent) option to suppress unnecessary information.

If the `mysqld` server is stopped, you should use the `--update-state` option to tell `myisamchk` to mark the table as "checked."

You have to repair only those tables for which `myisamchk` announces an error. For such tables, proceed to Stage 2.

If you get unexpected errors when checking (such as `out of memory` errors), or if `myisamchk` crashes, go to Stage 3.

Stage 2: Easy safe repair

First, try `myisamchk -r -q tbl_name` (`-r -q` means "quick recovery mode"). This attempts to repair the index file without touching the data file. If the data file contains everything that it should and the delete links point at the correct locations within the data file, this should work, and the table is fixed. Start repairing the next table. Otherwise, use the following procedure:

1. Make a backup of the data file before continuing.

2. Use `myisamchk -r tbl_name` (`-r` means "recovery mode"). This removes incorrect rows and deleted rows from the data file and reconstructs the index file.

3. If the preceding step fails, use `myisamchk --safe-recover tbl_name`. Safe recovery mode uses an old recovery method that handles a few cases that regular recovery mode does not (but is slower).

> **Note**
>
> If you want a repair operation to go much faster, you should set the values of the `sort_buffer_size` and `key_buffer_size` variables each to about 25% of your available memory when running `myisamchk`.

If you get unexpected errors when repairing (such as `out of memory` errors), or if `myisamchk` crashes, go to Stage 3.

Stage 3: Difficult repair

You should reach this stage only if the first 16KB block in the index file is destroyed or contains incorrect information, or if the index file is missing. In this case, it is necessary to create a new index file. Do so as follows:

1. Move the data file to a safe place.

2. Use the table description file to create new (empty) data and index files:

```
shell> mysql db_name
mysql> SET autocommit=1;
mysql> TRUNCATE TABLE tbl_name;
mysql> quit
```

3. Copy the old data file back onto the newly created data file. (Do not just move the old file back onto the new file. You want to retain a copy in case something goes wrong.)

> **Important**
>
> If you are using replication, you should stop it prior to performing the above procedure, since it involves file system operations, and these are not logged by MySQL.

Go back to Stage 2. `myisamchk -r -q` should work. (This should not be an endless loop.)

You can also use the `REPAIR TABLE tbl_name USE_FRM` SQL statement, which performs the whole procedure automatically. There is also no possibility of unwanted interaction between a utility and the server, because the server does all the work when you use `REPAIR TABLE`. See Section 13.7.2.6, "REPAIR TABLE Syntax".

Stage 4: Very difficult repair

You should reach this stage only if the `.frm` description file has also crashed. That should never happen, because the description file is not changed after the table is created:

1. Restore the description file from a backup and go back to Stage 3. You can also restore the index file and go back to Stage 2. In the latter case, you should start with `myisamchk -r`.

2. If you do not have a backup but know exactly how the table was created, create a copy of the table in another database. Remove the new data file, and then move the `.frm` description and `.MYI` index files from the other database to your crashed database. This gives you new description and index files, but leaves the `.MYD` data file alone. Go back to Stage 2 and attempt to reconstruct the index file.

7.6.4 MyISAM Table Optimization

To coalesce fragmented rows and eliminate wasted space that results from deleting or updating rows, run `myisamchk` in recovery mode:

```
shell> myisamchk -r tbl_name
```

You can optimize a table in the same way by using the `OPTIMIZE TABLE` SQL statement. `OPTIMIZE TABLE` does a table repair and a key analysis, and also sorts the index tree so that key lookups are faster. There is also no possibility of unwanted interaction between a utility and the server, because the server does all the work when you use `OPTIMIZE TABLE`. See Section 13.7.2.5, "OPTIMIZE TABLE Syntax".

`myisamchk` has a number of other options that you can use to improve the performance of a table:

- `--analyze` or `-a`: Perform key distribution analysis. This improves join performance by enabling the join optimizer to better choose the order in which to join the tables and which indexes it should use.

- `--sort-index` or `-S`: Sort the index blocks. This optimizes seeks and makes table scans that use indexes faster.

- `--sort-records=index_num` or `-R index_num`: Sort data rows according to a given index. This makes your data much more localized and may speed up range-based `SELECT` and `ORDER BY` operations that use this index.

For a full description of all available options, see Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility".

7.6.5 Setting Up a MyISAM Table Maintenance Schedule

It is a good idea to perform table checks on a regular basis rather than waiting for problems to occur. One way to check and repair `MyISAM` tables is with the `CHECK TABLE` and `REPAIR TABLE` statements. See Section 13.7.2, "Table Maintenance Statements".

Another way to check tables is to use `myisamchk`. For maintenance purposes, you can use `myisamchk -s`. The `-s` option (short for `--silent`) causes `myisamchk` to run in silent mode, printing messages only when errors occur.

It is also a good idea to enable automatic `MyISAM` table checking. For example, whenever the machine has done a restart in the middle of an update, you usually need to check each table that could have been affected before it is used further. (These are "expected crashed tables.") To cause the server to check `MyISAM` tables automatically, start it with the `--myisam-recover` option. See Section 5.1.3, "Server Command Options".

You should also check your tables regularly during normal system operation. For example, you can run a `cron` job to check important tables once a week, using a line like this in a `crontab` file:

```
35 0 * * 0 /path/to/myisamchk --fast --silent /path/to/datadir/*/*.MYI
```

This prints out information about crashed tables so that you can examine and repair them as necessary.

To start with, execute `myisamchk -s` each night on all tables that have been updated during the last 24 hours. As you see that problems occur infrequently, you can back off the checking frequency to once a week or so.

Normally, MySQL tables need little maintenance. If you are performing many updates to `MyISAM` tables with dynamic-sized rows (tables with `VARCHAR`, `BLOB`, or `TEXT` columns) or have tables with many deleted rows you may want to defragment/reclaim space from the tables from time to time. You can do this by using `OPTIMIZE TABLE` on the tables in question. Alternatively, if you can stop the `mysqld` server for a while, change location into the data directory and use this command while the server is stopped:

```
shell> myisamchk -r -s --sort-index --myisam_sort_buffer_size=16M */*.MYI
```

Chapter 8 Optimization

Table of Contents

This chapter explains how to optimize MySQL performance and provides examples. Optimization involves configuring, tuning, and measuring performance, at several levels. Depending on your job role (developer, DBA, or a combination of both), you might optimize at the level of individual SQL statements, entire applications, a single database server, or multiple networked database servers. Sometimes you can be proactive and plan in advance for performance, while other times you might troubleshoot a configuration or code issue after a problem occurs. Optimizing CPU and memory usage can also improve scalability, allowing the database to handle more load without slowing down.

8.1 Optimization Overview

Database performance depends on several factors at the database level, such as tables, queries, and configuration settings. These software constructs result in CPU and I/O operations at the hardware level, which you must minimize and make as efficient as possible. As you work on database performance, you start by learning the high-level rules and guidelines for the software side, and measuring performance using wall-clock time. As you become an expert, you learn more about what happens internally, and start measuring things such as CPU cycles and I/O operations.

Typical users aim to get the best database performance out of their existing software and hardware configurations. Advanced users look for opportunities to improve the MySQL software itself, or develop their own storage engines and hardware appliances to expand the MySQL ecosystem.

Optimizing at the Database Level

The most important factor in making a database application fast is its basic design:

- Are the tables structured properly? In particular, do the columns have the right data types, and does each table have the appropriate columns for the type of work? For example, applications that perform frequent updates often have many tables with few columns, while applications that analyze large amounts of data often have few tables with many columns.

- Are the right indexes in place to make queries efficient?

- Are you using the appropriate storage engine for each table, and taking advantage of the strengths and features of each storage engine you use? In particular, the choice of a nontransactional storage engine such as `MyISAM` or a transactional one such as `InnoDB` can be very important for performance and scalability.

- Does each table use an appropriate row format? This choice also depends on the storage engine used for the table. In particular, compressed tables use less disk space and so require less disk I/O to read and write the data. Compression is available for read-only `MyISAM` tables, and for all kinds of workloads with `InnoDB` tables.

- Does the application use an appropriate locking strategy? For example, by allowing shared access when possible so that database operations can run concurrently, and requesting exclusive access when appropriate so that critical operations get top priority. Again, the choice of storage engine is significant. The `InnoDB` storage engine handles most locking issues without involvement from you, allowing for better concurrency in the database and reducing the amount of experimentation and tuning for your code.

- Are all memory areas used for caching sized correctly? That is, large enough to hold frequently accessed data, but not so large that they overload physical memory and cause paging. The main memory areas to configure are the `MyISAM` key cache, the `InnoDB` buffer pool, and the MySQL query cache.

Optimizing at the Hardware Level

Any database application eventually hits hardware limits as the database becomes more and more busy. A DBA must evaluate whether it is possible to tune the application or reconfigure the server to avoid these bottlenecks, or whether more hardware resources are required. System bottlenecks typically arise from these sources:

- Disk seeks. It takes time for the disk to find a piece of data. With modern disks, the mean time for this is usually lower than 10ms, so we can in theory do about 100 seeks a second. This time improves slowly with new disks and is very hard to optimize for a single table. The way to optimize seek time is to distribute the data onto more than one disk.

- Disk reading and writing. When the disk is at the correct position, we need to read or write the data. With modern disks, one disk delivers at least 10–20MB/s throughput. This is easier to optimize than seeks because you can read in parallel from multiple disks.

- CPU cycles. When the data is in main memory, we must process it to get our result. Having large tables compared to the amount of memory is the most common limiting factor. But with small tables, speed is usually not the problem.

- Memory bandwidth. When the CPU needs more data than can fit in the CPU cache, main memory bandwidth becomes a bottleneck. This is an uncommon bottleneck for most systems, but one to be aware of.

Balancing Portability and Performance

Because all SQL servers implement different parts of standard SQL, it takes work to write portable database applications. It is very easy to achieve portability for very simple selects and inserts, but becomes

more difficult the more capabilities you require. If you want an application that is fast with many database systems, it becomes even more difficult.

All database systems have some weak points. That is, they have different design compromises that lead to different behavior.

To make a complex application portable, you need to determine which SQL servers it must work with, and then determine what features those servers support. You can use the MySQL `crash-me` program to find functions, types, and limits that you can use with a selection of database servers. `crash-me` does not check for every possible feature, but it is still reasonably comprehensive, performing about 450 tests. An example of the type of information `crash-me` can provide is that you should not use column names that are longer than 18 characters if you want to be able to use Informix or DB2.

The `crash-me` program and the MySQL benchmarks are all very database independent. By taking a look at how they are written, you can get a feeling for what you must do to make your own applications database independent. The programs can be found in the `sql-bench` directory of MySQL source distributions. They are written in Perl and use the DBI database interface. Use of DBI in itself solves part of the portability problem because it provides database-independent access methods. See Section 8.13.2, "The MySQL Benchmark Suite".

If you strive for database independence, you need to get a good feeling for each SQL server's bottlenecks. For example, MySQL is very fast in retrieving and updating rows for `MyISAM` tables, but has a problem in mixing slow readers and writers on the same table. Transactional database systems in general are not very good at generating summary tables from log tables, because in this case row locking is almost useless.

To make your application *really* database independent, you should define an easily extendable interface through which you manipulate your data. For example, C++ is available on most systems, so it makes sense to use a C++ class-based interface to the databases.

If you use some feature that is specific to a given database system (such as the `REPLACE` statement, which is specific to MySQL), you should implement the same feature for other SQL servers by coding an alternative method. Although the alternative might be slower, it enables the other servers to perform the same tasks.

To use performance-oriented SQL extensions in a portable MySQL program, you can wrap MySQL-specific keywords in a statement within `/*! */` comment delimiters. Other SQL servers ignore the commented keywords. For information about writing comments, see Section 9.6, "Comment Syntax".

If high performance is more important than exactness, as for some Web applications, it is possible to create an application layer that caches all results to give you even higher performance. By letting old results expire after a while, you can keep the cache reasonably fresh. This provides a method to handle high load spikes, in which case you can dynamically increase the cache size and set the expiration timeout higher until things get back to normal.

In this case, the table creation information should contain information about the initial cache size and how often the table should normally be refreshed.

An attractive alternative to implementing an application cache is to use the MySQL query cache. By enabling the query cache, the server handles the details of determining whether a query result can be reused. This simplifies your application. See Section 8.10.3, "The MySQL Query Cache".

8.2 Optimizing SQL Statements

The core logic of a database application is performed through SQL statements, whether issued directly through an interpreter or submitted behind the scenes through an API. The tuning guidelines in this section

help to speed up all kinds of MySQL applications. The guidelines cover SQL operations that read and write data, the behind-the-scenes overhead for SQL operations in general, and operations used in specific scenarios such as database monitoring.

8.2.1 Optimizing SELECT Statements

Queries, in the form of `SELECT` statements, perform all the lookup operations in the database. Tuning these statements is a top priority, whether to achieve sub-second response times for dynamic web pages, or to chop hours off the time to generate huge overnight reports.

Besides `SELECT` statements, the tuning techniques for queries also apply to constructs such as `CREATE TABLE...AS SELECT`, `INSERT INTO...SELECT`, and `WHERE` clauses in `DELETE` statements. Those statements have additional performance considerations because they combine write operations with the read-oriented query operations.

In MySQL Cluster NDB 7.2 and later, the `NDB` storage engine supports a join pushdown optimization whereby a qualifying join is sent in its entirety to MySQL Cluster data nodes, where it can be distributed among them and executed in parallel. For more information about this optimization, see Conditions for NDB pushdown joins.

8.2.1.1 Speed of SELECT Statements

The main considerations for optimizing queries are:

- To make a slow `SELECT ... WHERE` query faster, the first thing to check is whether you can add an index. Set up indexes on columns used in the `WHERE` clause, to speed up evaluation, filtering, and the final retrieval of results. To avoid wasted disk space, construct a small set of indexes that speed up many related queries used in your application.

  Indexes are especially important for queries that reference different tables, using features such as joins and foreign keys. You can use the `EXPLAIN` statement to determine which indexes are used for a `SELECT`. See Section 8.3.1, "How MySQL Uses Indexes" and Section 8.8.1, "Optimizing Queries with EXPLAIN".

- Isolate and tune any part of the query, such as a function call, that takes excessive time. Depending on how the query is structured, a function could be called once for every row in the result set, or even once for every row in the table, greatly magnifying any inefficiency.

- Minimize the number of full table scans in your queries, particularly for big tables.

- Keep table statistics up to date by using the `ANALYZE TABLE` statement periodically, so the optimizer has the information needed to construct an efficient execution plan.

- Learn the tuning techniques, indexing techniques, and configuration parameters that are specific to the storage engine for each table. Both `InnoDB` and `MyISAM` have sets of guidelines for enabling and sustaining high performance in queries. For details, see Section 8.6.5, "Optimizing InnoDB Queries" and Section 8.5.1, "Optimizing MyISAM Queries".

- Avoid transforming the query in ways that make it hard to understand, especially if the optimizer does some of the same transformations automatically.

- If a performance issue is not easily solved by one of the basic guidelines, investigate the internal details of the specific query by reading the `EXPLAIN` plan and adjusting your indexes, `WHERE` clauses, join clauses, and so on. (When you reach a certain level of expertise, reading the `EXPLAIN` plan might be your first step for every query.)

- Adjust the size and properties of the memory areas that MySQL uses for caching. With efficient use of the `MyISAM` key cache, `InnoDB` buffer pool, and the MySQL query cache, repeated queries run faster because the results are retrieved from memory the second and subsequent times.

- Even for a query that runs fast using the cache memory areas, you might still optimize further so that they require less cache memory, making your application more scalable. Scalability means that your application can handle more simultaneous users, larger requests, and so on without experiencing a big drop in performance.

- Deal with locking issues, where the speed of your query might be affected by other sessions accessing the tables at the same time.

8.2.1.2 How MySQL Optimizes WHERE Clauses

This section discusses optimizations that can be made for processing `WHERE` clauses. The examples use `SELECT` statements, but the same optimizations apply for `WHERE` clauses in `DELETE` and `UPDATE` statements.

Work on the MySQL optimizer is ongoing, so this section is incomplete. MySQL performs a great many optimizations, not all of which are documented here.

Some of the optimizations performed by MySQL follow:

- Removal of unnecessary parentheses:

```
   ((a AND b) AND c OR (((a AND b) AND (c AND d))))
-> (a AND b AND c) OR (a AND b AND c AND d)
```

- Constant folding:

```
   (a<b AND b=c) AND a=5
-> b>5 AND b=c AND a=5
```

- Constant condition removal (needed because of constant folding):

```
   (B>=5 AND B=5) OR (B=6 AND 5=5) OR (B=7 AND 5=6)
-> B=5 OR B=6
```

- Constant expressions used by indexes are evaluated only once.

- `COUNT(*)` on a single table without a `WHERE` is retrieved directly from the table information for `MyISAM` and `MEMORY` tables. This is also done for any `NOT NULL` expression when used with only one table.

- Early detection of invalid constant expressions. MySQL quickly detects that some `SELECT` statements are impossible and returns no rows.

- `HAVING` is merged with `WHERE` if you do not use `GROUP BY` or aggregate functions (`COUNT()`, `MIN()`, and so on).

- For each table in a join, a simpler `WHERE` is constructed to get a fast `WHERE` evaluation for the table and also to skip rows as soon as possible.

- All constant tables are read first before any other tables in the query. A constant table is any of the following:

  - An empty table or a table with one row.

- A table that is used with a `WHERE` clause on a `PRIMARY KEY` or a `UNIQUE` index, where all index parts are compared to constant expressions and are defined as `NOT NULL`.

All of the following tables are used as constant tables:

```
SELECT * FROM t WHERE primary_key=1;
SELECT * FROM t1,t2
  WHERE t1.primary_key=1 AND t2.primary_key=t1.id;
```

- The best join combination for joining the tables is found by trying all possibilities. If all columns in `ORDER BY` and `GROUP BY` clauses come from the same table, that table is preferred first when joining.

- If there is an `ORDER BY` clause and a different `GROUP BY` clause, or if the `ORDER BY` or `GROUP BY` contains columns from tables other than the first table in the join queue, a temporary table is created.

- If you use the `SQL_SMALL_RESULT` option, MySQL uses an in-memory temporary table.

- Each table index is queried, and the best index is used unless the optimizer believes that it is more efficient to use a table scan. At one time, a scan was used based on whether the best index spanned more than 30% of the table, but a fixed percentage no longer determines the choice between using an index or a scan. The optimizer now is more complex and bases its estimate on additional factors such as table size, number of rows, and I/O block size.

- MySQL can sometimes produce query results using data from the index, without consulting the table data. If all columns used from the index are numeric, only the index data is used to resolve the query.

- Before each row is output, those that do not match the `HAVING` clause are skipped.

Some examples of queries that are very fast:

```
SELECT COUNT(*) FROM tbl_name;

SELECT MIN(key_part1),MAX(key_part1) FROM tbl_name;

SELECT MAX(key_part2) FROM tbl_name
  WHERE key_part1=constant;

SELECT ... FROM tbl_name
  ORDER BY key_part1,key_part2,... LIMIT 10;

SELECT ... FROM tbl_name
  ORDER BY key_part1 DESC, key_part2 DESC, ... LIMIT 10;
```

MySQL resolves the following queries using only the index tree, assuming that the indexed columns are numeric:

```
SELECT key_part1,key_part2 FROM tbl_name WHERE key_part1=val;

SELECT COUNT(*) FROM tbl_name
  WHERE key_part1=val1 AND key_part2=val2;

SELECT key_part2 FROM tbl_name GROUP BY key_part1;
```

The following queries use indexing to retrieve the rows in sorted order without a separate sorting pass:

```
SELECT ... FROM tbl_name
  ORDER BY key_part1,key_part2,... ;
```

```
SELECT ... FROM tbl_name
  ORDER BY key_part1 DESC, key_part2 DESC, ... ;
```

8.2.1.3 Range Optimization

The `range` access method uses a single index to retrieve a subset of table rows that are contained within one or several index value intervals. It can be used for a single-part or multiple-part index. The following sections give a detailed description of how intervals are extracted from the `WHERE` clause.

The Range Access Method for Single-Part Indexes

For a single-part index, index value intervals can be conveniently represented by corresponding conditions in the `WHERE` clause, denoted as *range conditions* rather than "intervals."

The definition of a range condition for a single-part index is as follows:

- For both `BTREE` and `HASH` indexes, comparison of a key part with a constant value is a range condition when using the `=`, `<=>`, `IN()`, `IS NULL`, or `IS NOT NULL` operators.

- Additionally, for `BTREE` indexes, comparison of a key part with a constant value is a range condition when using the `>`, `<`, `>=`, `<=`, `BETWEEN`, `!=`, or `<>` operators, or `LIKE` comparisons if the argument to `LIKE` is a constant string that does not start with a wildcard character.

- For all index types, multiple range conditions combined with `OR` or `AND` form a range condition.

"Constant value" in the preceding descriptions means one of the following:

- A constant from the query string

- A column of a `const` or `system` table from the same join

- The result of an uncorrelated subquery

- Any expression composed entirely from subexpressions of the preceding types

Here are some examples of queries with range conditions in the `WHERE` clause:

```
SELECT * FROM t1
  WHERE key_col > 1
  AND key_col < 10;

SELECT * FROM t1
  WHERE key_col = 1
  OR key_col IN (15,18,20);

SELECT * FROM t1
  WHERE key_col LIKE 'ab%'
  OR key_col BETWEEN 'bar' AND 'foo';
```

Some nonconstant values may be converted to constants during the optimizer constant propagation phase.

MySQL tries to extract range conditions from the `WHERE` clause for each of the possible indexes. During the extraction process, conditions that cannot be used for constructing the range condition are dropped, conditions that produce overlapping ranges are combined, and conditions that produce empty ranges are removed.

Consider the following statement, where `key1` is an indexed column and `nonkey` is not indexed:

```
SELECT * FROM t1 WHERE
  (key1 < 'abc' AND (key1 LIKE 'abcde%' OR key1 LIKE '%b')) OR
  (key1 < 'bar' AND nonkey = 4) OR
  (key1 < 'uux' AND key1 > 'z');
```

The extraction process for key `key1` is as follows:

1. Start with original `WHERE` clause:

   ```
   (key1 < 'abc' AND (key1 LIKE 'abcde%' OR key1 LIKE '%b')) OR
   (key1 < 'bar' AND nonkey = 4) OR
   (key1 < 'uux' AND key1 > 'z')
   ```

2. Remove `nonkey = 4` and `key1 LIKE '%b'` because they cannot be used for a range scan. The
   correct way to remove them is to replace them with `TRUE`, so that we do not miss any matching rows
   when doing the range scan. Having replaced them with `TRUE`, we get:

   ```
   (key1 < 'abc' AND (key1 LIKE 'abcde%' OR TRUE)) OR
   (key1 < 'bar' AND TRUE) OR
   (key1 < 'uux' AND key1 > 'z')
   ```

3. Collapse conditions that are always true or false:

   - `(key1 LIKE 'abcde%' OR TRUE)` is always true

   - `(key1 < 'uux' AND key1 > 'z')` is always false

   Replacing these conditions with constants, we get:

   ```
   (key1 < 'abc' AND TRUE) OR (key1 < 'bar' AND TRUE) OR (FALSE)
   ```

   Removing unnecessary `TRUE` and `FALSE` constants, we obtain:

   ```
   (key1 < 'abc') OR (key1 < 'bar')
   ```

4. Combining overlapping intervals into one yields the final condition to be used for the range scan:

   ```
   (key1 < 'bar')
   ```

In general (and as demonstrated by the preceding example), the condition used for a range scan is less
restrictive than the `WHERE` clause. MySQL performs an additional check to filter out rows that satisfy the
range condition but not the full `WHERE` clause.

The range condition extraction algorithm can handle nested `AND`/`OR` constructs of arbitrary depth, and its
output does not depend on the order in which conditions appear in `WHERE` clause.

MySQL does not support merging multiple ranges for the `range` access method for spatial indexes. To
work around this limitation, you can use a `UNION` with identical `SELECT` statements, except that you put
each spatial predicate in a different `SELECT`.

The Range Access Method for Multiple-Part Indexes

Range conditions on a multiple-part index are an extension of range conditions for a single-part index. A
range condition on a multiple-part index restricts index rows to lie within one or several key tuple intervals.
Key tuple intervals are defined over a set of key tuples, using ordering from the index.

For example, consider a multiple-part index defined as `key1(key_part1, key_part2, key_part3)`, and the following set of key tuples listed in key order:

```
key_part1  key_part2  key_part3
  NULL         1          'abc'
  NULL         1          'xyz'
  NULL         2          'foo'
   1           1          'abc'
   1           1          'xyz'
   1           2          'abc'
   2           1          'aaa'
```

The condition `key_part1 = 1` defines this interval:

```
(1,-inf,-inf) <= (key_part1,key_part2,key_part3) < (1,+inf,+inf)
```

The interval covers the 4th, 5th, and 6th tuples in the preceding data set and can be used by the range access method.

By contrast, the condition `key_part3 = 'abc'` does not define a single interval and cannot be used by the range access method.

The following descriptions indicate how range conditions work for multiple-part indexes in greater detail.

- For `HASH` indexes, each interval containing identical values can be used. This means that the interval can be produced only for conditions in the following form:

```
    key_part1 cmp const1
AND key_part2 cmp const2
AND ...
AND key_partN cmp constN;
```

Here, `const1`, `const2`, … are constants, `cmp` is one of the `=`, `<=>`, or `IS NULL` comparison operators, and the conditions cover all index parts. (That is, there are `N` conditions, one for each part of an `N`-part index.) For example, the following is a range condition for a three-part `HASH` index:

```
key_part1 = 1 AND key_part2 IS NULL AND key_part3 = 'foo'
```

For the definition of what is considered to be a constant, see The Range Access Method for Single-Part Indexes.

- For a `BTREE` index, an interval might be usable for conditions combined with `AND`, where each condition compares a key part with a constant value using `=`, `<=>`, `IS NULL`, `>`, `<`, `>=`, `<=`, `!=`, `<>`, `BETWEEN`, or `LIKE 'pattern'` (where `'pattern'` does not start with a wildcard). An interval can be used as long as it is possible to determine a single key tuple containing all rows that match the condition (or two intervals if `<>` or `!=` is used).

  The optimizer attempts to use additional key parts to determine the interval as long as the comparison operator is `=`, `<=>`, or `IS NULL`. If the operator is `>`, `<`, `>=`, `<=`, `!=`, `<>`, `BETWEEN`, or `LIKE`, the optimizer uses it but considers no more key parts. For the following expression, the optimizer uses `=` from the first comparison. It also uses `>=` from the second comparison but considers no further key parts and does not use the third comparison for interval construction:

```
key_part1 = 'foo' AND key_part2 >= 10 AND key_part3 > 10
```

The single interval is:

```
('foo',10,-inf) < (key_part1,key_part2,key_part3) < ('foo',+inf,+inf)
```

It is possible that the created interval contains more rows than the initial condition. For example, the preceding interval includes the value ('foo', 11, 0), which does not satisfy the original condition.

- If conditions that cover sets of rows contained within intervals are combined with OR, they form a condition that covers a set of rows contained within the union of their intervals. If the conditions are combined with AND, they form a condition that covers a set of rows contained within the intersection of their intervals. For example, for this condition on a two-part index:

```
(key_part1 = 1 AND key_part2 < 2) OR (key_part1 > 5)
```

The intervals are:

```
(1,-inf) < (key_part1,key_part2) < (1,2)
(5,-inf) < (key_part1,key_part2)
```

In this example, the interval on the first line uses one key part for the left bound and two key parts for the right bound. The interval on the second line uses only one key part. The key_len column in the EXPLAIN output indicates the maximum length of the key prefix used.

In some cases, key_len may indicate that a key part was used, but that might be not what you would expect. Suppose that key_part1 and key_part2 can be NULL. Then the key_len column displays two key part lengths for the following condition:

```
key_part1 >= 1 AND key_part2 < 2
```

But, in fact, the condition is converted to this:

```
key_part1 >= 1 AND key_part2 IS NOT NULL
```

The Range Access Method for Single-Part Indexes, describes how optimizations are performed to combine or eliminate intervals for range conditions on a single-part index. Analogous steps are performed for range conditions on multiple-part indexes.

8.2.1.4 Index Merge Optimization

The *Index Merge* method is used to retrieve rows with several range scans and to merge their results into one. The merge can produce unions, intersections, or unions-of-intersections of its underlying scans. This access method merges index scans from a single table; it does not merge scans across multiple tables.

In EXPLAIN output, the Index Merge method appears as index_merge in the type column. In this case, the key column contains a list of indexes used, and key_len contains a list of the longest key parts for those indexes.

Examples:

```
SELECT * FROM tbl_name WHERE key1 = 10 OR key2 = 20;

SELECT * FROM tbl_name
  WHERE (key1 = 10 OR key2 = 20) AND non_key=30;

SELECT * FROM t1, t2
```

```
  WHERE (t1.key1 IN (1,2) OR t1.key2 LIKE 'value%')
  AND t2.key1=t1.some_col;

SELECT * FROM t1, t2
  WHERE t1.key1=1
  AND (t2.key1=t1.some_col OR t2.key2=t1.some_col2);
```

The Index Merge method has several access algorithms (seen in the `Extra` field of `EXPLAIN` output):

- `Using intersect(...)`

- `Using union(...)`

- `Using sort_union(...)`

The following sections describe these methods in greater detail.

> **Note**
>
> The Index Merge optimization algorithm has the following known deficiencies:
>
> - If your query has a complex `WHERE` clause with deep `AND`/`OR` nesting and MySQL does not choose the optimal plan, try distributing terms using the following identity laws:
>
>   ```
>   (x AND y) OR z = (x OR z) AND (y OR z)
>   (x OR y) AND z = (x AND z) OR (y AND z)
>   ```
>
> - Index Merge is not applicable to full-text indexes. We plan to extend it to cover these in a future MySQL release.
>
> - If a range scan is possible on some key, the optimizer will not consider using Index Merge Union or Index Merge Sort-Union algorithms. For example, consider this query:
>
>   ```
>   SELECT * FROM t1 WHERE (goodkey1 < 10 OR goodkey2 < 20) AND badkey < 30;
>   ```
>
>   For this query, two plans are possible:
>
>   - An Index Merge scan using the `(goodkey1 < 10 OR goodkey2 < 20)` condition.
>
>   - A range scan using the `badkey < 30` condition.
>
>   However, the optimizer considers only the second plan.

The choice between different possible variants of the Index Merge access method and other access methods is based on cost estimates of various available options.

The Index Merge Intersection Access Algorithm

This access algorithm can be employed when a `WHERE` clause was converted to several range conditions on different keys combined with `AND`, and each condition is one of the following:

- In this form, where the index has exactly N parts (that is, all index parts are covered):

  ```
  key_part1=const1 AND key_part2=const2 ... AND key_partN=constN
  ```

- Any range condition over a primary key of an `InnoDB` table.

Examples:

```
SELECT * FROM innodb_table WHERE primary_key < 10 AND key_col1=20;

SELECT * FROM tbl_name
  WHERE (key1_part1=1 AND key1_part2=2) AND key2=2;
```

The Index Merge intersection algorithm performs simultaneous scans on all used indexes and produces the intersection of row sequences that it receives from the merged index scans.

If all columns used in the query are covered by the used indexes, full table rows are not retrieved (`EXPLAIN` output contains `Using index` in `Extra` field in this case). Here is an example of such a query:

```
SELECT COUNT(*) FROM t1 WHERE key1=1 AND key2=1;
```

If the used indexes do not cover all columns used in the query, full rows are retrieved only when the range conditions for all used keys are satisfied.

If one of the merged conditions is a condition over a primary key of an `InnoDB` table, it is not used for row retrieval, but is used to filter out rows retrieved using other conditions.

The Index Merge Union Access Algorithm

The applicability criteria for this algorithm are similar to those for the Index Merge method intersection algorithm. The algorithm can be employed when the table's `WHERE` clause was converted to several range conditions on different keys combined with `OR`, and each condition is one of the following:

- In this form, where the index has exactly *N* parts (that is, all index parts are covered):

  ```
  key_part1=const1 AND key_part2=const2 ... AND key_partN=constN
  ```

- Any range condition over a primary key of an `InnoDB` table.

- A condition for which the Index Merge method intersection algorithm is applicable.

Examples:

```
SELECT * FROM t1 WHERE key1=1 OR key2=2 OR key3=3;

SELECT * FROM innodb_table WHERE (key1=1 AND key2=2) OR
  (key3='foo' AND key4='bar') AND key5=5;
```

The Index Merge Sort-Union Access Algorithm

This access algorithm is employed when the `WHERE` clause was converted to several range conditions combined by `OR`, but for which the Index Merge method union algorithm is not applicable.

Examples:

```
SELECT * FROM tbl_name WHERE key_col1 < 10 OR key_col2 < 20;

SELECT * FROM tbl_name
  WHERE (key_col1 > 10 OR key_col2 = 20) AND nonkey_col=30;
```

The difference between the sort-union algorithm and the union algorithm is that the sort-union algorithm must first fetch row IDs for all rows and sort them before returning any rows.

8.2.1.5 Engine Condition Pushdown Optimization

This optimization improves the efficiency of direct comparisons between a nonindexed column and a constant. In such cases, the condition is "pushed down" to the storage engine for evaluation. This optimization can be used only by the NDB storage engine.

For MySQL Cluster, this optimization can eliminate the need to send nonmatching rows over the network between the cluster's data nodes and the MySQL Server that issued the query, and can speed up queries where it is used by a factor of 5 to 10 times over cases where condition pushdown could be but is not used.

Suppose that a MySQL Cluster table is defined as follows:

```
CREATE TABLE t1 (
    a INT,
    b INT,
    KEY(a)
) ENGINE=NDB;
```

Condition pushdown can be used with queries such as the one shown here, which includes a comparison between a nonindexed column and a constant:

```
SELECT a, b FROM t1 WHERE b = 10;
```

The use of condition pushdown can be seen in the output of EXPLAIN:

```
mysql> EXPLAIN SELECT a,b FROM t1 WHERE b = 10\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 10
        Extra: Using where with pushed condition
```

However, condition pushdown *cannot* be used with either of these two queries:

```
SELECT a,b FROM t1 WHERE a = 10;
SELECT a,b FROM t1 WHERE b + 1 = 10;
```

Condition pushdown is not applicable to the first query because an index exists on column a. (An index access method would be more efficient and so would be chosen in preference to condition pushdown.) Condition pushdown cannot be employed for the second query because the comparison involving the nonindexed column b is indirect. (However, condition pushdown could be applied if you were to reduce b + 1 = 10 to b = 9 in the WHERE clause.)

Condition pushdown may also be employed when an indexed column is compared with a constant using a > or < operator:

```
mysql> EXPLAIN SELECT a, b FROM t1 WHERE a < 2\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
         type: range
possible_keys: a
          key: a
      key_len: 5
          ref: NULL
         rows: 2
        Extra: Using where with pushed condition
```

Other supported comparisons for condition pushdown include the following:

- *column* [NOT] LIKE *pattern*

  pattern must be a string literal containing the pattern to be matched; for syntax, see Section 12.5.1, "String Comparison Functions".

- *column* IS [NOT] NULL

- *column* IN (*value_list*)

  Each item in the *value_list* must be a constant, literal value.

- *column* BETWEEN *constant1* AND *constant2*

  constant1 and *constant2* must each be a constant, literal value.

In all of the cases in the preceding list, it is possible for the condition to be converted into the form of one or more direct comparisons between a column and a constant.

Engine condition pushdown is enabled by default. To disable it at server startup, set the engine_condition_pushdown system variable. For example, in a my.cnf file, use these lines:

```
[mysqld]
engine_condition_pushdown=0
```

At runtime, disable condition pushdown with either of the following statements:

```
SET engine_condition_pushdown=OFF;
```

```
SET engine_condition_pushdown=0;
```

Limitations.   Engine condition pushdown is subject to the following limitations:

- Condition pushdown is supported only by the NDB storage engine.

- Columns may be compared with constants only; however, this includes expressions which evaluate to constant values.

- Columns used in comparisons cannot be of any of the BLOB or TEXT types.

- A string value to be compared with a column must use the same collation as the column.

- Joins are not directly supported; conditions involving multiple tables are pushed separately where possible. Use EXPLAIN EXTENDED to determine which conditions are actually pushed down.

8.2.1.6 IS NULL Optimization

MySQL can perform the same optimization on `col_name IS NULL` that it can use for `col_name = constant_value`. For example, MySQL can use indexes and ranges to search for `NULL` with `IS NULL`.

Examples:

```
SELECT * FROM tbl_name WHERE key_col IS NULL;

SELECT * FROM tbl_name WHERE key_col <=> NULL;

SELECT * FROM tbl_name
  WHERE key_col=const1 OR key_col=const2 OR key_col IS NULL;
```

If a `WHERE` clause includes a `col_name IS NULL` condition for a column that is declared as `NOT NULL`, that expression is optimized away. This optimization does not occur in cases when the column might produce `NULL` anyway; for example, if it comes from a table on the right side of a `LEFT JOIN`.

MySQL can also optimize the combination `col_name = expr OR col_name IS NULL`, a form that is common in resolved subqueries. `EXPLAIN` shows `ref_or_null` when this optimization is used.

This optimization can handle one `IS NULL` for any key part.

Some examples of queries that are optimized, assuming that there is an index on columns `a` and `b` of table `t2`:

```
SELECT * FROM t1 WHERE t1.a=expr OR t1.a IS NULL;

SELECT * FROM t1, t2 WHERE t1.a=t2.a OR t2.a IS NULL;

SELECT * FROM t1, t2
  WHERE (t1.a=t2.a OR t2.a IS NULL) AND t2.b=t1.b;

SELECT * FROM t1, t2
  WHERE t1.a=t2.a AND (t2.b=t1.b OR t2.b IS NULL);

SELECT * FROM t1, t2
  WHERE (t1.a=t2.a AND t2.a IS NULL AND ...)
  OR (t1.a=t2.a AND t2.a IS NULL AND ...);
```

`ref_or_null` works by first doing a read on the reference key, and then a separate search for rows with a `NULL` key value.

The optimization can handle only one `IS NULL` level. In the following query, MySQL uses key lookups only on the expression `(t1.a=t2.a AND t2.a IS NULL)` and is not able to use the key part on `b`:

```
SELECT * FROM t1, t2
  WHERE (t1.a=t2.a AND t2.a IS NULL)
  OR (t1.b=t2.b AND t2.b IS NULL);
```

8.2.1.7 LEFT JOIN and RIGHT JOIN Optimization

MySQL implements an `A LEFT JOIN B join_condition` as follows:

• Table `B` is set to depend on table `A` and all tables on which `A` depends.

• Table `A` is set to depend on all tables (except `B`) that are used in the `LEFT JOIN` condition.

- The `LEFT JOIN` condition is used to decide how to retrieve rows from table `B`. (In other words, any condition in the `WHERE` clause is not used.)

- All standard join optimizations are performed, with the exception that a table is always read after all tables on which it depends. If there is a circular dependence, MySQL issues an error.

- All standard `WHERE` optimizations are performed.

- If there is a row in `A` that matches the `WHERE` clause, but there is no row in `B` that matches the `ON` condition, an extra `B` row is generated with all columns set to `NULL`.

- If you use `LEFT JOIN` to find rows that do not exist in some table and you have the following test: `col_name IS NULL` in the `WHERE` part, where `col_name` is a column that is declared as `NOT NULL`, MySQL stops searching for more rows (for a particular key combination) after it has found one row that matches the `LEFT JOIN` condition.

The implementation of `RIGHT JOIN` is analogous to that of `LEFT JOIN` with the roles of the tables reversed.

The join optimizer calculates the order in which tables should be joined. The table read order forced by `LEFT JOIN` or `STRAIGHT_JOIN` helps the join optimizer do its work much more quickly, because there are fewer table permutations to check. Note that this means that if you do a query of the following type, MySQL does a full scan on `b` because the `LEFT JOIN` forces it to be read before `d`:

```
SELECT *
  FROM a JOIN b LEFT JOIN c ON (c.key=a.key)
  LEFT JOIN d ON (d.key=a.key)
  WHERE b.key=d.key;
```

The fix in this case is reverse the order in which `a` and `b` are listed in the `FROM` clause:

```
SELECT *
  FROM b JOIN a LEFT JOIN c ON (c.key=a.key)
  LEFT JOIN d ON (d.key=a.key)
  WHERE b.key=d.key;
```

For a `LEFT JOIN`, if the `WHERE` condition is always false for the generated `NULL` row, the `LEFT JOIN` is changed to a normal join. For example, the `WHERE` clause would be false in the following query if `t2.column1` were `NULL`:

```
SELECT * FROM t1 LEFT JOIN t2 ON (column1) WHERE t2.column2=5;
```

Therefore, it is safe to convert the query to a normal join:

```
SELECT * FROM t1, t2 WHERE t2.column2=5 AND t1.column1=t2.column1;
```

This can be made faster because MySQL can use table `t2` before table `t1` if doing so would result in a better query plan. To provide a hint about the table join order, use `STRAIGHT_JOIN`. (See Section 13.2.8, "SELECT Syntax".)

8.2.1.8 Nested-Loop Join Algorithms

MySQL executes joins between tables using a nested-loop algorithm or variations on it.

Nested-Loop Join Algorithm

A simple nested-loop join (NLJ) algorithm reads rows from the first table in a loop one at a time, passing each row to a nested loop that processes the next table in the join. This process is repeated as many times as there remain tables to be joined.

Assume that a join between three tables `t1`, `t2`, and `t3` is to be executed using the following join types:

```
Table   Join Type
t1      range
t2      ref
t3      ALL
```

If a simple NLJ algorithm is used, the join is processed like this:

```
for each row in t1 matching range {
  for each row in t2 matching reference key {
    for each row in t3 {
      if row satisfies join conditions,
      send to client
    }
  }
}
```

Because the NLJ algorithm passes rows one at a time from outer loops to inner loops, it typically reads tables processed in the inner loops many times.

Block Nested-Loop Join Algorithm

A Block Nested-Loop (BNL) join algorithm uses buffering of rows read in outer loops to reduce the number of times that tables in inner loops must be read. For example, if 10 rows are read into a buffer and the buffer is passed to the next inner loop, each row read in the inner loop can be compared against all 10 rows in the buffer. The reduces the number of times the inner table must be read by an order of magnitude.

MySQL uses join buffering under these conditions:

- The `join_buffer_size` system variable determines the size of each join buffer.

- Join buffering can be used when the join is of type `ALL` or `index` (in other words, when no possible keys can be used, and a full scan is done, of either the data or index rows, respectively), or `range`.

- One buffer is allocated for each join that can be buffered, so a given query might be processed using multiple join buffers.

- A join buffer is never allocated for the first nonconst table, even if it would be of type `ALL` or `index`.

- A join buffer is allocated prior to executing the join and freed after the query is done.

- Only columns of interest to the join are stored in the join buffer, not whole rows.

For the example join described previously for the NLJ algorithm (without buffering), the join is done as follow using join buffering:

```
for each row in t1 matching range {
  for each row in t2 matching reference key {
    store used columns from t1, t2 in join buffer
    if buffer is full {
      for each row in t3 {
        for each t1, t2 combination in join buffer {
          if row satisfies join conditions,
```

```
            send to client
        }
      }
    }
    empty buffer
  }
 }
}

if buffer is not empty {
  for each row in t3 {
    for each t1, t2 combination in join buffer {
      if row satisfies join conditions,
      send to client
    }
  }
}
```

If S is the size of each stored `t1`, `t2` combination is the join buffer and C is the number of combinations in the buffer, the number of times table `t3` is scanned is:

```
(S * C)/join_buffer_size + 1
```

The number of `t3` scans decreases as the value of `join_buffer_size` increases, up to the point when `join_buffer_size` is large enough to hold all previous row combinations. At that point, there is no speed to be gained by making it larger.

8.2.1.9 Nested Join Optimization

The syntax for expressing joins permits nested joins. The following discussion refers to the join syntax described in Section 13.2.8.2, "JOIN Syntax".

The syntax of `table_factor` is extended in comparison with the SQL Standard. The latter accepts only `table_reference`, not a list of them inside a pair of parentheses. This is a conservative extension if we consider each comma in a list of `table_reference` items as equivalent to an inner join. For example:

```
SELECT * FROM t1 LEFT JOIN (t2, t3, t4)
              ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

is equivalent to:

```
SELECT * FROM t1 LEFT JOIN (t2 CROSS JOIN t3 CROSS JOIN t4)
              ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

In MySQL, `CROSS JOIN` is a syntactic equivalent to `INNER JOIN` (they can replace each other). In standard SQL, they are not equivalent. `INNER JOIN` is used with an `ON` clause; `CROSS JOIN` is used otherwise.

In general, parentheses can be ignored in join expressions containing only inner join operations. After removing parentheses and grouping operations to the left, the join expression:

```
t1 LEFT JOIN (t2 LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL)
   ON t1.a=t2.a
```

transforms into the expression:

```
(t1 LEFT JOIN t2 ON t1.a=t2.a) LEFT JOIN t3
    ON t2.b=t3.b OR t2.b IS NULL
```

Yet, the two expressions are not equivalent. To see this, suppose that the tables `t1`, `t2`, and `t3` have the following state:

- Table `t1` contains rows `(1)`, `(2)`

- Table `t2` contains row `(1,101)`

- Table `t3` contains row `(101)`

In this case, the first expression returns a result set including the rows `(1,1,101,101)`, `(2,NULL,NULL,NULL)`, whereas the second expression returns the rows `(1,1,101,101)`, `(2,NULL,NULL,101)`:

```
mysql> SELECT *
    -> FROM t1
    ->      LEFT JOIN
    ->      (t2 LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL)
    ->      ON t1.a=t2.a;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL | NULL |
+------+------+------+------+

mysql> SELECT *
    -> FROM (t1 LEFT JOIN t2 ON t1.a=t2.a)
    ->      LEFT JOIN t3
    ->      ON t2.b=t3.b OR t2.b IS NULL;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL |  101 |
+------+------+------+------+
```

In the following example, an outer join operation is used together with an inner join operation:

```
t1 LEFT JOIN (t2, t3) ON t1.a=t2.a
```

That expression cannot be transformed into the following expression:

```
t1 LEFT JOIN t2 ON t1.a=t2.a, t3.
```

For the given table states, the two expressions return different sets of rows:

```
mysql> SELECT *
    -> FROM t1 LEFT JOIN (t2, t3) ON t1.a=t2.a;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL | NULL |
+------+------+------+------+

mysql> SELECT *
    -> FROM t1 LEFT JOIN t2 ON t1.a=t2.a, t3;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
```

```
|      1 |      1 |  101 |  101 |
|      2 |  NULL |  NULL |  101 |
+------+------+------+------+
```

Therefore, if we omit parentheses in a join expression with outer join operators, we might change the result set for the original expression.

More exactly, we cannot ignore parentheses in the right operand of the left outer join operation and in the left operand of a right join operation. In other words, we cannot ignore parentheses for the inner table expressions of outer join operations. Parentheses for the other operand (operand for the outer table) can be ignored.

The following expression:

```
(t1,t2) LEFT JOIN t3 ON P(t2.b,t3.b)
```

is equivalent to this expression:

```
t1, t2 LEFT JOIN t3 ON P(t2.b,t3.b)
```

for any tables `t1,t2,t3` and any condition `P` over attributes `t2.b` and `t3.b`.

Whenever the order of execution of the join operations in a join expression (*join_table*) is not from left to right, we talk about nested joins. Consider the following queries:

```
SELECT * FROM t1 LEFT JOIN (t2 LEFT JOIN t3 ON t2.b=t3.b) ON t1.a=t2.a
  WHERE t1.a > 1

SELECT * FROM t1 LEFT JOIN (t2, t3) ON t1.a=t2.a
  WHERE (t2.b=t3.b OR t2.b IS NULL) AND t1.a > 1
```

Those queries are considered to contain these nested joins:

```
t2 LEFT JOIN t3 ON t2.b=t3.b
t2, t3
```

The nested join is formed in the first query with a left join operation, whereas in the second query it is formed with an inner join operation.

In the first query, the parentheses can be omitted: The grammatical structure of the join expression will dictate the same order of execution for join operations. For the second query, the parentheses cannot be omitted, although the join expression here can be interpreted unambiguously without them. (In our extended syntax the parentheses in `(t2, t3)` of the second query are required, although theoretically the query could be parsed without them: We still would have unambiguous syntactical structure for the query because `LEFT JOIN` and `ON` would play the role of the left and right delimiters for the expression `(t2,t3)`.)

The preceding examples demonstrate these points:

• For join expressions involving only inner joins (and not outer joins), parentheses can be removed. You can remove parentheses and evaluate left to right (or, in fact, you can evaluate the tables in any order).

• The same is not true, in general, for outer joins or for outer joins mixed with inner joins. Removal of parentheses may change the result.

Queries with nested outer joins are executed in the same pipeline manner as queries with inner joins. More exactly, a variation of the nested-loop join algorithm is exploited. Recall by what algorithmic schema the nested-loop join executes a query. Suppose that we have a join query over 3 tables `T1,T2,T3` of the form:

```
SELECT * FROM T1 INNER JOIN T2 ON P1(T1,T2)
                INNER JOIN T3 ON P2(T2,T3)
  WHERE P(T1,T2,T3).
```

Here, `P1(T1,T2)` and `P2(T3,T3)` are some join conditions (on expressions), whereas `P(T1,T2,T3)` is a condition over columns of tables `T1,T2,T3`.

The nested-loop join algorithm would execute this query in the following manner:

```
FOR each row t1 in T1 {
  FOR each row t2 in T2 such that P1(t1,t2) {
    FOR each row t3 in T3 such that P2(t2,t3) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
    }
  }
}
```

The notation `t1||t2||t3` means "a row constructed by concatenating the columns of rows `t1`, `t2`, and `t3`." In some of the following examples, `NULL` where a row name appears means that `NULL` is used for each column of that row. For example, `t1||t2||NULL` means "a row constructed by concatenating the columns of rows `t1` and `t2`, and `NULL` for each column of `t3`."

Now let's consider a query with nested outer joins:

```
SELECT * FROM T1 LEFT JOIN
             (T2 LEFT JOIN T3 ON P2(T2,T3))
             ON P1(T1,T2)
  WHERE P(T1,T2,T3).
```

For this query, we modify the nested-loop pattern to get:

```
FOR each row t1 in T1 {
  BOOL f1:=FALSE;
  FOR each row t2 in T2 such that P1(t1,t2) {
    BOOL f2:=FALSE;
    FOR each row t3 in T3 such that P2(t2,t3) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
      f2=TRUE;
      f1=TRUE;
    }
    IF (!f2) {
      IF P(t1,t2,NULL) {
        t:=t1||t2||NULL; OUTPUT t;
      }
      f1=TRUE;
    }
  }
  IF (!f1) {
    IF P(t1,NULL,NULL) {
      t:=t1||NULL||NULL; OUTPUT t;
```

```
    }
  }
}
```

In general, for any nested loop for the first inner table in an outer join operation, a flag is introduced that is turned off before the loop and is checked after the loop. The flag is turned on when for the current row from the outer table a match from the table representing the inner operand is found. If at the end of the loop cycle the flag is still off, no match has been found for the current row of the outer table. In this case, the row is complemented by NULL values for the columns of the inner tables. The result row is passed to the final check for the output or into the next nested loop, but only if the row satisfies the join condition of all embedded outer joins.

In our example, the outer join table expressed by the following expression is embedded:

```
(T2 LEFT JOIN T3 ON P2(T2,T3))
```

For the query with inner joins, the optimizer could choose a different order of nested loops, such as this one:

```
FOR each row t3 in T3 {
  FOR each row t2 in T2 such that P2(t2,t3) {
    FOR each row t1 in T1 such that P1(t1,t2) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
    }
  }
}
```

For the queries with outer joins, the optimizer can choose only such an order where loops for outer tables precede loops for inner tables. Thus, for our query with outer joins, only one nesting order is possible. For the following query, the optimizer will evaluate two different nestings:

```
SELECT * T1 LEFT JOIN (T2,T3) ON P1(T1,T2) AND P2(T1,T3)
  WHERE P(T1,T2,T3)
```

The nestings are these:

```
FOR each row t1 in T1 {
  BOOL f1:=FALSE;
  FOR each row t2 in T2 such that P1(t1,t2) {
    FOR each row t3 in T3 such that P2(t1,t3) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
      f1:=TRUE
    }
  }
  IF (!f1) {
    IF P(t1,NULL,NULL) {
      t:=t1||NULL||NULL; OUTPUT t;
    }
  }
}
```

and:

```
FOR each row t1 in T1 {
```

```
   BOOL f1:=FALSE;
   FOR each row t3 in T3 such that P2(t1,t3) {
     FOR each row t2 in T2 such that P1(t1,t2) {
       IF P(t1,t2,t3) {
         t:=t1||t2||t3; OUTPUT t;
       }
       f1:=TRUE
     }
   }
   IF (!f1) {
     IF P(t1,NULL,NULL) {
       t:=t1||NULL||NULL; OUTPUT t;
     }
   }
}
```

In both nestings, `T1` must be processed in the outer loop because it is used in an outer join. `T2` and `T3` are used in an inner join, so that join must be processed in the inner loop. However, because the join is an inner join, `T2` and `T3` can be processed in either order.

When discussing the nested-loop algorithm for inner joins, we omitted some details whose impact on the performance of query execution may be huge. We did not mention so-called "pushed-down" conditions. Suppose that our `WHERE` condition `P(T1,T2,T3)` can be represented by a conjunctive formula:

```
P(T1,T2,T2) = C1(T1) AND C2(T2) AND C3(T3).
```

In this case, MySQL actually uses the following nested-loop schema for the execution of the query with inner joins:

```
FOR each row t1 in T1 such that C1(t1) {
  FOR each row t2 in T2 such that P1(t1,t2) AND C2(t2)  {
    FOR each row t3 in T3 such that P2(t2,t3) AND C3(t3) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
    }
  }
}
```

You see that each of the conjuncts `C1(T1)`, `C2(T2)`, `C3(T3)` are pushed out of the most inner loop to the most outer loop where it can be evaluated. If `C1(T1)` is a very restrictive condition, this condition pushdown may greatly reduce the number of rows from table `T1` passed to the inner loops. As a result, the execution time for the query may improve immensely.

For a query with outer joins, the `WHERE` condition is to be checked only after it has been found that the current row from the outer table has a match in the inner tables. Thus, the optimization of pushing conditions out of the inner nested loops cannot be applied directly to queries with outer joins. Here we have to introduce conditional pushed-down predicates guarded by the flags that are turned on when a match has been encountered.

For our example with outer joins with:

```
P(T1,T2,T3)=C1(T1) AND C(T2) AND C3(T3)
```

the nested-loop schema using guarded pushed-down conditions looks like this:

```
FOR each row t1 in T1 such that C1(t1) {
```

```
  BOOL f1:=FALSE;
 FOR each row t2 in T2
     such that P1(t1,t2) AND (f1?C2(t2):TRUE) {
   BOOL f2:=FALSE;
   FOR each row t3 in T3
       such that P2(t2,t3) AND (f1&&f2?C3(t3):TRUE) {
     IF (f1&&f2?TRUE:(C2(t2) AND C3(t3))) {
       t:=t1||t2||t3; OUTPUT t;
     }
     f2=TRUE;
     f1=TRUE;
   }
   IF (!f2) {
     IF (f1?TRUE:C2(t2) && P(t1,t2,NULL)) {
       t:=t1||t2||NULL; OUTPUT t;
     }
     f1=TRUE;
   }
 }
 IF (!f1 && P(t1,NULL,NULL)) {
     t:=t1||NULL||NULL; OUTPUT t;
 }
}
```

In general, pushed-down predicates can be extracted from join conditions such as `P1(T1,T2)` and `P(T2,T3)`. In this case, a pushed-down predicate is guarded also by a flag that prevents checking the predicate for the `NULL`-complemented row generated by the corresponding outer join operation.

Access by key from one inner table to another in the same nested join is prohibited if it is induced by a predicate from the `WHERE` condition. (We could use conditional key access in this case, but this technique is not employed yet in MySQL 5.1.)

8.2.1.10 Outer Join Simplification

Table expressions in the `FROM` clause of a query are simplified in many cases.

At the parser stage, queries with right outer joins operations are converted to equivalent queries containing only left join operations. In the general case, the conversion is performed according to the following rule:

```
(T1, ...) RIGHT JOIN (T2,...) ON P(T1,...,T2,...) =
(T2, ...) LEFT JOIN (T1,...) ON P(T1,...,T2,...)
```

All inner join expressions of the form `T1 INNER JOIN T2 ON P(T1,T2)` are replaced by the list `T1,T2`, `P(T1,T2)` being joined as a conjunct to the `WHERE` condition (or to the join condition of the embedding join, if there is any).

When the optimizer evaluates plans for join queries with outer join operation, it takes into consideration only the plans where, for each such operation, the outer tables are accessed before the inner tables. The optimizer options are limited because only such plans enables us to execute queries with outer joins operations by the nested loop schema.

Suppose that we have a query of the form:

```
SELECT * T1 LEFT JOIN T2 ON P1(T1,T2)
  WHERE P(T1,T2) AND R(T2)
```

with `R(T2)` narrowing greatly the number of matching rows from table `T2`. If we executed the query as it is, the optimizer would have no other choice besides to access table `T1` before table `T2` that may lead to a very inefficient execution plan.

Fortunately, MySQL converts such a query into a query without an outer join operation if the `WHERE` condition is null-rejected. A condition is called null-rejected for an outer join operation if it evaluates to `FALSE` or to `UNKNOWN` for any `NULL`-complemented row built for the operation.

Thus, for this outer join:

```
T1 LEFT JOIN T2 ON T1.A=T2.A
```

Conditions such as these are null-rejected:

```
T2.B IS NOT NULL,
T2.B > 3,
T2.C <= T1.C,
T2.B < 2 OR T2.C > 1
```

Conditions such as these are not null-rejected:

```
T2.B IS NULL,
T1.B < 3 OR T2.B IS NOT NULL,
T1.B < 3 OR T2.B > 3
```

The general rules for checking whether a condition is null-rejected for an outer join operation are simple. A condition is null-rejected in the following cases:

- If it is of the form `A IS NOT NULL`, where `A` is an attribute of any of the inner tables

- If it is a predicate containing a reference to an inner table that evaluates to `UNKNOWN` when one of its arguments is `NULL`

- If it is a conjunction containing a null-rejected condition as a conjunct

- If it is a disjunction of null-rejected conditions

A condition can be null-rejected for one outer join operation in a query and not null-rejected for another. In the query:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                LEFT JOIN T3 ON T3.B=T1.B
  WHERE T3.C > 0
```

the `WHERE` condition is null-rejected for the second outer join operation but is not null-rejected for the first one.

If the `WHERE` condition is null-rejected for an outer join operation in a query, the outer join operation is replaced by an inner join operation.

For example, the preceding query is replaced with the query:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                INNER JOIN T3 ON T3.B=T1.B
  WHERE T3.C > 0
```

For the original query, the optimizer would evaluate plans compatible with only one access order `T1,T2,T3`. For the replacing query, it additionally considers the access sequence `T3,T1,T2`.

A conversion of one outer join operation may trigger a conversion of another. Thus, the query:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                 LEFT JOIN T3 ON T3.B=T2.B
  WHERE T3.C > 0
```

will be first converted to the query:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                 INNER JOIN T3 ON T3.B=T2.B
  WHERE T3.C > 0
```

which is equivalent to the query:

```
SELECT * FROM (T1 LEFT JOIN T2 ON T2.A=T1.A), T3
  WHERE T3.C > 0 AND T3.B=T2.B
```

Now the remaining outer join operation can be replaced by an inner join, too, because the condition `T3.B=T2.B` is null-rejected and we get a query without outer joins at all:

```
SELECT * FROM (T1 INNER JOIN T2 ON T2.A=T1.A), T3
  WHERE T3.C > 0 AND T3.B=T2.B
```

Sometimes we succeed in replacing an embedded outer join operation, but cannot convert the embedding outer join. The following query:

```
SELECT * FROM T1 LEFT JOIN
              (T2 LEFT JOIN T3 ON T3.B=T2.B)
              ON T2.A=T1.A
  WHERE T3.C > 0
```

is converted to:

```
SELECT * FROM T1 LEFT JOIN
              (T2 INNER JOIN T3 ON T3.B=T2.B)
              ON T2.A=T1.A
  WHERE T3.C > 0,
```

That can be rewritten only to the form still containing the embedding outer join operation:

```
SELECT * FROM T1 LEFT JOIN
              (T2,T3)
              ON (T2.A=T1.A AND T3.B=T2.B)
  WHERE T3.C > 0.
```

When trying to convert an embedded outer join operation in a query, we must take into account the join condition for the embedding outer join together with the `WHERE` condition. In the query:

```
SELECT * FROM T1 LEFT JOIN
              (T2 LEFT JOIN T3 ON T3.B=T2.B)
              ON T2.A=T1.A AND T3.C=T1.C
  WHERE T3.D > 0 OR T1.D > 0
```

the `WHERE` condition is not null-rejected for the embedded outer join, but the join condition of the embedding outer join `T2.A=T1.A AND T3.C=T1.C` is null-rejected. So the query can be converted to:

```
SELECT * FROM T1 LEFT JOIN
            (T2, T3)
            ON T2.A=T1.A AND T3.C=T1.C AND T3.B=T2.B
  WHERE T3.D > 0 OR T1.D > 0
```

8.2.1.11 ORDER BY Optimization

In some cases, MySQL can use an index to satisfy an `ORDER BY` clause without doing extra sorting.

The index can also be used even if the `ORDER BY` does not match the index exactly, as long as all unused portions of the index and all extra `ORDER BY` columns are constants in the `WHERE` clause. The following queries use the index to resolve the `ORDER BY` part:

```
SELECT * FROM t1
  ORDER BY key_part1,key_part2,... ;

SELECT * FROM t1
  WHERE key_part1 = constant
  ORDER BY key_part2;

SELECT * FROM t1
  ORDER BY key_part1 DESC, key_part2 DESC;

SELECT * FROM t1
  WHERE key_part1 = 1
  ORDER BY key_part1 DESC, key_part2 DESC;

SELECT * FROM t1
  WHERE key_part1 > constant
  ORDER BY key_part1 ASC;

SELECT * FROM t1
  WHERE key_part1 < constant
  ORDER BY key_part1 DESC;

SELECT * FROM t1
  WHERE key_part1 = constant1 AND key_part2 > constant2
  ORDER BY key_part2;
```

In some cases, MySQL *cannot* use indexes to resolve the `ORDER BY`, although it still uses indexes to find the rows that match the `WHERE` clause. These cases include the following:

* The query uses `ORDER BY` on different indexes:

  ```
  SELECT * FROM t1 ORDER BY key1, key2;
  ```

* The query uses `ORDER BY` on nonconsecutive parts of an index:

  ```
  SELECT * FROM t1 WHERE key2=constant ORDER BY key_part2;
  ```

* The query mixes `ASC` and `DESC`:

  ```
  SELECT * FROM t1 ORDER BY key_part1 DESC, key_part2 ASC;
  ```

* The index used to fetch the rows differs from the one used in the `ORDER BY`:

  ```
  SELECT * FROM t1 WHERE key2=constant ORDER BY key1;
  ```

- The query uses `ORDER BY` with an expression that includes terms other than the index column name:

```
SELECT * FROM t1 ORDER BY ABS(key);
SELECT * FROM t1 ORDER BY -key;
```

- The query joins many tables, and the columns in the `ORDER BY` are not all from the first nonconstant table that is used to retrieve rows. (This is the first table in the `EXPLAIN` output that does not have a `const` join type.)

- The query has different `ORDER BY` and `GROUP BY` expressions.

- There is an index on only a prefix of a column named in the `ORDER BY` clause. In this case, the index cannot be used to fully resolve the sort order. For example, if only the first 10 bytes of a `CHAR(20)` column are indexed, the index cannot distinguish values past the 10th byte and a `filesort` will be needed.

- The index does not store rows in order. For example, this is true for a `HASH` index in a `MEMORY` table.

Availability of an index for sorting may be affected by the use of column aliases. Suppose that the column `t1.a` is indexed. In this statement, the name of the column in the select list is `a`. It refers to `t1.a`, so for the reference to `a` in the `ORDER BY`, the index can be used:

```
SELECT a FROM t1 ORDER BY a;
```

In this statement, the name of the column in the select list is also `a`, but it is the alias name. It refers to `ABS(a)`, so for the reference to `a` in the `ORDER BY`, the index cannot be used:

```
SELECT ABS(a) AS a FROM t1 ORDER BY a;
```

In the following statement, the `ORDER BY` refers to a name that is not the name of a column in the select list. But there is a column in `t1` named `a`, so the `ORDER BY` uses that and the index can be used. (The resulting sort order may be completely different from the order for `ABS(a)`, of course.)

```
SELECT ABS(a) AS b FROM t1 ORDER BY a;
```

By default, MySQL sorts all `GROUP BY col1, col2, ...` queries as if you specified `ORDER BY col1, col2, ...` in the query as well. If you include an explicit `ORDER BY` clause that contains the same column list, MySQL optimizes it away without any speed penalty, although the sorting still occurs.

If a query includes `GROUP BY` but you want to avoid the overhead of sorting the result, you can suppress sorting by specifying `ORDER BY NULL`. For example:

```
INSERT INTO foo
SELECT a, COUNT(*) FROM bar GROUP BY a ORDER BY NULL;
```

The optimizer may still choose to use sorting to implement grouping operations. `ORDER BY NULL` suppresses sorting of the result, not prior sorting done by grouping operations to determine the result.

With `EXPLAIN SELECT ... ORDER BY`, you can check whether MySQL can use indexes to resolve the query. It cannot if you see `Using filesort` in the `Extra` column. See Section 8.8.1, "Optimizing Queries with EXPLAIN". Filesort uses a fixed-length row-storage format similar to that used by the `MEMORY` storage engine. Variable-length types such as `VARCHAR` are stored using a fixed length.

MySQL has two `filesort` algorithms for sorting and retrieving results. The original method uses only the `ORDER BY` columns. The modified method uses not just the `ORDER BY` columns, but all the columns referenced by the query.

The optimizer selects which `filesort` algorithm to use. It normally uses the modified algorithm except when `BLOB` or `TEXT` columns are involved, in which case it uses the original algorithm. For both algorithms, the sort buffer size is the `sort_buffer_size` system variable value.

The original `filesort` algorithm works as follows:

1. Read all rows according to key or by table scanning. Skip rows that do not match the `WHERE` clause.

2. For each row, store in the sort buffer a tuple consisting of a pair of values (the sort key value and the row ID).

3. If all pairs fit into the sort buffer, no temporary file is created. Otherwise, when the sort buffer becomes full, run a qsort (quicksort) on it in memory and write it to a temporary file. Save a pointer to the sorted block.

4. Repeat the preceding steps until all rows have been read.

5. Do a multi-merge of up to `MERGEBUFF` (7) regions to one block in another temporary file. Repeat until all blocks from the first file are in the second file.

6. Repeat the following until there are fewer than `MERGEBUFF2` (15) blocks left.

7. On the last multi-merge, only the row ID (the last part of the value pair) is written to a result file.

8. Read the rows in sorted order using the row IDs in the result file. To optimize this, read in a large block of row IDs, sort them, and use them to read the rows in sorted order into a row buffer. The row buffer size is the `read_rnd_buffer_size` system variable value. The code for this step is in the `sql/records.cc` source file.

One problem with this approach is that it reads rows twice: One time during `WHERE` clause evaluation, and again after sorting the value pairs. And even if the rows were accessed successively the first time (for example, if a table scan is done), the second time they are accessed randomly. (The sort keys are ordered, but the row positions are not.)

The modified `filesort` algorithm incorporates an optimization to avoid reading the rows twice: It records the sort key value, but instead of the row ID, it records the columns referenced by the query. The modified `filesort` algorithm works like this:

1. Read the rows that match the `WHERE` clause.

2. For each row, store in the sort buffer a tuple consisting of the sort key value and the columns referenced by the query.

3. When the sort buffer becomes full, sort the tuples by sort key value in memory and write it to a temporary file.

4. After merge-sorting the temporary file, retrieve the rows in sorted order, but read the columns required by the query directly from the sorted tuples rather than by accessing the table a second time.

The tuples used by the modified `filesort` algorithm are longer than the pairs used by the original algorithm, and fewer of them fit in the sort buffer. As a result, it is possible for the extra I/O to make the modified approach slower, not faster. To avoid a slowdown, the optimizer uses the modified

algorithm only if the total size of the extra columns in the sort tuple does not exceed the value of the `max_length_for_sort_data` system variable. (A symptom of setting the value of this variable too high is a combination of high disk activity and low CPU activity.)

If a `filesort` is done, `EXPLAIN` output includes `Using filesort` in the `Extra` column.

Suppose that a table `t1` has four `VARCHAR` columns `a`, `b`, `c`, and `d` and that the optimizer uses `filesort` for this query:

```
SELECT * FROM t1 ORDER BY a, b;
```

The query sorts by `a` and `b`, but returns all columns, so the columns referenced by the query are `a`, `b`, `c`, and `d`. Depending on which `filesort` algorithm the optimizer chooses, the query executes as follows:

For the original algorithm, sort buffer tuples have these contents:

```
(fixed size a value, fixed size b value,
row ID into t1)
```

The optimizer sorts on the fixed size values. After sorting, the optimizer reads the tuples in order and uses the row ID in each tuple to read rows from `t1` to obtain the select list column values.

For the modified algorithm, sort buffer tuples have these contents:

```
(fixed size a value, fixed size b value,
a value, b value, c value, d value)
```

The optimizer sorts on the fixed size values. After sorting, the optimizer reads the tuples in order and uses the values for `a`, `b`, `c`, and `d` to obtain the select list column values without reading `t1` again.

For slow queries for which `filesort` is not used, try lowering `max_length_for_sort_data` to a value that is appropriate to trigger a `filesort`.

To increase `ORDER BY` speed, check whether you can get MySQL to use indexes rather than an extra sorting phase. If this is not possible, you can try the following strategies:

- Increase the `sort_buffer_size` variable value.

- Increase the `read_rnd_buffer_size` variable value.

- Use less RAM per row by declaring columns only as large as they need to be to hold the values stored in them. For example, `CHAR(16)` is better than `CHAR(200)` if values never exceed 16 characters.

- Change the `tmpdir` system variable to point to a dedicated file system with large amounts of free space. The variable value can list several paths that are used in round-robin fashion; you can use this feature to spread the load across several directories. Paths should be separated by colon characters ("`:`") on Unix and semicolon characters ("`;`") on Windows, NetWare, and OS/2. The paths should name directories in file systems located on different *physical* disks, not different partitions on the same disk.

8.2.1.12 GROUP BY Optimization

The most general way to satisfy a `GROUP BY` clause is to scan the whole table and create a new temporary table where all rows from each group are consecutive, and then use this temporary table to discover groups and apply aggregate functions (if any). In some cases, MySQL is able to do much better than that and to avoid creation of temporary tables by using index access.

The most important preconditions for using indexes for `GROUP BY` are that all `GROUP BY` columns reference attributes from the same index, and that the index stores its keys in order (for example, this is a `BTREE` index and not a `HASH` index). Whether use of temporary tables can be replaced by index access also depends on which parts of an index are used in a query, the conditions specified for these parts, and the selected aggregate functions.

There are two ways to execute a `GROUP BY` query through index access, as detailed in the following sections. In the first method, the grouping operation is applied together with all range predicates (if any). The second method first performs a range scan, and then groups the resulting tuples.

In MySQL, `GROUP BY` is used for sorting, so the server may also apply `ORDER BY` optimizations to grouping. See Section 8.2.1.11, "ORDER BY Optimization".

Loose Index Scan

The most efficient way to process `GROUP BY` is when an index is used to directly retrieve the grouping columns. With this access method, MySQL uses the property of some index types that the keys are ordered (for example, `BTREE`). This property enables use of lookup groups in an index without having to consider all keys in the index that satisfy all `WHERE` conditions. This access method considers only a fraction of the keys in an index, so it is called a *loose index scan*. When there is no `WHERE` clause, a loose index scan reads as many keys as the number of groups, which may be a much smaller number than that of all keys. If the `WHERE` clause contains range predicates (see the discussion of the `range` join type in Section 8.8.1, "Optimizing Queries with EXPLAIN"), a loose index scan looks up the first key of each group that satisfies the range conditions, and again reads the least possible number of keys. This is possible under the following conditions:

- The query is over a single table.

- The `GROUP BY` names only columns that form a leftmost prefix of the index and no other columns. (If, instead of `GROUP BY`, the query has a `DISTINCT` clause, all distinct attributes refer to columns that form a leftmost prefix of the index.) For example, if a table `t1` has an index on `(c1,c2,c3)`, loose index scan is applicable if the query has `GROUP BY c1, c2,`. It is not applicable if the query has `GROUP BY c2, c3` (the columns are not a leftmost prefix) or `GROUP BY c1, c2, c4` (`c4` is not in the index).

- The only aggregate functions used in the select list (if any) are `MIN()` and `MAX()`, and all of them refer to the same column. The column must be in the index and must immediately follow the columns in the `GROUP BY`.

- Any other parts of the index than those from the `GROUP BY` referenced in the query must be constants (that is, they must be referenced in equalities with constants), except for the argument of `MIN()` or `MAX()` functions.

- For columns in the index, full column values must be indexed, not just a prefix. For example, with `c1 VARCHAR(20), INDEX (c1(10))`, the index cannot be used for loose index scan.

If loose index scan is applicable to a query, the `EXPLAIN` output shows `Using index for group-by` in the `Extra` column.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The loose index scan access method can be used for the following queries:

```
SELECT c1, c2 FROM t1 GROUP BY c1, c2;
SELECT DISTINCT c1, c2 FROM t1;
SELECT c1, MIN(c2) FROM t1 GROUP BY c1;
SELECT c1, c2 FROM t1 WHERE c1 < const GROUP BY c1, c2;
SELECT MAX(c3), MIN(c3), c1, c2 FROM t1 WHERE c2 > const GROUP BY c1, c2;
SELECT c2 FROM t1 WHERE c1 < const GROUP BY c1, c2;
```

```
SELECT c1, c2 FROM t1 WHERE c3 = const GROUP BY c1, c2;
```

The following queries cannot be executed with this quick select method, for the reasons given:

- There are aggregate functions other than MIN() or MAX():

```
SELECT c1, SUM(c2) FROM t1 GROUP BY c1;
```

- The columns in the GROUP BY clause do not form a leftmost prefix of the index:

```
SELECT c1, c2 FROM t1 GROUP BY c2, c3;
```

- The query refers to a part of a key that comes after the GROUP BY part, and for which there is no equality with a constant:

```
SELECT c1, c3 FROM t1 GROUP BY c1, c2;
```

  Were the query to include WHERE c3 = const, loose index scan could be used.

Tight Index Scan

A tight index scan may be either a full index scan or a range index scan, depending on the query conditions.

When the conditions for a loose index scan are not met, it still may be possible to avoid creation of temporary tables for GROUP BY queries. If there are range conditions in the WHERE clause, this method reads only the keys that satisfy these conditions. Otherwise, it performs an index scan. Because this method reads all keys in each range defined by the WHERE clause, or scans the whole index if there are no range conditions, we term it a *tight index scan*. With a tight index scan, the grouping operation is performed only after all keys that satisfy the range conditions have been found.

For this method to work, it is sufficient that there is a constant equality condition for all columns in a query referring to parts of the key coming before or in between parts of the GROUP BY key. The constants from the equality conditions fill in any "gaps" in the search keys so that it is possible to form complete prefixes of the index. These index prefixes then can be used for index lookups. If we require sorting of the GROUP BY result, and it is possible to form search keys that are prefixes of the index, MySQL also avoids extra sorting operations because searching with prefixes in an ordered index already retrieves all the keys in order.

Assume that there is an index idx(c1,c2,c3) on table t1(c1,c2,c3,c4). The following queries do not work with the loose index scan access method described earlier, but still work with the tight index scan access method.

- There is a gap in the GROUP BY, but it is covered by the condition c2 = 'a':

```
SELECT c1, c2, c3 FROM t1 WHERE c2 = 'a' GROUP BY c1, c3;
```

- The GROUP BY does not begin with the first part of the key, but there is a condition that provides a constant for that part:

```
SELECT c1, c2, c3 FROM t1 WHERE c1 = 'a' GROUP BY c2, c3;
```

8.2.1.13 DISTINCT Optimization

DISTINCT combined with ORDER BY needs a temporary table in many cases.

Because `DISTINCT` may use `GROUP BY`, learn how MySQL works with columns in `ORDER BY` or `HAVING` clauses that are not part of the selected columns. See Section 12.17.3, "MySQL Handling of GROUP BY".

In most cases, a `DISTINCT` clause can be considered as a special case of `GROUP BY`. For example, the following two queries are equivalent:

```
SELECT DISTINCT c1, c2, c3 FROM t1
WHERE c1 > const;

SELECT c1, c2, c3 FROM t1
WHERE c1 > const GROUP BY c1, c2, c3;
```

Due to this equivalence, the optimizations applicable to `GROUP BY` queries can be also applied to queries with a `DISTINCT` clause. Thus, for more details on the optimization possibilities for `DISTINCT` queries, see Section 8.2.1.12, "GROUP BY Optimization".

When combining `LIMIT row_count` with `DISTINCT`, MySQL stops as soon as it finds `row_count` unique rows.

If you do not use columns from all tables named in a query, MySQL stops scanning any unused tables as soon as it finds the first match. In the following case, assuming that `t1` is used before `t2` (which you can check with `EXPLAIN`), MySQL stops reading from `t2` (for any particular row in `t1`) when it finds the first row in `t2`:

```
SELECT DISTINCT t1.a FROM t1, t2 where t1.a=t2.a;
```

8.2.1.14 Optimizing Subqueries with EXISTS Strategy

Certain optimizations are applicable to comparisons that use the `IN` operator to test subquery results (or that use `=ANY`, which is equivalent). This section discusses these optimizations, particularly with regard to the challenges that `NULL` values present. The last part of the discussion includes suggestions on what you can do to help the optimizer.

Consider the following subquery comparison:

```
outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

MySQL evaluates queries "from outside to inside." That is, it first obtains the value of the outer expression `outer_expr`, and then runs the subquery and captures the rows that it produces.

A very useful optimization is to "inform" the subquery that the only rows of interest are those where the inner expression `inner_expr` is equal to `outer_expr`. This is done by pushing down an appropriate equality into the subquery's `WHERE` clause. That is, the comparison is converted to this:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND outer_expr=inner_expr)
```

After the conversion, MySQL can use the pushed-down equality to limit the number of rows that it must examine when evaluating the subquery.

More generally, a comparison of N values to a subquery that returns N-value rows is subject to the same conversion. If oe_i and ie_i represent corresponding outer and inner expression values, this subquery comparison:

```
(oe_1, ..., oe_N) IN
  (SELECT ie_1, ..., ie_N FROM ... WHERE subquery_where)
```

Becomes:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where
                         AND oe_1 = ie_1
                         AND ...
                         AND oe_N = ie_N)
```

The following discussion assumes a single pair of outer and inner expression values for simplicity.

The conversion just described has its limitations. It is valid only if we ignore possible NULL values. That is, the "pushdown" strategy works as long as both of these two conditions are true:

• *outer_expr* and *inner_expr* cannot be NULL.

• You do not need to distinguish NULL from FALSE subquery results. (If the subquery is a part of an OR or AND expression in the WHERE clause, MySQL assumes that you do not care.)

When either or both of those conditions do not hold, optimization is more complex.

Suppose that *outer_expr* is known to be a non-NULL value but the subquery does not produce a row such that *outer_expr* = *inner_expr*. Then *outer_expr* IN (SELECT ...) evaluates as follows:

• NULL, if the SELECT produces any row where *inner_expr* is NULL

• FALSE, if the SELECT produces only non-NULL values or produces nothing

In this situation, the approach of looking for rows with *outer_expr* = *inner_expr* is no longer valid. It is necessary to look for such rows, but if none are found, also look for rows where *inner_expr* is NULL. Roughly speaking, the subquery can be converted to:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND
        (outer_expr=inner_expr OR inner_expr IS NULL))
```

The need to evaluate the extra IS NULL condition is why MySQL has the ref_or_null access method:

```
mysql> EXPLAIN
    -> SELECT outer_expr IN (SELECT t2.maybe_null_key
    ->                       FROM t2, t3 WHERE ...)
    -> FROM t1;
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
...
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: ref_or_null
possible_keys: maybe_null_key
          key: maybe_null_key
      key_len: 5
          ref: func
         rows: 2
        Extra: Using where; Using index
...
```

The `unique_subquery` and `index_subquery` subquery-specific access methods also have "or `NULL`" variants. However, they are not visible in `EXPLAIN` output, so you must use `EXPLAIN EXTENDED` followed by `SHOW WARNINGS` (note the `checking NULL` in the warning message):

```
mysql> EXPLAIN EXTENDED
    -> SELECT outer_expr IN (SELECT maybe_null_key FROM t2) FROM t1\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
...
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: index_subquery
possible_keys: maybe_null_key
          key: maybe_null_key
      key_len: 5
          ref: func
         rows: 2
        Extra: Using index

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Note
   Code: 1003
Message: select (`test`.`t1`.`outer_expr`,
         (((`test`.`t1`.`outer_expr`) in t2 on
         maybe_null_key checking NULL))) AS `outer_expr IN (SELECT
         maybe_null_key FROM t2)` from `test`.`t1`
```

The additional `OR ... IS NULL` condition makes query execution slightly more complicated (and some optimizations within the subquery become inapplicable), but generally this is tolerable.

The situation is much worse when *outer_expr* can be `NULL`. According to the SQL interpretation of `NULL` as "unknown value," `NULL IN (SELECT inner_expr ...)` should evaluate to:

- `NULL`, if the `SELECT` produces any rows

- `FALSE`, if the `SELECT` produces no rows

For proper evaluation, it is necessary to be able to check whether the `SELECT` has produced any rows at all, so *outer_expr = inner_expr* cannot be pushed down into the subquery. This is a problem, because many real world subqueries become very slow unless the equality can be pushed down.

Essentially, there must be different ways to execute the subquery depending on the value of *outer_expr*. In MySQL 5.1 before 5.1.16, the optimizer chose speed over distinguishing a `NULL` from `FALSE` result, so for some queries, you might get a `FALSE` result rather than `NULL`.

As of MySQL 5.1.16, the optimizer chooses SQL compliance over speed, so it accounts for the possibility that *outer_expr* might be `NULL`.

If *outer_expr* is `NULL`, to evaluate the following expression, it is necessary to run the `SELECT` to determine whether it produces any rows:

```
NULL IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

It is necessary to run the original `SELECT` here, without any pushed-down equalities of the kind mentioned earlier.

On the other hand, when *outer_expr* is not NULL, it is absolutely essential that this comparison:

```
outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

be converted to this expression that uses a pushed-down condition:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND outer_expr=inner_expr)
```

Without this conversion, subqueries will be slow. To solve the dilemma of whether to push down or not push down conditions into the subquery, the conditions are wrapped in "trigger" functions. Thus, an expression of the following form:

```
outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

is converted into:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where
                          AND trigcond(outer_expr=inner_expr))
```

More generally, if the subquery comparison is based on several pairs of outer and inner expressions, the conversion takes this comparison:

```
(oe_1, ..., oe_N) IN (SELECT ie_1, ..., ie_N FROM ... WHERE subquery_where)
```

and converts it to this expression:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where
                          AND trigcond(oe_1=ie_1)
                          AND ...
                          AND trigcond(oe_N=ie_N)
        )
```

Each `trigcond(X)` is a special function that evaluates to the following values:

- `X` when the "linked" outer expression `oe_i` is not NULL

- TRUE when the "linked" outer expression `oe_i` is NULL

> **Note**
>
> Trigger functions are *not* triggers of the kind that you create with CREATE TRIGGER.

Equalities that are wrapped into `trigcond()` functions are not first class predicates for the query optimizer. Most optimizations cannot deal with predicates that may be turned on and off at query execution time, so they assume any `trigcond(X)` to be an unknown function and ignore it. At the moment, triggered equalities can be used by those optimizations:

- Reference optimizations: `trigcond(X=Y [OR Y IS NULL])` can be used to construct ref, eq_ref, or `ref_or_null` table accesses.

- Index lookup-based subquery execution engines: `trigcond(X=Y)` can be used to construct `unique_subquery` or `index_subquery` accesses.

- Table-condition generator: If the subquery is a join of several tables, the triggered condition will be checked as soon as possible.

When the optimizer uses a triggered condition to create some kind of index lookup-based access (as for the first two items of the preceding list), it must have a fallback strategy for the case when the condition is turned off. This fallback strategy is always the same: Do a full table scan. In `EXPLAIN` output, the fallback shows up as `Full scan on NULL key` in the `Extra` column:

```
mysql> EXPLAIN SELECT t1.col1,
    -> t1.col1 IN (SELECT t2.key1 FROM t2 WHERE t2.col2=t1.col2) FROM t1\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
        ...
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: index_subquery
possible_keys: key1
          key: key1
      key_len: 5
          ref: func
         rows: 2
        Extra: Using where; Full scan on NULL key
```

If you run `EXPLAIN EXTENDED` followed by `SHOW WARNINGS`, you can see the triggered condition:

```
*************************** 1. row ***************************
  Level: Note
   Code: 1003
Message: select `test`.`t1`.`col1` AS `col1`,
         <in_optimizer>(`test`.`t1`.`col1`,
         <exists>(<index_lookup>(<cache>(`test`.`t1`.`col1`) in t2
         on key1 checking NULL
         where (`test`.`t2`.`col2` = `test`.`t1`.`col2`) having
         trigcond(<is_not_null_test>(`test`.`t2`.`key1`))))) AS
         `t1.col1 IN (select t2.key1 from t2 where t2.col2=t1.col2)`
         from `test`.`t1`
```

The use of triggered conditions has some performance implications. A `NULL IN (SELECT ...)` expression now may cause a full table scan (which is slow) when it previously did not. This is the price paid for correct results (the goal of the trigger-condition strategy was to improve compliance and not speed).

For multiple-table subqueries, execution of `NULL IN (SELECT ...)` will be particularly slow because the join optimizer does not optimize for the case where the outer expression is `NULL`. It assumes that subquery evaluations with `NULL` on the left side are very rare, even if there are statistics that indicate otherwise. On the other hand, if the outer expression might be `NULL` but never actually is, there is no performance penalty.

To help the query optimizer better execute your queries, use these tips:

- Declare a column as `NOT NULL` if it really is. (This also helps other aspects of the optimizer by simplifying condition testing for the column.)

- If you do not need to distinguish a `NULL` from `FALSE` subquery result, you can easily avoid the slow execution path. Replace a comparison that looks like this:

```
outer_expr IN (SELECT inner_expr FROM ...)
```

with this expression:

```
(outer_expr IS NOT NULL) AND (outer_expr IN (SELECT inner_expr FROM ...))
```

Then `NULL IN (SELECT ...)` will never be evaluated because MySQL stops evaluating `AND` parts as soon as the expression result is clear.

8.2.1.15 LIMIT Query Optimization

In some cases, MySQL handles a query differently when you are using `LIMIT row_count` and not using `HAVING`:

- If you select only a few rows with `LIMIT`, MySQL uses indexes in some cases when normally it would prefer to do a full table scan.

- If you combine `LIMIT row_count` with `ORDER BY`, MySQL ends the sorting as soon as it has found the first `row_count` rows of the sorted result, rather than sorting the entire result. If ordering is done by using an index, this is very fast. If a filesort must be done, all rows that match the query without the `LIMIT` clause must be selected, and most or all of them must be sorted, before it can be ascertained that the first `row_count` rows have been found. In either case, after the initial rows have been found, there is no need to sort any remainder of the result set, and MySQL does not do so.

- If you combine `LIMIT row_count` with `DISTINCT`, MySQL stops as soon as it finds `row_count` unique rows.

- In some cases, a `GROUP BY` can be resolved by reading the index in order (or doing a sort on the index) and then calculating summaries until the index value changes. In this case, `LIMIT row_count` does not calculate any unnecessary `GROUP BY` values.

- As soon as MySQL has sent the required number of rows to the client, it aborts the query unless you are using `SQL_CALC_FOUND_ROWS`. The number of rows can then be retrieved with `SELECT FOUND_ROWS()`. See Section 12.14, "Information Functions".

- `LIMIT 0` quickly returns an empty set. This can be useful for checking the validity of a query. It can also be employed to obtain the types of the result columns if you are using a MySQL API that makes result set metadata available. With the `mysql` client program, you can use the `--column-type-info` option to display result column types.

- If the server uses temporary tables to resolve the query, it uses the `LIMIT row_count` clause to calculate how much space is required.

8.2.1.16 Row Constructor Expression Optimization

Row constructors permit simultaneous comparisons of multiple values. For example, these two statements are semantically equivalent:

```
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

In addition, the optimizer handles both expressions the same way.

The optimizer is less likely to use available indexes if the row constructor columns do not cover the prefix of an index. Consider the following table, which has a primary key on `(c1, c2, c3)`:

```
CREATE TABLE t1 (
  c1 INT, c2 INT, c3 INT, c4 CHAR(100),
  PRIMARY KEY(c1,c2,c3)
);
```

In this query, the `WHERE` clause uses all columns in the index. However, the row constructor itself does not cover an index prefix, with the result that the optimizer uses only `c1` (`key_len=4`, the size of `c1`):

```
mysql> EXPLAIN SELECT * FROM t1
    -> WHERE c1=1 AND (c2,c3) > (1,1)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
   partitions: NULL
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: const
         rows: 3
        Extra: Using where
```

In such cases, rewriting the row constructor expression using an equivalent nonconstructor expression may result in more complete index use. For the given query, the row constructor and equivalent nonconstructor expressions are:

```
(c2,c3) > (1,1)
c2 > 1 OR ((c2 = 1) AND (c3 > 1))
```

Rewriting the query to use the nonconstructor expression results in the optimizer using all three columns in the index (`key_len=12`):

```
mysql> EXPLAIN SELECT * FROM t1
    -> WHERE c1 = 1 AND (c2 > 1 OR ((c2 = 1) AND (c3 > 1)))\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
   partitions: NULL
         type: range
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 12
          ref: NULL
         rows: 3
        Extra: Using where
```

Thus, for better results, avoid mixing row constructors with `AND`/`OR` expressions. Use one or the other.

8.2.1.17 How to Avoid Full Table Scans

The output from `EXPLAIN` shows `ALL` in the `type` column when MySQL uses a table scan to resolve a query. This usually happens under the following conditions:

- The table is so small that it is faster to perform a table scan than to bother with a key lookup. This is common for tables with fewer than 10 rows and a short row length.

- There are no usable restrictions in the `ON` or `WHERE` clause for indexed columns.

- You are comparing indexed columns with constant values and MySQL has calculated (based on the index tree) that the constants cover too large a part of the table and that a table scan would be faster. See Section 8.2.1.2, "How MySQL Optimizes WHERE Clauses".

- You are using a key with low cardinality (many rows match the key value) through another column. In this case, MySQL assumes that by using the key it probably will do many key lookups and that a table scan would be faster.

For small tables, a table scan often is appropriate and the performance impact is negligible. For large tables, try the following techniques to avoid having the optimizer incorrectly choose a table scan:

- Use `ANALYZE TABLE` *`tbl_name`* to update the key distributions for the scanned table. See Section 13.7.2.1, "ANALYZE TABLE Syntax".

- Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to using the given index:

```
SELECT * FROM t1, t2 FORCE INDEX (index_for_column)
  WHERE t1.col_name=t2.col_name;
```

  See Section 8.9.3, "Index Hints".

- Start `mysqld` with the `--max-seeks-for-key=1000` option or use `SET max_seeks_for_key=1000` to tell the optimizer to assume that no key scan causes more than 1,000 key seeks. See Section 5.1.4, "Server System Variables".

8.2.2 Optimizing Data Change Statements

This section explains how to speed up data change statements: `INSERT`, `UPDATE`, and `DELETE`. Traditional OLTP applications and modern web applications typically do many small data change operations, where concurrency is vital. Data analysis and reporting applications typically run data change operations that affect many rows at once, where the main considerations is the I/O to write large amounts of data and keep indexes up-to-date. For inserting and updating large volumes of data (known in the industry as ETL, for "extract-transform-load"), sometimes you use other SQL statements or external commands, that mimic the effects of `INSERT`, `UPDATE`, and `DELETE` statements.

8.2.2.1 Speed of INSERT Statements

To optimize insert speed, combine many small operations into a single large operation. Ideally, you make a single connection, send the data for many new rows at once, and delay all index updates and consistency checking until the very end.

The time required for inserting a row is determined by the following factors, where the numbers indicate approximate proportions:

- Connecting: (3)

- Sending query to server: (2)

- Parsing query: (2)

- Inserting row: (1 × size of row)

- Inserting indexes: (1 × number of indexes)

- Closing: (1)

This does not take into consideration the initial overhead to open tables, which is done once for each concurrently running query.

The size of the table slows down the insertion of indexes by log N, assuming B-tree indexes.

You can use the following methods to speed up inserts:

- If you are inserting many rows from the same client at the same time, use `INSERT` statements with multiple `VALUES` lists to insert several rows at a time. This is considerably faster (many times faster in some cases) than using separate single-row `INSERT` statements. If you are adding data to a nonempty table, you can tune the `bulk_insert_buffer_size` variable to make data insertion even faster. See Section 5.1.4, "Server System Variables".

- When loading a table from a text file, use `LOAD DATA INFILE`. This is usually 20 times faster than using `INSERT` statements. See Section 13.2.6, "LOAD DATA INFILE Syntax".

- Take advantage of the fact that columns have default values. Insert values explicitly only when the value to be inserted differs from the default. This reduces the parsing that MySQL must do and improves the insert speed.

- See Section 8.5.2, "Bulk Data Loading for MyISAM Tables" for tips specific to `MyISAM` tables.

8.2.2.2 Speed of UPDATE Statements

An update statement is optimized like a `SELECT` query with the additional overhead of a write. The speed of the write depends on the amount of data being updated and the number of indexes that are updated. Indexes that are not changed do not get updated.

Another way to get fast updates is to delay updates and then do many updates in a row later. Performing multiple updates together is much quicker than doing one at a time if you lock the table.

For a `MyISAM` table that uses dynamic row format, updating a row to a longer total length may split the row. If you do this often, it is very important to use `OPTIMIZE TABLE` occasionally. See Section 13.7.2.5, "OPTIMIZE TABLE Syntax".

8.2.2.3 Speed of DELETE Statements

The time required to delete individual rows is exactly proportional to the number of indexes. To delete rows more quickly, you can increase the size of the key cache by increasing the `key_buffer_size` system variable. See Section 8.12.2, "Tuning Server Parameters".

To delete all rows from a table, `TRUNCATE TABLE` *tbl_name* is faster than `DELETE FROM` *tbl_name*. Truncate operations are not transaction-safe; an error occurs when attempting one in the course of an active transaction or active table lock. See Section 13.1.34, "TRUNCATE TABLE Syntax".

8.2.3 Optimizing Database Privileges

The more complex your privilege setup, the more overhead applies to all SQL statements. Simplifying the privileges established by `GRANT` statements enables MySQL to reduce permission-checking overhead when clients execute statements. For example, if you do not grant any table-level or column-level privileges, the server need not ever check the contents of the `tables_priv` and `columns_priv` tables. Similarly, if you place no resource limits on any accounts, the server does not have to perform resource counting. If you have a very high statement-processing load, consider using a simplified grant structure to reduce permission-checking overhead.

8.2.4 INFORMATION_SCHEMA Optimization

As of MySQL 5.1.21, the implementation of `INFORMATION_SCHEMA` is such that certain types of queries for `INFORMATION_SCHEMA` tables can be optimized to execute more quickly. This section provides guidelines on writing queries that take advantage of these optimizations. In general, the strategies outlined here minimize the need for the server to access the file system to obtain the information that makes up the contents of `INFORMATION_SCHEMA` tables. By writing queries that enable the server to avoid directory scans or opening table files, you will obtain better performance. These optimizations do have an effect on how collations are used for searches in `INFORMATION_SCHEMA` tables. For more information, see Section 10.1.7.9, "Collation and INFORMATION_SCHEMA Searches".

1) Try to use constant lookup values for database and table names in the `WHERE` clause

You can take advantage of this principle as follows:

- To look up databases or tables, use expressions that evaluate to a constant, such as literal values, functions that return a constant, or scalar subqueries.

- Avoid queries that use a nonconstant database name lookup value (or no lookup value) because they require a scan of the data directory to find matching database directory names.

- Within a database, avoid queries that use a nonconstant table name lookup value (or no lookup value) because they require a scan of the database directory to find matching table files.

This principle applies to the `INFORMATION_SCHEMA` tables shown in the following table, which shows the columns for which a constant lookup value enables the server to avoid a directory scan. For example, if you are selecting from `TABLES`, using a constant lookup value for `TABLE_SCHEMA` in the `WHERE` clause enables a data directory scan to be avoided.

Table	Column to specify to avoid data directory scan	Column to specify to avoid database directory scan
COLUMNS	TABLE_SCHEMA	TABLE_NAME
KEY_COLUMN_USAGE	TABLE_SCHEMA	TABLE_NAME
PARTITIONS	TABLE_SCHEMA	TABLE_NAME
REFERENTIAL_CONSTRAINTS	CONSTRAINT_SCHEMA	TABLE_NAME
STATISTICS	TABLE_SCHEMA	TABLE_NAME
TABLES	TABLE_SCHEMA	TABLE_NAME
TABLE_CONSTRAINTS	TABLE_SCHEMA	TABLE_NAME
TRIGGERS	EVENT_OBJECT_SCHEMA	EVENT_OBJECT_TABLE
VIEWS	TABLE_SCHEMA	TABLE_NAME

The benefit of a query that is limited to a specific constant database name is that checks need be made only for the named database directory. Example:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test';
```

Use of the literal database name `test` enables the server to check only the `test` database directory, regardless of how many databases there might be. By contrast, the following query is less efficient because it requires a scan of the data directory to determine which database names match the pattern `'test%'`:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
```

```
WHERE TABLE_SCHEMA LIKE 'test%';
```

For a query that is limited to a specific constant table name, checks need be made only for the named table within the corresponding database directory. Example:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 't1';
```

Use of the literal table name `t1` enables the server to check only the files for the `t1` table, regardless of how many tables there might be in the `test` database. By contrast, the following query requires a scan of the `test` database directory to determine which table names match the pattern `'t%'`:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME LIKE 't%';
```

The following query requires a scan of the database directory to determine matching database names for the pattern `'test%'`, and for each matching database, it requires a scan of the database directory to determine matching table names for the pattern `'t%'`:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test%' AND TABLE_NAME LIKE 't%';
```

2) Write queries that minimize the number of table files that must be opened

For queries that refer to certain `INFORMATION_SCHEMA` table columns, several optimizations are available that minimize the number of table files that must be opened. Example:

```
SELECT TABLE_NAME, ENGINE FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test';
```

In this case, after the server has scanned the database directory to determine the names of the tables in the database, those names become available with no further file system lookups. Thus, `TABLE_NAME` requires no files to be opened. The `ENGINE` (storage engine) value can be determined by opening the table's `.frm` file, without touching other table files such as the `.MYD` or `.MYI` file.

Some values, such as `INDEX_LENGTH` for `MyISAM` tables, require opening the `.MYD` or `.MYI` file as well.

The file-opening optimization types are denoted thus:

- `SKIP_OPEN_TABLE`: Table files do not need to be opened. The information has already become available within the query by scanning the database directory.

- `OPEN_FRM_ONLY`: Only the table's `.frm` file need be opened.

- `OPEN_TRIGGER_ONLY`: Only the table's `.TRG` file need be opened.

- `OPEN_FULL_TABLE`: The unoptimized information lookup. The `.frm`, `.MYD`, and `.MYI` files must be opened.

The following list indicates how the preceding optimization types apply to `INFORMATION_SCHEMA` table columns. For tables and columns not named, none of the optimizations apply.

- `COLUMNS`: `OPEN_FRM_ONLY` applies to all columns

- `KEY_COLUMN_USAGE`: `OPEN_FULL_TABLE` applies to all columns

- `PARTITIONS`: `OPEN_FULL_TABLE` applies to all columns

- `REFERENTIAL_CONSTRAINTS`: `OPEN_FULL_TABLE` applies to all columns

- STATISTICS:

Column	Optimization type
TABLE_CATALOG	OPEN_FRM_ONLY
TABLE_SCHEMA	OPEN_FRM_ONLY
TABLE_NAME	OPEN_FRM_ONLY
NON_UNIQUE	OPEN_FRM_ONLY
INDEX_SCHEMA	OPEN_FRM_ONLY
INDEX_NAME	OPEN_FRM_ONLY
SEQ_IN_INDEX	OPEN_FRM_ONLY
COLUMN_NAME	OPEN_FRM_ONLY
COLLATION	OPEN_FRM_ONLY
CARDINALITY	OPEN_FULL_TABLE
SUB_PART	OPEN_FRM_ONLY
PACKED	OPEN_FRM_ONLY
NULLABLE	OPEN_FRM_ONLY
INDEX_TYPE	OPEN_FULL_TABLE
COMMENT	OPEN_FRM_ONLY

- TABLES:

Column	Optimization type
TABLE_CATALOG	SKIP_OPEN_TABLE
TABLE_SCHEMA	SKIP_OPEN_TABLE
TABLE_NAME	SKIP_OPEN_TABLE
TABLE_TYPE	OPEN_FRM_ONLY
ENGINE	OPEN_FRM_ONLY
VERSION	OPEN_FRM_ONLY
ROW_FORMAT	OPEN_FULL_TABLE
TABLE_ROWS	OPEN_FULL_TABLE
AVG_ROW_LENGTH	OPEN_FULL_TABLE
DATA_LENGTH	OPEN_FULL_TABLE
MAX_DATA_LENGTH	OPEN_FULL_TABLE
INDEX_LENGTH	OPEN_FULL_TABLE
DATA_FREE	OPEN_FULL_TABLE
AUTO_INCREMENT	OPEN_FULL_TABLE
CREATE_TIME	OPEN_FULL_TABLE
UPDATE_TIME	OPEN_FULL_TABLE
CHECK_TIME	OPEN_FULL_TABLE
TABLE_COLLATION	OPEN_FRM_ONLY
CHECKSUM	OPEN_FULL_TABLE

Column	Optimization type
CREATE_OPTIONS	OPEN_FRM_ONLY
TABLE_COMMENT	OPEN_FRM_ONLY

- TABLE_CONSTRAINTS: OPEN_FULL_TABLE applies to all columns

- TRIGGERS: OPEN_FULL_TABLE applies to all columns

- VIEWS:

Column	Optimization type
TABLE_CATALOG	OPEN_FRM_ONLY
TABLE_SCHEMA	OPEN_FRM_ONLY
TABLE_NAME	OPEN_FRM_ONLY
VIEW_DEFINITION	OPEN_FULL_TABLE
CHECK_OPTION	OPEN_FULL_TABLE
IS_UPDATABLE	OPEN_FULL_TABLE
DEFINER	OPEN_FULL_TABLE
SECURITY_TYPE	OPEN_FULL_TABLE
CHARACTER_SET_CLIENT	OPEN_FULL_TABLE
COLLATION_CONNECTION	OPEN_FULL_TABLE

3) Use EXPLAIN to determine whether the server can use INFORMATION_SCHEMA optimizations for a query

This applies particularly for INFORMATION_SCHEMA queries that search for information from more than one database, which might take a long time and impact performance. The Extra value in EXPLAIN output indicates which, if any, of the optimizations described earlier the server can use to evaluate INFORMATION_SCHEMA queries. The following examples demonstrate the kinds of information you can expect to see in the Extra value.

```
mysql> EXPLAIN SELECT TABLE_NAME FROM INFORMATION_SCHEMA.VIEWS WHERE
    -> TABLE_SCHEMA = 'test' AND TABLE_NAME = 'v1'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: VIEWS
         type: ALL
possible_keys: NULL
          key: TABLE_SCHEMA,TABLE_NAME
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Open_frm_only; Scanned 0 databases
```

Use of constant database and table lookup values enables the server to avoid directory scans. For references to VIEWS.TABLE_NAME, only the .frm file need be opened.

```
mysql> EXPLAIN SELECT TABLE_NAME, ROW_FORMAT FROM INFORMATION_SCHEMA.TABLES\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: TABLES
         type: ALL
possible_keys: NULL
```

```
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Open_full_table; Scanned all databases
```

No lookup values are provided (there is no `WHERE` clause), so the server must scan the data directory and each database directory. For each table thus identified, the table name and row format are selected. `TABLE_NAME` requires no further table files to be opened (the `SKIP_OPEN_TABLE` optimization applies). `ROW_FORMAT` requires all table files to be opened (`OPEN_FULL_TABLE` applies). `EXPLAIN` reports `OPEN_FULL_TABLE` because it is more expensive than `SKIP_OPEN_TABLE`.

```
mysql> EXPLAIN SELECT TABLE_NAME, TABLE_TYPE FROM INFORMATION_SCHEMA.TABLES
    -> WHERE TABLE_SCHEMA = 'test'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: TABLES
         type: ALL
possible_keys: NULL
          key: TABLE_SCHEMA
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Open_frm_only; Scanned 1 database
```

No table name lookup value is provided, so the server must scan the `test` database directory. For the `TABLE_NAME` and `TABLE_TYPE` columns, the `SKIP_OPEN_TABLE` and `OPEN_FRM_ONLY` optimizations apply, respectively. `EXPLAIN` reports `OPEN_FRM_ONLY` because it is more expensive.

```
mysql> EXPLAIN SELECT B.TABLE_NAME
    -> FROM INFORMATION_SCHEMA.TABLES AS A, INFORMATION_SCHEMA.COLUMNS AS B
    -> WHERE A.TABLE_SCHEMA = 'test'
    -> AND A.TABLE_NAME = 't1'
    -> AND B.TABLE_NAME = A.TABLE_NAME\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: A
         type: ALL
possible_keys: NULL
          key: TABLE_SCHEMA,TABLE_NAME
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Skip_open_table; Scanned 0 databases
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: B
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Open_frm_only; Scanned all databases;
               Using join buffer
```

For the first `EXPLAIN` output row: Constant database and table lookup values enable the server to avoid directory scans for `TABLES` values. References to `TABLES.TABLE_NAME` require no further table files.

For the second `EXPLAIN` output row: All `COLUMNS` table values are `OPEN_FRM_ONLY` lookups, so `COLUMNS.TABLE_NAME` requires the `.frm` file to be opened.

```
mysql> EXPLAIN SELECT * FROM INFORMATION_SCHEMA.COLLATIONS\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: COLLATIONS
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra:
```

In this case, no optimizations apply because `COLLATIONS` is not one of the `INFORMATION_SCHEMA` tables for which optimizations are available.

8.2.5 Other Optimization Tips

This section lists a number of miscellaneous tips for improving query processing speed:

- If your application makes several database requests to perform related updates, combining the statements into a stored routine can help performance. Similarly, if your application computes a single result based on several column values or large volumes of data, combining the computation into a UDF (user-defined function) can help performance. The resulting fast database operations are then available to be reused by other queries, applications, and even code written in different programming languages. See Section 19.2, "Using Stored Routines (Procedures and Functions)" and Section 22.3, "Adding New Functions to MySQL" for more information.

- To fix any compression issues that occur with `ARCHIVE` tables, use `OPTIMIZE TABLE`. See Section 14.12, "The ARCHIVE Storage Engine".

- If possible, classify reports as "live" or as "statistical", where data needed for statistical reports is created only from summary tables that are generated periodically from the live data.

- If you have data that does not conform well to a rows-and-columns table structure, you can pack and store data into a `BLOB` column. In this case, you must provide code in your application to pack and unpack information, but this might save I/O operations to read and write the sets of related values.

- With Web servers, store images and other binary assets as files, with the path name stored in the database rather than the file itself. Most Web servers are better at caching files than database contents, so using files is generally faster. (Although you must handle backups and storage issues yourself in this case.)

- If you need really high speed, look at the low-level MySQL interfaces. For example, by accessing the MySQL `InnoDB` or `MyISAM` storage engine directly, you could get a substantial speed increase compared to using the SQL interface.

- Replication can provide a performance benefit for some operations. You can distribute client retrievals among replication servers to split up the load. To avoid slowing down the master while making backups, you can make backups using a slave server. See Chapter 16, *Replication*.

8.3 Optimization and Indexes

The best way to improve the performance of `SELECT` operations is to create indexes on one or more of the columns that are tested in the query. The index entries act like pointers to the table rows, allowing the query to quickly determine which rows match a condition in the `WHERE` clause, and retrieve the other column values for those rows. All MySQL data types can be indexed.

Although it can be tempting to create an indexes for every possible column used in a query, unnecessary indexes waste space and waste time for MySQL to determine which indexes to use. Indexes also add to the cost of inserts, updates, and deletes because each index must be updated. You must find the right balance to achieve fast queries using the optimal set of indexes.

8.3.1 How MySQL Uses Indexes

Indexes are used to find rows with specific column values quickly. Without an index, MySQL must begin with the first row and then read through the entire table to find the relevant rows. The larger the table, the more this costs. If the table has an index for the columns in question, MySQL can quickly determine the position to seek to in the middle of the data file without having to look at all the data. This is much faster than reading every row sequentially.

Most MySQL indexes (`PRIMARY KEY`, `UNIQUE`, `INDEX`, and `FULLTEXT`) are stored in B-trees. Exceptions are that indexes on spatial data types use R-trees, and that `MEMORY` tables also support hash indexes.

Strings are automatically prefix- and end-space compressed. See Section 13.1.13, "CREATE INDEX Syntax".

In general, indexes are used as described in the following discussion. Characteristics specific to hash indexes (as used in `MEMORY` tables) are described in Section 8.3.8, "Comparison of B-Tree and Hash Indexes".

MySQL uses indexes for these operations:

- To find the rows matching a `WHERE` clause quickly.

- To eliminate rows from consideration. If there is a choice between multiple indexes, MySQL normally uses the index that finds the smallest number of rows.

- If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimizer to look up rows. For example, if you have a three-column index on `(col1, col2, col3)`, you have indexed search capabilities on `(col1)`, `(col1, col2)`, and `(col1, col2, col3)`. For more information, see Section 8.3.5, "Multiple-Column Indexes".

- To retrieve rows from other tables when performing joins. MySQL can use indexes on columns more efficiently if they are declared as the same type and size. In this context, `VARCHAR` and `CHAR` are considered the same if they are declared as the same size. For example, `VARCHAR(10)` and `CHAR(10)` are the same size, but `VARCHAR(10)` and `CHAR(15)` are not.

  For comparisons between nonbinary string columns, both columns should use the same character set. For example, comparing a `utf8` column with a `latin1` column precludes use of an index.

  Comparison of dissimilar columns (comparing a string column to a temporal or numeric column, for example) may prevent use of indexes if values cannot be compared directly without conversion. For a given value such as `1` in the numeric column, it might compare equal to any number of values in the string column such as `'1'`, `' 1'`, `'00001'`, or `'01.e1'`. This rules out use of any indexes for the string column.

- To find the `MIN()` or `MAX()` value for a specific indexed column `key_col`. This is optimized by a preprocessor that checks whether you are using `WHERE key_part_N = constant` on all key parts that occur before `key_col` in the index. In this case, MySQL does a single key lookup for each `MIN()` or `MAX()` expression and replaces it with a constant. If all expressions are replaced with constants, the query returns at once. For example:

```
SELECT MIN(key_part2),MAX(key_part2)
  FROM tbl_name WHERE key_part1=10;
```

- To sort or group a table if the sorting or grouping is done on a leftmost prefix of a usable index (for example, `ORDER BY key_part1, key_part2`). If all key parts are followed by `DESC`, the key is read in reverse order. See Section 8.2.1.11, "ORDER BY Optimization", and Section 8.2.1.12, "GROUP BY Optimization".

- In some cases, a query can be optimized to retrieve values without consulting the data rows. If a query uses from a table only columns that are included in some index, the selected values can be be retrieved from the index tree for greater speed:

```
SELECT key_part3 FROM tbl_name
  WHERE key_part1=1
```

Indexes are less important for queries on small tables, or big tables where report queries process most or all of the rows. When a query needs to access most of the rows, reading sequentially is faster than working through an index. Sequential reads minimize disk seeks, even if not all the rows are needed for the query. See Section 8.2.1.17, "How to Avoid Full Table Scans" for details.

8.3.2 Using Primary Keys

The primary key for a table represents the column or set of columns that you use in your most vital queries. It has an associated index, for fast query performance. Query performance benefits from the `NOT NULL` optimization, because it cannot include any `NULL` values. With the `InnoDB` storage engine, the table data is physically organized to do ultra-fast lookups and sorts based on the primary key column or columns.

If your table is big and important, but does not have an obvious column or set of columns to use as a primary key, you might create a separate column with auto-increment values to use as the primary key. These unique IDs can serve as pointers to corresponding rows in other tables when you join tables using foreign keys.

8.3.3 Using Foreign Keys

If a table has many columns, and you query many different combinations of columns, it might be efficient to split the less-frequently used data into separate tables with a few columns each, and relate them back to the main table by duplicating the numeric ID column from the main table. That way, each small table can have a primary key for fast lookups of its data, and you can query just the set of columns that you need using a join operation. Depending on how the data is distributed, the queries might perform less I/O and take up less cache memory because the relevant columns are packed together on disk. (To maximize performance, queries try to read as few data blocks as possible from disk; tables with only a few columns can fit more rows in each data block.)

8.3.4 Column Indexes

All MySQL data types can be indexed. Use of indexes on the relevant columns is the best way to improve the performance of `SELECT` operations.

The maximum number of indexes per table and the maximum index length is defined per storage engine. See Chapter 14, *Storage Engines*. All storage engines support at least 16 indexes per table and a total index length of at least 256 bytes. Most storage engines have higher limits.

For additional information about column indexes, see Section 13.1.13, "CREATE INDEX Syntax".

Prefix Indexes

With `col_name(N)` syntax in an index specification for a string column, you can create an index that uses only the first `N` characters of the column. Indexing only a prefix of column values in this way can make the index file much smaller. When you index a `BLOB` or `TEXT` column, you *must* specify a prefix length for the index. For example:

```
CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));
```

Prefixes can be up to 1000 bytes long (767 bytes for `InnoDB` tables).

> **Note**
>
> Prefix limits are measured in bytes, whereas the prefix length in `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements is interpreted as number of characters for nonbinary string types (`CHAR`, `VARCHAR`, `TEXT`) and number of bytes for binary string types (`BINARY`, `VARBINARY`, `BLOB`). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

For additional information about index prefixes, see Section 13.1.13, "CREATE INDEX Syntax".

FULLTEXT Indexes

`FULLTEXT` indexes are used for full-text searches. Only the `MyISAM` storage engine supports `FULLTEXT` indexes and only for `CHAR`, `VARCHAR`, and `TEXT` columns. Indexing always takes place over the entire column and column prefix indexing is not supported. For details, see Section 12.9, "Full-Text Search Functions".

Spatial Indexes

You can create indexes on spatial data types. Only `MyISAM` supports R-tree indexes on spatial types. Other storage engines use B-trees for indexing spatial types (except for `ARCHIVE` and `NDB`, which do not support spatial type indexing).

Indexes in the MEMORY Storage Engine

The `MEMORY` storage engine uses `HASH` indexes by default, but also supports `BTREE` indexes.

8.3.5 Multiple-Column Indexes

MySQL can create composite indexes (that is, indexes on multiple columns). An index may consist of up to 16 columns. For certain data types, you can index a prefix of the column (see Section 8.3.4, "Column Indexes").

MySQL can use multiple-column indexes for queries that test all the columns in the index, or queries that test just the first column, the first two columns, the first three columns, and so on. If you specify the columns in the right order in the index definition, a single composite index can speed up several kinds of queries on the same table.

A multiple-column index can be considered a sorted array, the rows of which contain values that are created by concatenating the values of the indexed columns.

> **Note**
>
> As an alternative to a composite index, you can introduce a column that is "hashed" based on information from other columns. If this column is short, reasonably unique, and indexed, it might be faster than a "wide" index on many columns. In MySQL, it is very easy to use this extra column:

```
SELECT * FROM tbl_name
  WHERE hash_col=MD5(CONCAT(val1,val2))
  AND col1=val1 AND col2=val2;
```

Suppose that a table has the following specification:

```
CREATE TABLE test (
    id         INT NOT NULL,
    last_name  CHAR(30) NOT NULL,
    first_name CHAR(30) NOT NULL,
    PRIMARY KEY (id),
    INDEX name (last_name,first_name)
);
```

The `name` index is an index over the `last_name` and `first_name` columns. The index can be used for lookups in queries that specify values in a known range for combinations of `last_name` and `first_name` values. It can also be used for queries that specify just a `last_name` value because that column is a leftmost prefix of the index (as described later in this section). Therefore, the `name` index is used for lookups in the following queries:

```
SELECT * FROM test WHERE last_name='Widenius';

SELECT * FROM test
  WHERE last_name='Widenius' AND first_name='Michael';

SELECT * FROM test
  WHERE last_name='Widenius'
  AND (first_name='Michael' OR first_name='Monty');

SELECT * FROM test
  WHERE last_name='Widenius'
  AND first_name >='M' AND first_name < 'N';
```

However, the `name` index is *not* used for lookups in the following queries:

```
SELECT * FROM test WHERE first_name='Michael';

SELECT * FROM test
  WHERE last_name='Widenius' OR first_name='Michael';
```

Suppose that you issue the following `SELECT` statement:

```
SELECT * FROM tbl_name
  WHERE col1=val1 AND col2=val2;
```

If a multiple-column index exists on `col1` and `col2`, the appropriate rows can be fetched directly. If separate single-column indexes exist on `col1` and `col2`, the optimizer attempts to use the Index Merge optimization (see Section 8.2.1.4, "Index Merge Optimization"), or attempts to find the most restrictive index by deciding which index excludes more rows and using that index to fetch the rows.

If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimizer to look up rows. For example, if you have a three-column index on `(col1, col2, col3)`, you have indexed search capabilities on `(col1)`, `(col1, col2)`, and `(col1, col2, col3)`.

MySQL cannot use the index to perform lookups if the columns do not form a leftmost prefix of the index. Suppose that you have the `SELECT` statements shown here:

```
SELECT * FROM tbl_name WHERE col1=val1;
SELECT * FROM tbl_name WHERE col1=val1 AND col2=val2;

SELECT * FROM tbl_name WHERE col2=val2;
SELECT * FROM tbl_name WHERE col2=val2 AND col3=val3;
```

If an index exists on `(col1, col2, col3)`, only the first two queries use the index. The third and fourth queries do involve indexed columns, but `(col2)` and `(col2, col3)` are not leftmost prefixes of `(col1, col2, col3)`.

8.3.6 Verifying Index Usage

Always check whether all your queries really use the indexes that you have created in the tables. Use the `EXPLAIN` statement, as described in Section 8.8.1, "Optimizing Queries with EXPLAIN".

8.3.7 InnoDB and MyISAM Index Statistics Collection

Storage engines collect statistics about tables for use by the optimizer. Table statistics are based on value groups, where a value group is a set of rows with the same key prefix value. For optimizer purposes, an important statistic is the average value group size.

MySQL uses the average value group size in the following ways:

- To estimate how may rows must be read for each `ref` access

- To estimate how many row a partial join will produce; that is, the number of rows that an operation of this form will produce:

```
(...) JOIN tbl_name ON tbl_name.key = expr
```

As the average value group size for an index increases, the index is less useful for those two purposes because the average number of rows per lookup increases: For the index to be good for optimization purposes, it is best that each index value target a small number of rows in the table. When a given index value yields a large number of rows, the index is less useful and MySQL is less likely to use it.

The average value group size is related to table cardinality, which is the number of value groups. The `SHOW INDEX` statement displays a cardinality value based on N/S, where N is the number of rows in the table and S is the average value group size. That ratio yields an approximate number of value groups in the table.

For a join based on the `<=>` comparison operator, `NULL` is not treated differently from any other value: `NULL <=> NULL`, just as N `<=>` N for any other N.

However, for a join based on the `=` operator, `NULL` is different from non-`NULL` values: $expr1 = expr2$ is not true when $expr1$ or $expr2$ (or both) are `NULL`. This affects `ref` accesses for comparisons of the form `tbl_name.key = expr`: MySQL will not access the table if the current value of $expr$ is `NULL`, because the comparison cannot be true.

For `=` comparisons, it does not matter how many `NULL` values are in the table. For optimization purposes, the relevant value is the average size of the non-`NULL` value groups. However, MySQL does not currently enable that average size to be collected or used.

For `InnoDB` and `MyISAM` tables, you have some control over collection of table statistics by means of the `innodb_stats_method` and `myisam_stats_method` system variables, respectively. These variables have three possible values, which differ as follows:

- When the variable is set to `nulls_equal`, all `NULL` values are treated as identical (that is, they all form a single value group).

  If the `NULL` value group size is much higher than the average non-`NULL` value group size, this method skews the average value group size upward. This makes index appear to the optimizer to be less useful than it really is for joins that look for non-`NULL` values. Consequently, the `nulls_equal` method may cause the optimizer not to use the index for `ref` accesses when it should.

- When the variable is set to `nulls_unequal`, `NULL` values are not considered the same. Instead, each `NULL` value forms a separate value group of size 1.

  If you have many `NULL` values, this method skews the average value group size downward. If the average non-`NULL` value group size is large, counting `NULL` values each as a group of size 1 causes the optimizer to overestimate the value of the index for joins that look for non-`NULL` values. Consequently, the `nulls_unequal` method may cause the optimizer to use this index for `ref` lookups when other methods may be better.

- When the variable is set to `nulls_ignored`, `NULL` values are ignored.

If you tend to use many joins that use `<=>` rather than `=`, `NULL` values are not special in comparisons and one `NULL` is equal to another. In this case, `nulls_equal` is the appropriate statistics method.

The `innodb_stats_method` system variable has a global value; the `myisam_stats_method` system variable has both global and session values. Setting the global value affects statistics collection for tables from the corresponding storage engine. Setting the session value affects statistics collection only for the current client connection. This means that you can force a table's statistics to be regenerated with a given method without affecting other clients by setting the session value of `myisam_stats_method`.

To regenerate `MyISAM` table statistics, you can use any of the following methods:

- Execute `myisamchk --stats_method=method_name --analyze`

- Change the table to cause its statistics to go out of date (for example, insert a row and then delete it), and then set `myisam_stats_method` and issue an `ANALYZE TABLE` statement

Some caveats regarding the use of `innodb_stats_method` and `myisam_stats_method`:

- You can force table statistics to be collected explicitly, as just described. However, MySQL may also collect statistics automatically. For example, if during the course of executing statements for a table, some of those statements modify the table, MySQL may collect statistics. (This may occur for bulk inserts or deletes, or some `ALTER TABLE` statements, for example.) If this happens, the statistics are collected using whatever value `innodb_stats_method` or `myisam_stats_method` has at the time. Thus, if you collect statistics using one method, but the system variable is set to the other method when a table's statistics are collected automatically later, the other method will be used.

- There is no way to tell which method was used to generate statistics for a given table.

- These variables apply only to `InnoDB` and `MyISAM` tables. Other storage engines have only one method for collecting table statistics. Usually it is closer to the `nulls_equal` method.

8.3.8 Comparison of B-Tree and Hash Indexes

Understanding the B-tree and hash data structures can help predict how different queries perform on different storage engines that use these data structures in their indexes, particularly for the `MEMORY` storage engine that lets you choose B-tree or hash indexes.

B-Tree Index Characteristics

A B-tree index can be used for column comparisons in expressions that use the `=`, `>`, `>=`, `<`, `<=`, or `BETWEEN` operators. The index also can be used for `LIKE` comparisons if the argument to `LIKE` is a constant string that does not start with a wildcard character. For example, the following `SELECT` statements use indexes:

```
SELECT * FROM tbl_name WHERE key_col LIKE 'Patrick%';
SELECT * FROM tbl_name WHERE key_col LIKE 'Pat%_ck%';
```

In the first statement, only rows with `'Patrick' <= key_col < 'Patricl'` are considered. In the second statement, only rows with `'Pat' <= key_col < 'Pau'` are considered.

The following `SELECT` statements do not use indexes:

```
SELECT * FROM tbl_name WHERE key_col LIKE '%Patrick%';
SELECT * FROM tbl_name WHERE key_col LIKE other_col;
```

In the first statement, the `LIKE` value begins with a wildcard character. In the second statement, the `LIKE` value is not a constant.

If you use `... LIKE '%string%'` and `string` is longer than three characters, MySQL uses the *Turbo Boyer-Moore algorithm* to initialize the pattern for the string and then uses this pattern to perform the search more quickly.

A search using `col_name IS NULL` employs indexes if `col_name` is indexed.

Any index that does not span all `AND` levels in the `WHERE` clause is not used to optimize the query. In other words, to be able to use an index, a prefix of the index must be used in every `AND` group.

The following `WHERE` clauses use indexes:

```
... WHERE index_part1=1 AND index_part2=2 AND other_column=3

    /* index = 1 OR index = 2 */
... WHERE index=1 OR A=10 AND index=2

    /* optimized like "index_part1='hello'" */
... WHERE index_part1='hello' AND index_part3=5

    /* Can use index on index1 but not on index2 or index3 */
... WHERE index1=1 AND index2=2 OR index1=3 AND index3=3;
```

These `WHERE` clauses do *not* use indexes:

```
    /* index_part1 is not used */
... WHERE index_part2=1 AND index_part3=2

    /*  Index is not used in both parts of the WHERE clause  */
... WHERE index=1 OR A=10

    /* No index spans all rows  */
... WHERE index_part1=1 OR index_part2=10
```

Sometimes MySQL does not use an index, even if one is available. One circumstance under which this occurs is when the optimizer estimates that using the index would require MySQL to access a very large percentage of the rows in the table. (In this case, a table scan is likely to be much faster because it requires fewer seeks.) However, if such a query uses `LIMIT` to retrieve only some of the rows, MySQL uses an index anyway, because it can much more quickly find the few rows to return in the result.

Hash Index Characteristics

Hash indexes have somewhat different characteristics from those just discussed:

- They are used only for equality comparisons that use the `=` or `<=>` operators (but are *very* fast). They are not used for comparison operators such as `<` that find a range of values. Systems that rely on this type of single-value lookup are known as "key-value stores"; to use MySQL for such applications, use hash indexes wherever possible.

- The optimizer cannot use a hash index to speed up `ORDER BY` operations. (This type of index cannot be used to search for the next entry in order.)

- MySQL cannot determine approximately how many rows there are between two values (this is used by the range optimizer to decide which index to use). This may affect some queries if you change a `MyISAM` or `InnoDB` table to a hash-indexed `MEMORY` table.

- Only whole keys can be used to search for a row. (With a B-tree index, any leftmost prefix of the key can be used to find rows.)

8.4 Optimizing Database Structure

In your role as a database designer, look for the most efficient way to organize your schemas, tables, and columns. As when tuning application code, you minimize I/O, keep related items together, and plan ahead so that performance stays high as the data volume increases. Starting with an efficient database design makes it easier for team members to write high-performing application code, and makes the database likely to endure as applications evolve and are rewritten.

8.4.1 Optimizing Data Size

Design your tables to minimize their space on the disk. This can result in huge improvements by reducing the amount of data written to and read from disk. Smaller tables normally require less main memory while their contents are being actively processed during query execution. Any space reduction for table data also results in smaller indexes that can be processed faster.

MySQL supports many different storage engines (table types) and row formats. For each table, you can decide which storage and indexing method to use. Choosing the proper table format for your application can give you a big performance gain. See Chapter 14, *Storage Engines*.

You can get better performance for a table and minimize storage space by using the techniques listed here:

Table Columns

- Use the most efficient (smallest) data types possible. MySQL has many specialized types that save disk space and memory. For example, use the smaller integer types if possible to get smaller tables. `MEDIUMINT` is often a better choice than `INT` because a `MEDIUMINT` column uses 25% less space.

- Declare columns to be `NOT NULL` if possible. It makes SQL operations faster, by enabling better use of indexes and eliminating overhead for testing whether each value is `NULL`. You also save some storage space, one bit per column. If you really need `NULL` values in your tables, use them. Just avoid the default setting that allows `NULL` values in every column.

Row Format

- For `MyISAM` tables, if you do not have any variable-length columns (`VARCHAR`, `TEXT`, or `BLOB` columns), a fixed-size row format is used. This is faster but may waste some space. See Section 14.5.3, "MyISAM

Table Storage Formats". You can hint that you want to have fixed length rows even if you have `VARCHAR` columns with the `CREATE TABLE` option `ROW_FORMAT=FIXED`.

- `InnoDB` tables use a compact storage format. By default, tables are created in the compact format (`ROW_FORMAT=COMPACT`). If you wish to downgrade to older versions of MySQL, you can request the old format with `ROW_FORMAT=REDUNDANT`.

  The presence of the compact row format decreases row storage space by about 20% at the cost of increasing CPU use for some operations. If your workload is a typical one that is limited by cache hit rates and disk speed it is likely to be faster. If it is a rare case that is limited by CPU speed, it might be slower.

  The compact `InnoDB` format also changes how `CHAR` columns containing UTF-8 data are stored. With `ROW_FORMAT=REDUNDANT`, a UTF-8 `CHAR($N$)` occupies 3 × N bytes, given that the maximum length of a UTF-8 encoded character is three bytes. Many languages can be written primarily using single-byte UTF-8 characters, so a fixed storage length often wastes space. With `ROW_FORMAT=COMPACT` format, `InnoDB` allocates a variable amount of storage in the range from N to 3 × N bytes for these columns by stripping trailing spaces if necessary. The minimum storage length is kept as N bytes to facilitate in-place updates in typical cases.

Indexes

- The primary index of a table should be as short as possible. This makes identification of each row easy and efficient.

- Create only the indexes that you need to improve query performance. Indexes are good for retrieval, but slow down insert and update operations. If you access a table mostly by searching on a combination of columns, create a single composite index on them rather than a separate index for each column. The first part of the index should be the column most used. If you *always* use many columns when selecting from the table, the first column in the index should be the one with the most duplicates, to obtain better compression of the index.

- If it is very likely that a string column has a unique prefix on the first number of characters, it is better to index only this prefix, using MySQL's support for creating an index on the leftmost part of the column (see Section 13.1.13, "CREATE INDEX Syntax"). Shorter indexes are faster, not only because they require less disk space, but because they also give you more hits in the index cache, and thus fewer disk seeks. See Section 8.12.2, "Tuning Server Parameters".

Joins

- In some circumstances, it can be beneficial to split into two a table that is scanned very often. This is especially true if it is a dynamic-format table and it is possible to use a smaller static format table that can be used to find the relevant rows when scanning the table.

- Declare columns with identical information in different tables with identical data types, to speed up joins based on the corresponding columns.

- Keep column names simple, so that you can use the same name across different tables and simplify join queries. For example, in a table named `customer`, use a column name of `name` instead of `customer_name`. To make your names portable to other SQL servers, consider keeping them shorter than 18 characters.

Normalization

- Normally, try to keep all data nonredundant (observing what is referred to in database theory as *third normal form*). Instead of repeating lengthy values such as names and addresses, assign them unique

IDs, repeat these IDs as needed across multiple smaller tables, and join the tables in queries by referencing the IDs in the join clause.

- If speed is more important than disk space and the maintenance costs of keeping multiple copies of data, for example in a business intelligence scenario where you analyze all the data from large tables, you can relax the normalization rules, duplicating information or creating summary tables to gain more speed.

8.4.2 Optimizing MySQL Data Types

8.4.2.1 Optimizing for Numeric Data

- For unique IDs or other values that can be represented as either strings or numbers, prefer numeric columns to string columns. Since large numeric values can be stored in fewer bytes than the corresponding strings, it is faster and takes less memory to transfer and compare them.

- If you are using numeric data, it is faster in many cases to access information from a database (using a live connection) than to access a text file. Information in the database is likely to be stored in a more compact format than in the text file, so accessing it involves fewer disk accesses. You also save code in your application because you can avoid parsing the text file to find line and column boundaries.

8.4.2.2 Optimizing for Character and String Types

For character and string columns, follow these guidelines:

- Use binary collation order for fast comparison and sort operations, when you do not need language-specific collation features. You can use the `BINARY` operator to use binary collation within a particular query.

- When comparing values from different columns, declare those columns with the same character set and collation wherever possible, to avoid string conversions while running the query.

- For column values less than 8KB in size, use binary `VARCHAR` instead of `BLOB`. The `GROUP BY` and `ORDER BY` clauses can generate temporary tables, and these temporary tables can use the `MEMORY` storage engine if the original table does not contain any `BLOB` columns.

- If a table contains string columns such as name and address, but many queries do not retrieve those columns, consider splitting the string columns into a separate table and using join queries with a foreign key when necessary. When MySQL retrieves any value from a row, it reads a data block containing all the columns of that row (and possibly other adjacent rows). Keeping each row small, with only the most frequently used columns, allows more rows to fit in each data block. Such compact tables reduce disk I/O and memory usage for common queries.

- When you use a randomly generated value as a primary key in an `InnoDB` table, prefix it with an ascending value such as the current date and time if possible. When consecutive primary values are physically stored near each other, `InnoDB` can insert and retrieve them faster.

- See Section 8.4.2.1, "Optimizing for Numeric Data" for reasons why a numeric column is usually preferable to an equivalent string column.

8.4.2.3 Optimizing for BLOB Types

- When storing a large blob containing textual data, consider compressing it first. Do not use this technique when the entire table is compressed by `InnoDB` or `MyISAM`.

- For a table with several columns, to reduce memory requirements for queries that do not use the BLOB column, consider splitting the BLOB column into a separate table and referencing it with a join query when needed.

- Since the performance requirements to retrieve and display a BLOB value might be very different from other data types, you could put the BLOB-specific table on a different storage device or even a separate database instance. For example, to retrieve a BLOB might require a large sequential disk read that is better suited to a traditional hard drive than to an SSD device.

- See Section 8.4.2.2, "Optimizing for Character and String Types" for reasons why a binary `VARCHAR` column is sometimes preferable to an equivalent BLOB column.

- Rather than testing for equality against a very long text string, you can store a hash of the column value in a separate column, index that column, and test the hashed value in queries. (Use the `MD5()` or `CRC32()` function to produce the hash value.) Since hash functions can produce duplicate results for different inputs, you still include a clause `AND blob_column = long_string_value` in the query to guard against false matches; the performance benefit comes from the smaller, easily scanned index for the hashed values.

8.4.2.4 Using PROCEDURE ANALYSE

```
ANALYSE([max_elements[,max_memory]])
```

`ANALYSE()` examines the result from a query and returns an analysis of the results that suggests optimal data types for each column that may help reduce table sizes. To obtain this analysis, append `PROCEDURE ANALYSE` to the end of a `SELECT` statement:

```
SELECT ... FROM ... WHERE ... PROCEDURE ANALYSE([max_elements,[max_memory]])
```

For example:

```
SELECT col1, col2 FROM table1 PROCEDURE ANALYSE(10, 2000);
```

The results show some statistics for the values returned by the query, and propose an optimal data type for the columns. This can be helpful for checking your existing tables, or after importing new data. You may need to try different settings for the arguments so that `PROCEDURE ANALYSE()` does not suggest the `ENUM` data type when it is not appropriate.

The arguments are optional and are used as follows:

- `max_elements` (default 256) is the maximum number of distinct values that `ANALYSE()` notices per column. This is used by `ANALYSE()` to check whether the optimal data type should be of type `ENUM`; if there are more than `max_elements` distinct values, then `ENUM` is not a suggested type.

- `max_memory` (default 8192) is the maximum amount of memory that `ANALYSE()` should allocate per column while trying to find all distinct values.

A `PROCEDURE` clause is not permitted in a `UNION` statement.

8.4.3 Optimizing for Many Tables

Some techniques for keeping individual queries fast involve splitting data across many tables. When the number of tables runs into the thousands or even millions, the overhead of dealing with all these tables becomes a new performance consideration.

8.4.3.1 How MySQL Opens and Closes Tables

When you execute a `mysqladmin status` command, you should see something like this:

```
Uptime: 426 Running threads: 1 Questions: 11082
Reloads: 1 Open tables: 12
```

The `Open tables` value of 12 can be somewhat puzzling if you have only six tables.

MySQL is multi-threaded, so there may be many clients issuing queries for a given table simultaneously. To minimize the problem with multiple client sessions having different states on the same table, the table is opened independently by each concurrent session. This uses additional memory but normally increases performance. With `MyISAM` tables, one extra file descriptor is required for the data file for each client that has the table open. (By contrast, the index file descriptor is shared between all sessions.)

> **Note**
>
> `table_open_cache` was known as `table_cache` in MySQL 5.1.2 and earlier.

The `table_open_cache` and `max_connections` system variables affect the maximum number of files the server keeps open. If you increase one or both of these values, you may run up against a limit imposed by your operating system on the per-process number of open file descriptors. Many operating systems permit you to increase the open-files limit, although the method varies widely from system to system. Consult your operating system documentation to determine whether it is possible to increase the limit and how to do so.

`table_open_cache` is related to `max_connections`. For example, for 200 concurrent running connections, you should have a table cache size of at least $200 * N$, where N is the maximum number of tables per join in any of the queries which you execute. You must also reserve some extra file descriptors for temporary tables and files.

Make sure that your operating system can handle the number of open file descriptors implied by the `table_open_cache` setting. If `table_open_cache` is set too high, MySQL may run out of file descriptors and refuse connections, fail to perform queries, and be very unreliable.

You should also take into account the fact that the `MyISAM` storage engine needs two file descriptors for each unique open table. For a partitioned `MyISAM` table, two file descriptors are required for each partition of the opened table. (Note further that when `MyISAM` opens a partitioned table, it opens every partition of this table, whether or not a given partition is actually used. See MyISAM and partition file descriptor usage.) You can increase the number of file descriptors available to MySQL using the `--open-files-limit` startup option to `mysqld`. See Section B.5.2.18, "File Not Found and Similar Errors".

The cache of open tables is kept at a level of `table_open_cache` entries. The default value is 64; this can be changed with the `--table_open_cache` option to `mysqld`. Note that MySQL may temporarily open more tables than this to execute queries.

MySQL closes an unused table and removes it from the table cache under the following circumstances:

* When the cache is full and a thread tries to open a table that is not in the cache.

* When the cache contains more than `table_open_cache` entries and a table in the cache is no longer being used by any threads.

* When a table flushing operation occurs. This happens when someone issues a `FLUSH TABLES` statement or executes a `mysqladmin flush-tables` or `mysqladmin refresh` command.

When the table cache fills up, the server uses the following procedure to locate a cache entry to use:

* Tables that are not currently in use are released, beginning with the table least recently used.

- If a new table needs to be opened, but the cache is full and no tables can be released, the cache is temporarily extended as necessary. When the cache is in a temporarily extended state and a table goes from a used to unused state, the table is closed and released from the cache.

A `MyISAM` table is opened for each concurrent access. This means the table needs to be opened twice if two threads access the same table or if a thread accesses the table twice in the same query (for example, by joining the table to itself). Each concurrent open requires an entry in the table cache. The first open of any `MyISAM` table takes two file descriptors: one for the data file and one for the index file. Each additional use of the table takes only one file descriptor for the data file. The index file descriptor is shared among all threads.

If you are opening a table with the `HANDLER` *tbl_name* `OPEN` statement, a dedicated table object is allocated for the thread. This table object is not shared by other threads and is not closed until the thread calls `HANDLER` *tbl_name* `CLOSE` or the thread terminates. When this happens, the table is put back in the table cache (if the cache is not full). See Section 13.2.4, "HANDLER Syntax".

You can determine whether your table cache is too small by checking the `mysqld` status variable `Opened_tables`, which indicates the number of table-opening operations since the server started:

```
mysql> SHOW GLOBAL STATUS LIKE 'Opened_tables';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Opened_tables | 2741  |
+---------------+-------+
```

If the value is very large or increases rapidly, even when you have not issued many `FLUSH TABLES` statements, you should increase the table cache size. See Section 5.1.4, "Server System Variables", and Section 5.1.6, "Server Status Variables".

8.4.3.2 Disadvantages of Creating Many Tables in the Same Database

If you have many `MyISAM` tables in the same database directory, open, close, and create operations are slow. If you execute `SELECT` statements on many different tables, there is a little overhead when the table cache is full, because for every table that has to be opened, another must be closed. You can reduce this overhead by increasing the number of entries permitted in the table cache.

8.4.4 Internal Temporary Table Use in MySQL

In some cases, the server creates internal temporary tables while processing statements. Users have no direct control over when this occurs.

The server creates temporary tables under conditions such as these:

- Evaluation of `UNION` statements.

- Evaluation of some views, such those that use the `TEMPTABLE` algorithm, `UNION`, or aggregation.

- Evaluation of statements that contain an `ORDER BY` clause and a different `GROUP BY` clause, or for which the `ORDER BY` or `GROUP BY` contains columns from tables other than the first table in the join queue.

- Evaluation of `DISTINCT` combined with `ORDER BY` may require a temporary table.

- For queries that use the `SQL_SMALL_RESULT` option, MySQL uses an in-memory temporary table, unless the query also contains elements (described later) that require on-disk storage.

- Evaluation of multiple-table `UPDATE` statements.

- Evaluation of `GROUP_CONCAT()` or `COUNT(DISTINCT)` expressions.

To determine whether a statement requires a temporary table, use `EXPLAIN` and check the `Extra` column to see whether it says `Using temporary` (see Section 8.8.1, "Optimizing Queries with EXPLAIN").

When the server creates an internal temporary table (either in memory or on disk), it increments the `Created_tmp_tables` status variable. If the server creates the table on disk (either initially or by converting an in-memory table) it increments the `Created_tmp_disk_tables` status variable.

Some query conditions prevent the use of an in-memory temporary table, in which case the server uses an on-disk table instead:

- Presence of a `BLOB` or `TEXT` column in the table

- Presence of any string column in a `GROUP BY` or `DISTINCT` clause larger than 512 bytes

- Presence of any string column with a maximum length larger than 512 (bytes for binary strings, characters for nonbinary strings) in the `SELECT` list, if `UNION` or `UNION ALL` is used

- The `SHOW COLUMNS` and `DESCRIBE` statements use `BLOB` as the type for some columns, thus the temporary table used for the results is an on-disk table.

Storage Engines Used for Temporary Tables

An internal temporary table can be held in memory and processed by the `MEMORY` storage engine, or stored on disk and processed by the `MyISAM` storage engine.

If an internal temporary table is created as an in-memory table but becomes too large, MySQL automatically converts it to an on-disk table. The maximum size for in-memory temporary tables is the minimum of the `tmp_table_size` and `max_heap_table_size` values. This differs from `MEMORY` tables explicitly created with `CREATE TABLE`: For such tables, only the `max_heap_table_size` system variable determines how large the table is permitted to grow and there is no conversion to on-disk format.

Temporary Table Storage Format

Internal temporary tables are stored using fixed-length row format, whether managed by the `MEMORY` or `MyISAM` storage engine.

8.5 Optimizing for MyISAM Tables

The `MyISAM` storage engine performs best with read-mostly data or with low-concurrency operations, because table locks limit the ability to perform simultaneous updates.

8.5.1 Optimizing MyISAM Queries

Some general tips for speeding up queries on `MyISAM` tables:

- To help MySQL better optimize queries, use `ANALYZE TABLE` or run `myisamchk --analyze` on a table after it has been loaded with data. This updates a value for each index part that indicates the average number of rows that have the same value. (For unique indexes, this is always 1.) MySQL uses this to decide which index to choose when you join two tables based on a nonconstant expression. You can check the result from the table analysis by using `SHOW INDEX FROM` *tbl_name* and examining the `Cardinality` value. `myisamchk --description --verbose` shows index distribution information.

- To sort an index and data according to an index, use `myisamchk --sort-index --sort-records=1` (assuming that you want to sort on index 1). This is a good way to make queries faster if

you have a unique index from which you want to read all rows in order according to the index. The first time you sort a large table this way, it may take a long time.

- Try to avoid complex `SELECT` queries on `MyISAM` tables that are updated frequently, to avoid problems with table locking that occur due to contention between readers and writers.

- `MyISAM` supports concurrent inserts: If a table has no free blocks in the middle of the data file, you can `INSERT` new rows into it at the same time that other threads are reading from the table. If it is important to be able to do this, consider using the table in ways that avoid deleting rows. Another possibility is to run `OPTIMIZE TABLE` to defragment the table after you have deleted a lot of rows from it. This behavior is altered by setting the `concurrent_insert` variable. You can force new rows to be appended (and therefore permit concurrent inserts), even in tables that have deleted rows. See Section 8.11.3, "Concurrent Inserts".

- For `MyISAM` tables that change frequently, try to avoid all variable-length columns (`VARCHAR`, `BLOB`, and `TEXT`). The table uses dynamic row format if it includes even a single variable-length column. See Chapter 14, *Storage Engines*.

- It is normally not useful to split a table into different tables just because the rows become large. In accessing a row, the biggest performance hit is the disk seek needed to find the first byte of the row. After finding the data, most modern disks can read the entire row fast enough for most applications. The only cases where splitting up a table makes an appreciable difference is if it is a `MyISAM` table using dynamic row format that you can change to a fixed row size, or if you very often need to scan the table but do not need most of the columns. See Chapter 14, *Storage Engines*.

- Use `ALTER TABLE ... ORDER BY expr1, expr2, ...` if you usually retrieve rows in `expr1, expr2, ...` order. By using this option after extensive changes to the table, you may be able to get higher performance.

- If you often need to calculate results such as counts based on information from a lot of rows, it may be preferable to introduce a new table and update the counter in real time. An update of the following form is very fast:

```
UPDATE tbl_name SET count_col=count_col+1 WHERE key_col=constant;
```

This is very important when you use a MySQL storage engine such as `MyISAM` that has only table-level locking (multiple readers with single writers). This also gives better performance with most database systems, because the row locking manager in this case has less to do.

- Use `INSERT DELAYED` when you do not need to know when your data is written. This reduces the overall insertion impact because many rows can be written with a single disk write.

- Use `INSERT LOW_PRIORITY` when you want to give `SELECT` statements higher priority than your inserts.

  Use `SELECT HIGH_PRIORITY` to get retrievals that jump the queue. That is, the `SELECT` is executed even if there is another client waiting to do a write.

  `LOW_PRIORITY` and `HIGH_PRIORITY` have an effect only for storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- Use `OPTIMIZE TABLE` periodically to avoid fragmentation with dynamic-format `MyISAM` tables. See Section 14.5.3, "MyISAM Table Storage Formats".

- Declaring a `MyISAM` table with the `DELAY_KEY_WRITE=1` table option makes index updates faster because they are not flushed to disk until the table is closed. The downside is that if something kills the

server while such a table is open, you must ensure that the table is okay by running the server with the `--myisam-recover` option, or by running `myisamchk` before restarting the server. (However, even in this case, you should not lose anything by using `DELAY_KEY_WRITE`, because the key information can always be generated from the data rows.)

- Strings are automatically prefix- and end-space compressed in `MyISAM` indexes. See Section 13.1.13, "CREATE INDEX Syntax".

- You can increase performance by caching queries or answers in your application and then executing many inserts or updates together. Locking the table during this operation ensures that the index cache is only flushed once after all updates. You can also take advantage of MySQL's query cache to achieve similar results; see Section 8.10.3, "The MySQL Query Cache".

8.5.2 Bulk Data Loading for MyISAM Tables

These performance tips supplement the general guidelines for fast inserts in Section 8.2.2.1, "Speed of INSERT Statements".

- To improve performance when multiple clients insert a lot of rows, use the `INSERT DELAYED` statement. See Section 13.2.5.2, "INSERT DELAYED Syntax". This technique works for `MyISAM` and some other storage engines, but not `InnoDB`.

- For a `MyISAM` table, you can use concurrent inserts to add rows at the same time that `SELECT` statements are running, if there are no deleted rows in middle of the data file. See Section 8.11.3, "Concurrent Inserts".

- With some extra work, it is possible to make `LOAD DATA INFILE` run even faster for a `MyISAM` table when the table has many indexes. Use the following procedure:

  1. Execute a `FLUSH TABLES` statement or a `mysqladmin flush-tables` command.

  2. Use `myisamchk --keys-used=0 -rq /path/to/db/tbl_name` to remove all use of indexes for the table.

  3. Insert data into the table with `LOAD DATA INFILE`. This does not update any indexes and therefore is very fast.

  4. If you intend only to read from the table in the future, use `myisampack` to compress it. See Section 14.5.3.3, "Compressed Table Characteristics".

  5. Re-create the indexes with `myisamchk -rq /path/to/db/tbl_name`. This creates the index tree in memory before writing it to disk, which is much faster than updating the index during `LOAD DATA INFILE` because it avoids lots of disk seeks. The resulting index tree is also perfectly balanced.

  6. Execute a `FLUSH TABLES` statement or a `mysqladmin flush-tables` command.

`LOAD DATA INFILE` performs the preceding optimization automatically if the `MyISAM` table into which you insert data is empty. The main difference between automatic optimization and using the procedure explicitly is that you can let `myisamchk` allocate much more temporary memory for the index creation than you might want the server to allocate for index re-creation when it executes the `LOAD DATA INFILE` statement.

You can also disable or enable the nonunique indexes for a `MyISAM` table by using the following statements rather than `myisamchk`. If you use these statements, you can skip the `FLUSH TABLE` operations:

```
ALTER TABLE tbl_name DISABLE KEYS;
ALTER TABLE tbl_name ENABLE KEYS;
```

- To speed up `INSERT` operations that are performed with multiple statements for nontransactional tables, lock your tables:

```
LOCK TABLES a WRITE;
INSERT INTO a VALUES (1,23),(2,34),(4,33);
INSERT INTO a VALUES (8,26),(6,29);
...
UNLOCK TABLES;
```

This benefits performance because the index buffer is flushed to disk only once, after all `INSERT` statements have completed. Normally, there would be as many index buffer flushes as there are `INSERT` statements. Explicit locking statements are not needed if you can insert all rows with a single `INSERT`.

Locking also lowers the total time for multiple-connection tests, although the maximum wait time for individual connections might go up because they wait for locks. Suppose that five clients attempt to perform inserts simultaneously as follows:

- Connection 1 does 1000 inserts

- Connections 2, 3, and 4 do 1 insert

- Connection 5 does 1000 inserts

If you do not use locking, connections 2, 3, and 4 finish before 1 and 5. If you use locking, connections 2, 3, and 4 probably do not finish before 1 or 5, but the total time should be about 40% faster.

`INSERT`, `UPDATE`, and `DELETE` operations are very fast in MySQL, but you can obtain better overall performance by adding locks around everything that does more than about five successive inserts or updates. If you do very many successive inserts, you could do a `LOCK TABLES` followed by an `UNLOCK TABLES` once in a while (each 1,000 rows or so) to permit other threads to access table. This would still result in a nice performance gain.

`INSERT` is still much slower for loading data than `LOAD DATA INFILE`, even when using the strategies just outlined.

- To increase performance for `MyISAM` tables, for both `LOAD DATA INFILE` and `INSERT`, enlarge the key cache by increasing the `key_buffer_size` system variable. See Section 8.12.2, "Tuning Server Parameters".

8.5.3 Speed of REPAIR TABLE Statements

`REPAIR TABLE` for `MyISAM` tables is similar to using `myisamchk` for repair operations, and some of the same performance optimizations apply:

- `myisamchk` has variables that control memory allocation. You may be able to its improve performance by setting these variables, as described in Section 4.6.3.6, "myisamchk Memory Usage".

- For `REPAIR TABLE`, the same principle applies, but because the repair is done by the server, you set server system variables instead of `myisamchk` variables. Also, In addition to setting memory-allocation variables, increasing the `myisam_max_sort_file_size` system variable increases the likelihood that the repair will use the faster filesort method and avoid the slower repair by key cache method. Set the variable to the maximum file size for your system, after checking to be sure that there is enough free

space to hold a copy of the table files. The free space must be available in the file system containing the original table files.

Suppose that a `myisamchk` table-repair operation is done using the following options to set its memory-allocation variables:

```
--key_buffer_size=128M --myisam_sort_buffer_size=256M
--read_buffer_size=64M --write_buffer_size=64M
```

Some of those `myisamchk` variables correspond to server system variables:

`myisamchk` Variable	System Variable
`key_buffer_size`	`key_buffer_size`
`myisam_sort_buffer_size`	`myisam_sort_buffer_size`
`read_buffer_size`	`read_buffer_size`
`write_buffer_size`	none

Each of the server system variables can be set at runtime, and some of them (`myisam_sort_buffer_size`, `read_buffer_size`) have a session value in addition to a global value. Setting a session value limits the effect of the change to your current session and does not affect other users. Changing a global-only variable (`key_buffer_size`, `myisam_max_sort_file_size`) affects other users as well. For `key_buffer_size`, you must take into account that the buffer is shared with those users. For example, if you set the `myisamchk key_buffer_size` variable to 128MB, you could set the corresponding `key_buffer_size` system variable larger than that (if it is not already set larger), to permit key buffer use by activity in other sessions. However, changing the global key buffer size invalidates the buffer, causing increased disk I/O and slowdown for other sessions. An alternative that avoids this problem is to use a separate key cache, assign to it the indexes from the table to be repaired, and deallocate it when the repair is complete. See Section 8.10.1.2, "Multiple Key Caches".

Based on the preceding remarks, a `REPAIR TABLE` operation can be done as follows to use settings similar to the `myisamchk` command. Here a separate 128MB key buffer is allocated and the file system is assumed to permit a file size of at least 100GB.

```
SET SESSION myisam_sort_buffer_size = 256*1024*1024;
SET SESSION read_buffer_size = 64*1024*1024;
SET GLOBAL myisam_max_sort_file_size = 100*1024*1024*1024;
SET GLOBAL repair_cache.key_buffer_size = 128*1024*1024;
CACHE INDEX tbl_name IN repair_cache;
LOAD INDEX INTO CACHE tbl_name;
REPAIR TABLE tbl_name ;
SET GLOBAL repair_cache.key_buffer_size = 0;
```

If you intend to change a global variable but want to do so only for the duration of a `REPAIR TABLE` operation to minimally affect other users, save its value in a user variable and restore it afterward. For example:

```
SET @old_myisam_sort_buffer_size = @@global.myisam_max_sort_file_size;
SET GLOBAL myisam_max_sort_file_size = 100*1024*1024*1024;
REPAIR TABLE tbl_name ;
SET GLOBAL myisam_max_sort_file_size = @old_myisam_max_sort_file_size;
```

The system variables that affect `REPAIR TABLE` can be set globally at server startup if you want the values to be in effect by default. For example, add these lines to the server `my.cnf` file:

```
[mysqld]
```

```
myisam_sort_buffer_size=256M
key_buffer_size=1G
myisam_max_sort_file_size=100G
```

These settings do not include `read_buffer_size`. Setting `read_buffer_size` globally to a large value does so for all sessions and can cause performance to suffer due to excessive memory allocation for a server with many simultaneous sessions.

8.6 Optimizing for InnoDB Tables

This section explains how to optimize database operations for `InnoDB` tables.

8.6.1 Optimizing Storage Layout for InnoDB Tables

- Once your data reaches a stable size, or a growing table has increased by tens or some hundreds of megabytes, consider using the `OPTIMIZE TABLE` statement to reorganize the table and compact any wasted space. The reorganized tables require less disk I/O to perform full table scans. This is a straightforward technique that can improve performance when other techniques such as improving index usage or tuning application code are not practical.

  `OPTIMIZE TABLE` copies the data part of the table and rebuilds the indexes. The benefits come from improved packing of data within indexes, and reduced fragmentation within the tablespaces and on disk. The benefits vary depending on the data in each table. You may find that there are significant gains for some and not for others, or that the gains decrease over time until you next optimize the table. This operation can be slow if the table is large or if the indexes being rebuilt do not fit into the buffer pool. The first run after adding a lot of data to a table is often much slower than later runs.

- In `InnoDB`, having a long `PRIMARY KEY` (either a single column with a lengthy value, or several columns that form a long composite value) wastes a lot of disk space. The primary key value for a row is duplicated in all the secondary index records that point to the same row. (See Section 14.6.3.2, "InnoDB Table and Index Structures".) Create an `AUTO_INCREMENT` column as the primary key if your primary key is long, or index a prefix of a long `VARCHAR` column instead of the entire column.

- Use the `VARCHAR` data type instead of `CHAR` to store variable-length strings or for columns with many `NULL` values. A `CHAR(N)` column always takes N characters to store data, even if the string is shorter or its value is `NULL`. Smaller tables fit better in the buffer pool and reduce disk I/O.

  When using `COMPACT` row format (the default `InnoDB` format) and variable-length character sets, such as `utf8` or `sjis`, `CHAR(N)` columns occupy a variable amount of space, but still at least N bytes.

- For tables that are big, or contain lots of repetitive text or numeric data, consider using `COMPRESSED` row format. Less disk I/O is required to bring data into the buffer pool, or to perform full table scans. Before making a permanent decision, measure the amount of compression you can achieve by using `COMPRESSED` versus `COMPACT` row format.

8.6.2 Optimizing InnoDB Transaction Management

To optimize `InnoDB` transaction processing, find the ideal balance between the performance overhead of transactional features and the workload of your server. For example, an application might encounter performance issues if it commits thousands of times per second, and different performance issues if it commits only every 2-3 hours.

- The default MySQL setting `AUTOCOMMIT=1` can impose performance limitations on a busy database server. Where practical, wrap several related data change operations into a single transaction, by issuing `SET AUTOCOMMIT=0` or a `START TRANSACTION` statement, followed by a `COMMIT` statement after making all the changes.

`InnoDB` must flush the log to disk at each transaction commit if that transaction made modifications to the database. When each change is followed by a commit (as with the default autocommit setting), the I/O throughput of the storage device puts a cap on the number of potential operations per second.

- Avoid performing rollbacks after inserting, updating, or deleting huge numbers of rows. If a big transaction is slowing down server performance, rolling it back can make the problem worse, potentially taking several times as long to perform as the original data change operations. Killing the database process does not help, because the rollback starts again on server startup.

  To minimize the chance of this issue occurring:

  - Increase the size of the buffer pool so that all the data change changes can be cached rather than immediately written to disk.

  - Set `innodb_change_buffering=all` so that update and delete operations are buffered in addition to inserts.

  - Consider issuing `COMMIT` statements periodically during the big data change operation, possibly breaking a single delete or update into multiple statements that operate on smaller numbers of rows.

  To get rid of a runaway rollback once it occurs, increase the buffer pool so that the rollback becomes CPU-bound and runs fast, or kill the server and restart with `innodb_force_recovery=3`, as explained in Section 14.6.10.1, "The InnoDB Recovery Process".

- If you can afford the loss of some of the latest committed transactions if a crash occurs, you can set the `innodb_flush_log_at_trx_commit` parameter to 0. `InnoDB` tries to flush the log once per second anyway, although the flush is not guaranteed.

- When rows are modified or deleted, the rows and associated undo logs are not physically removed immediately, or even immediately after the transaction commits. The old data is preserved until transactions that started earlier or concurrently are finished, so that those transactions can access the previous state of modified or deleted rows. Thus, a long-running transaction can prevent `InnoDB` from purging data that was changed by a different transaction.

- When rows are modified or deleted within a long-running transaction, other transactions using the `READ COMMITTED` and `REPEATABLE READ` isolation levels have to do more work to reconstruct the older data if they read those same rows.

- When a long-running transaction modifies a table, queries against that table from other transactions do not make use of the covering index technique. Queries that normally could retrieve all the result columns from a secondary index, instead look up the appropriate values from the table data.

8.6.3 Optimizing InnoDB Redo Logging

Consider the following guidelines for optimizing redo logging:

- Make your redo log files big, even as big as the buffer pool. When `InnoDB` has written the redo log files full, it must write the modified contents of the buffer pool to disk in a checkpoint. Small redo log files cause many unnecessary disk writes. Although historically big redo log files caused lengthy recovery times, recovery is now much faster and you can confidently use large redo log files.

  The size and number of redo log files are configured using the `innodb_log_file_size` and `innodb_log_files_in_group` configuration options. For information about modifying an existing redo log file configuration, see Section 14.6.5.2, "Changing the Number or Size of InnoDB Redo Log Files".

- Consider increasing the size of the log_buffer. A large log buffer enables large transactions to run without a need to write the log to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, making the log buffer larger saves disk I/O. Log buffer size is configured using the `innodb_log_buffer_size` configuration option.

8.6.4 Bulk Data Loading for InnoDB Tables

These performance tips supplement the general guidelines for fast inserts in Section 8.2.2.1, "Speed of INSERT Statements".

- When importing data into `InnoDB`, turn off autocommit mode, because it performs a log flush to disk for every insert. To disable autocommit during your import operation, surround it with `SET autocommit` and `COMMIT` statements:

```
SET autocommit=0;
... SQL import statements ...
COMMIT;
```

  The `mysqldump` option `--opt` creates dump files that are fast to import into an `InnoDB` table, even without wrapping them with the `SET autocommit` and `COMMIT` statements.

- If you have `UNIQUE` constraints on secondary keys, you can speed up table imports by temporarily turning off the uniqueness checks during the import session:

```
SET unique_checks=0;
... SQL import statements ...
SET unique_checks=1;
```

  For big tables, this saves a lot of disk I/O because `InnoDB` can use its change buffer to write secondary index records in a batch. Be certain that the data contains no duplicate keys.

- If you have `FOREIGN KEY` constraints in your tables, you can speed up table imports by turning off the foreign key checks for the duration of the import session:

```
SET foreign_key_checks=0;
... SQL import statements ...
SET foreign_key_checks=1;
```

  For big tables, this can save a lot of disk I/O.

- Use the multiple-row `INSERT` syntax to reduce communication overhead between the client and the server if you need to insert many rows:

```
INSERT INTO yourtable VALUES (1,2), (5,5), ...;
```

  This tip is valid for inserts into any table, not just `InnoDB` tables.

- When doing bulk inserts into tables with auto-increment columns, set `innodb_autoinc_lock_mode` to 2 instead of the default value 1. See Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB" for details.

8.6.5 Optimizing InnoDB Queries

To tune queries for `InnoDB` tables, create an appropriate set of indexes on each table. See Section 8.3.1, "How MySQL Uses Indexes" for details. Follow these guidelines for `InnoDB` indexes:

- Because each `InnoDB` table has a primary key (whether you request one or not), specify a set of primary key columns for each table, columns that are used in the most important and time-critical queries.

- Do not specify too many or too long columns in the primary key, because these column values are duplicated in each secondary index. When an index contains unnecessary data, the I/O to read this data and memory to cache it reduce the performance and scalability of the server.

- Do not create a separate secondary index for each column, because each query can only make use of one index. Indexes on rarely tested columns or columns with only a few different values might not be helpful for any queries. If you have many queries for the same table, testing different combinations of columns, try to create a small number of concatenated indexes rather than a large number of single-column indexes. If an index contains all the columns needed for the result set (known as a covering index), the query might be able to avoid reading the table data at all.

- If an indexed column cannot contain any `NULL` values, declare it as `NOT NULL` when you create the table. The optimizer can better determine which index is most effective to use for a query, when it knows whether each column contains `NULL` values.

- If you often have recurring queries for tables that are not updated frequently, enable the query cache:

```
[mysqld]
query_cache_type = 1
query_cache_size = 10M
```

8.6.6 Optimizing InnoDB DDL Operations

- "Fast index creation" makes it faster in some cases to drop an index before loading data into a table, then re-create the index after loading the data.

- Use `TRUNCATE TABLE` to empty a table, not `DELETE FROM` *tbl_name*. Foreign key constraints can make a `TRUNCATE` statement work like a regular `DELETE` statement, in which case a sequence of commands like `DROP TABLE` and `CREATE TABLE` might be fastest.

- Because the primary key is integral to the storage layout of each `InnoDB` table, and changing the definition of the primary key involves reorganizing the whole table, always set up the primary key as part of the `CREATE TABLE` statement, and plan ahead so that you do not need to `ALTER` or `DROP` the primary key afterward.

8.6.7 Optimizing InnoDB Disk I/O

If you follow the best practices for database design and the tuning techniques for SQL operations, but your database is still slowed by heavy disk I/O activity, explore these low-level techniques related to disk I/O. If the Unix `top` tool or the Windows Task Manager shows that the CPU usage percentage with your workload is less than 70%, your workload is probably disk-bound.

- When table data is cached in the `InnoDB` buffer pool, it can be accessed repeatedly by queries without requiring any disk I/O. Specify the size of the buffer pool with the `innodb_buffer_pool_size` option. This memory area is important enough that busy databases often specify a size approximately 80% of the amount of physical memory. For more information, see Section 8.10.2, "The InnoDB Buffer Pool".

- In some versions of GNU/Linux and Unix, flushing files to disk with the Unix `fsync()` call (which `InnoDB` uses by default) and similar methods is surprisingly slow. If database write performance is an issue, conduct benchmarks with the `innodb_flush_method` parameter set to `O_DSYNC`.

- When using the `InnoDB` storage engine on Solaris 10 for x86_64 architecture (AMD Opteron), use direct I/O for `InnoDB`-related files, to avoid degradation of `InnoDB` performance. To use direct I/O for an

entire UFS file system used for storing `InnoDB`-related files, mount it with the `forcedirectio` option; see `mount_ufs(1M)`. (The default on Solaris 10/x86_64 is *not* to use this option.) Alternatively, as of MySQL 5.1.18, to apply direct I/O only to `InnoDB` file operations rather than the whole file system, set `innodb_flush_method = O_DIRECT`. With this setting, `InnoDB` calls `directio()` instead of `fcntl()` for I/O to data files (not for I/O to log files).

- When using the `InnoDB` storage engine with a large `innodb_buffer_pool_size` value on any release of Solaris 2.6 and up and any platform (sparc/x86/x64/amd64), conduct benchmarks with `InnoDB` data files and log files on raw devices or on a separate direct I/O UFS file system, using the `forcedirectio` mount option as described earlier. (It is necessary to use the mount option rather than setting `innodb_flush_method` if you want direct I/O for the log files.) Users of the Veritas file system VxFS should use the `convosync=direct` mount option.

  Do not place other MySQL data files, such as those for `MyISAM` tables, on a direct I/O file system. Executables or libraries *must not* be placed on a direct I/O file system.

- If you have additional storage devices available to set up a RAID configuration or symbolic links to different disks, Section 8.12.3, "Optimizing Disk I/O" for additional low-level I/O tips.

- If throughput drops periodically because of `InnoDB` checkpoint operations, consider increasing the value of the `innodb_io_capacity` configuration option. Higher values cause more frequent flushing, avoiding the backlog of work that can cause dips in throughput.

- If the system is not falling behind with `InnoDB` flushing operations, consider lowering the value of the `innodb_io_capacity` configuration option. Typically, you keep this option value as low as practical, but not so low that it causes periodic drops in throughput as mentioned in the preceding bullet. In a typical scenario where you could lower the option value, you might see a combination like this in the output from `SHOW ENGINE INNODB STATUS`:

  - History list length low, below a few thousand.

  - Insert buffer merges close to rows inserted.

  - Modified pages in buffer pool consistently well below `innodb_max_dirty_pages_pct` of the buffer pool. (Measure at a time when the server is not doing bulk inserts; it is normal during bulk inserts for the modified pages percentage to rise significantly.)

  - `Log sequence number - Last checkpoint` is at less than 7/8 or ideally less than 6/8 of the total size of the `InnoDB` log files.

- Other `InnoDB` configuration options to consider when tuning I/O-bound workloads include `innodb_adaptive_flushing`, `innodb_change_buffering`, `innodb_log_buffer_size`, `innodb_log_file_size`, `innodb_max_dirty_pages_pct`, `innodb_max_purge_lag`, `innodb_open_files`, `innodb_random_read_ahead`, `innodb_read_ahead_threshold`, `innodb_read_io_threads`, `innodb_write_io_threads`, and `sync_binlog`.

8.6.8 Optimizing InnoDB for Systems with Many Tables

- `InnoDB` computes index cardinality values for a table the first time that table is accessed after startup, instead of storing such values in the table. This step can take significant time on systems that partition the data into many tables. Since this overhead only applies to the initial table open operation, to "warm up" a table for later use, access it immediately after startup by issuing a statement such as `SELECT 1 FROM tbl_name LIMIT 1`.

8.7 Optimizing for MEMORY Tables

Consider using `MEMORY` tables for noncritical data that is accessed often, and is read-only or rarely updated. Benchmark your application against equivalent `InnoDB` or `MyISAM` tables under a realistic workload, to confirm that any additional performance is worth the risk of losing data, or the overhead of copying data from a disk-based table at application start.

For best performance with `MEMORY` tables, examine the kinds of queries against each table, and specify the type to use for each associated index, either a B-tree index or a hash index. On the `CREATE INDEX` statement, use the clause `USING BTREE` or `USING HASH`. B-tree indexes are fast for queries that do greater-than or less-than comparisons through operators such as `>` or `BETWEEN`. Hash indexes are only fast for queries that look up single values through the `=` operator, or a restricted set of values through the `IN` operator. For why `USING BTREE` is often a better choice than the default `USING HASH`, see Section 8.2.1.17, "How to Avoid Full Table Scans". For implementation details of the different types of `MEMORY` indexes, see Section 8.3.8, "Comparison of B-Tree and Hash Indexes".

8.8 Understanding the Query Execution Plan

Depending on the details of your tables, columns, indexes, and the conditions in your `WHERE` clause, the MySQL optimizer considers many techniques to efficiently perform the lookups involved in an SQL query. A query on a huge table can be performed without reading all the rows; a join involving several tables can be performed without comparing every combination of rows. The set of operations that the optimizer chooses to perform the most efficient query is called the "query execution plan", also known as the `EXPLAIN` plan. Your goals are to recognize the aspects of the `EXPLAIN` plan that indicate a query is optimized well, and to learn the SQL syntax and indexing techniques to improve the plan if you see some inefficient operations.

8.8.1 Optimizing Queries with EXPLAIN

The `EXPLAIN` statement can be used to obtain information about how MySQL executes a statement:

- When you precede a `SELECT` statement with the keyword `EXPLAIN`, MySQL displays information from the optimizer about the statement execution plan. That is, MySQL explains how it would process the statement, including information about how tables are joined and in which order. For information about using `EXPLAIN` to obtain execution plan information, see Section 8.8.2, "EXPLAIN Output Format".

- `EXPLAIN EXTENDED` can be used to obtain additional execution plan information. See Section 8.8.3, "EXPLAIN EXTENDED Output Format".

- As of MySQL 5.1.5, `EXPLAIN PARTITIONS` is useful for examining queries involving partitioned tables. See Section 18.3.4, "Obtaining Information About Partitions".

 With the help of `EXPLAIN`, you can see where you should add indexes to tables so that the statement executes faster by using indexes to find rows. You can also use `EXPLAIN` to check whether the optimizer joins the tables in an optimal order. To give a hint to the optimizer to use a join order corresponding to the order in which the tables are named in a `SELECT` statement, begin the statement with `SELECT STRAIGHT_JOIN` rather than just `SELECT`. (See Section 13.2.8, "SELECT Syntax".)

If you have a problem with indexes not being used when you believe that they should be, run `ANALYZE TABLE` to update table statistics, such as cardinality of keys, that can affect the choices the optimizer makes. See Section 13.7.2.1, "ANALYZE TABLE Syntax".

> **Note**
>
> `EXPLAIN` can also be used to obtain information about the columns in a table. `EXPLAIN` *tbl_name* is synonymous with `DESCRIBE` *tbl_name* and `SHOW COLUMNS FROM` *tbl_name*. For more information, see Section 13.8.1, "DESCRIBE Syntax", and Section 13.7.5.6, "SHOW COLUMNS Syntax".

8.8.2 EXPLAIN Output Format

The `EXPLAIN` statement provides information about the execution plan for a `SELECT` statement.

`EXPLAIN` returns a row of information for each table used in the `SELECT` statement. It lists the tables in the output in the order that MySQL would read them while processing the statement. MySQL resolves all joins using a nested-loop join method. This means that MySQL reads a row from the first table, and then finds a matching row in the second table, the third table, and so on. When all tables are processed, MySQL outputs the selected columns and backtracks through the table list until a table is found for which there are more matching rows. The next row is read from this table and the process continues with the next table.

When the `EXTENDED` keyword is used, `EXPLAIN` produces extra information that can be viewed by issuing a `SHOW WARNINGS` statement following the `EXPLAIN` statement. `EXPLAIN EXTENDED` also displays the `filtered` column as of MySQL 5.1.12. See Section 8.8.3, "EXPLAIN EXTENDED Output Format".

> **Note**
>
> You cannot use the `EXTENDED` and `PARTITIONS` keywords together in the same `EXPLAIN` statement.

- `EXPLAIN` Output Columns
- `EXPLAIN` Join Types
- `EXPLAIN` Extra Information
- `EXPLAIN` Output Interpretation

EXPLAIN Output Columns

This section describes the output columns produced by `EXPLAIN`. Later sections provide additional information about the `type` and `Extra` columns.

Each output row from `EXPLAIN` provides information about one table. Each row contains the values summarized in Table 8.1, "EXPLAIN Output Columns", and described in more detail following the table.

Table 8.1 EXPLAIN Output Columns

Column	Meaning
`id`	The `SELECT` identifier
`select_type`	The `SELECT` type
`table`	The table for the output row
`partitions`	The matching partitions
`type`	The join type
`possible_keys`	The possible indexes to choose
`key`	The index actually chosen
`key_len`	The length of the chosen key
`ref`	The columns compared to the index
`rows`	Estimate of rows to be examined
`filtered`	Percentage of rows filtered by table condition
`Extra`	Additional information

- `id`

The `SELECT` identifier. This is the sequential number of the `SELECT` within the query. The value can be `NULL` if the row refers to the union result of other rows. In this case, the `table` column shows a value like `<unionM,N>` to indicate that the row refers to the union of the rows with `id` values of *M* and *N*.

- `select_type`

  The type of `SELECT`, which can be any of those shown in the following table.

`select_type` Value	Meaning
`SIMPLE`	Simple `SELECT` (not using `UNION` or subqueries)
`PRIMARY`	Outermost `SELECT`
`UNION`	Second or later `SELECT` statement in a `UNION`
`DEPENDENT UNION`	Second or later `SELECT` statement in a `UNION`, dependent on outer query
`UNION RESULT`	Result of a `UNION`.
`SUBQUERY`	First `SELECT` in subquery
`DEPENDENT SUBQUERY`	First `SELECT` in subquery, dependent on outer query
`DERIVED`	Derived table `SELECT` (subquery in `FROM` clause)
`UNCACHEABLE SUBQUERY`	A subquery for which the result cannot be cached and must be re-evaluated for each row of the outer query
`UNCACHEABLE UNION`	The second or later select in a `UNION` that belongs to an uncacheable subquery (see `UNCACHEABLE SUBQUERY`)

  `DEPENDENT` typically signifies the use of a correlated subquery. See Section 13.2.9.7, "Correlated Subqueries".

  `DEPENDENT SUBQUERY` evaluation differs from `UNCACHEABLE SUBQUERY` evaluation. For `DEPENDENT SUBQUERY`, the subquery is re-evaluated only once for each set of different values of the variables from its outer context. For `UNCACHEABLE SUBQUERY`, the subquery is re-evaluated for each row of the outer context.

  Cacheability of subqueries differs from caching of query results in the query cache (which is described in Section 8.10.3.1, "How the Query Cache Operates"). Subquery caching occurs during query execution, whereas the query cache is used to store results only after query execution finishes.

- `table`

  The name of the table to which the row of output refers. This can also be one of the following values:

  - `<unionM,N>`: The row refers to the union of the rows with `id` values of *M* and *N*.

  - `<derivedN>`: The row refers to the derived table result for the row with an `id` value of *N*. A derived table may result, for example, from a subquery in the `FROM` clause.

- `partitions`

  The partitions from which records would be matched by the query. This column is displayed only if the `PARTITIONS` keyword is used. The value is `NULL` for nonpartitioned tables. See Section 18.3.4, "Obtaining Information About Partitions".

- `type`

  The join type. For descriptions of the different types, see `EXPLAIN` Join Types.

- `possible_keys`

  The `possible_keys` column indicates which indexes MySQL can choose from use to find the rows in this table. Note that this column is totally independent of the order of the tables as displayed in the output from `EXPLAIN`. That means that some of the keys in `possible_keys` might not be usable in practice with the generated table order.

  If this column is `NULL`, there are no relevant indexes. In this case, you may be able to improve the performance of your query by examining the `WHERE` clause to check whether it refers to some column or columns that would be suitable for indexing. If so, create an appropriate index and check the query with `EXPLAIN` again. See Section 13.1.7, "ALTER TABLE Syntax".

  To see what indexes a table has, use `SHOW INDEX FROM` *tbl_name*.

- `key`

  The `key` column indicates the key (index) that MySQL actually decided to use. If MySQL decides to use one of the `possible_keys` indexes to look up rows, that index is listed as the key value.

  It is possible that `key` will name an index that is not present in the `possible_keys` value. This can happen if none of the `possible_keys` indexes are suitable for looking up rows, but all the columns selected by the query are columns of some other index. That is, the named index covers the selected columns, so although it is not used to determine which rows to retrieve, an index scan is more efficient than a data row scan.

  For `InnoDB`, a secondary index might cover the selected columns even if the query also selects the primary key because `InnoDB` stores the primary key value with each secondary index. If `key` is `NULL`, MySQL found no index to use for executing the query more efficiently.

  To force MySQL to use or ignore an index listed in the `possible_keys` column, use `FORCE INDEX`, `USE INDEX`, or `IGNORE INDEX` in your query. See Section 8.9.3, "Index Hints".

  For `MyISAM` and `NDB` tables, running `ANALYZE TABLE` helps the optimizer choose better indexes. For `MyISAM` tables, `myisamchk --analyze` does the same as `ANALYZE TABLE`. See Section 7.6, "MyISAM Table Maintenance and Crash Recovery".

- `key_len`

  The `key_len` column indicates the length of the key that MySQL decided to use. The length is `NULL` if the `key` column says `NULL`. Note that the value of `key_len` enables you to determine how many parts of a multiple-part key MySQL actually uses.

- `ref`

  The `ref` column shows which columns or constants are compared to the index named in the `key` column to select rows from the table.

- `rows`

  The `rows` column indicates the number of rows MySQL believes it must examine to execute the query.

  For `InnoDB` tables, this number is an estimate, and may not always be exact.

- `filtered`

  The `filtered` column indicates an estimated percentage of table rows that will be filtered by the table condition. That is, `rows` shows the estimated number of rows examined and `rows` × `filtered` / `100`

shows the number of rows that will be joined with previous tables. This column is displayed if you use `EXPLAIN EXTENDED`. (New in MySQL 5.1.12)

- `Extra`

  This column contains additional information about how MySQL resolves the query. For descriptions of the different values, see `EXPLAIN` Extra Information.

EXPLAIN Join Types

The `type` column of `EXPLAIN` output describes how tables are joined. The following list describes the join types, ordered from the best type to the worst:

- `system`

  The table has only one row (= system table). This is a special case of the `const` join type.

- `const`

  The table has at most one matching row, which is read at the start of the query. Because there is only one row, values from the column in this row can be regarded as constants by the rest of the optimizer. `const` tables are very fast because they are read only once.

  `const` is used when you compare all parts of a `PRIMARY KEY` or `UNIQUE` index to constant values. In the following queries, `tbl_name` can be used as a `const` table:

  ```
  SELECT * FROM tbl_name WHERE primary_key=1;

  SELECT * FROM tbl_name
    WHERE primary_key_part1=1 AND primary_key_part2=2;
  ```

- `eq_ref`

  One row is read from this table for each combination of rows from the previous tables. Other than the `system` and `const` types, this is the best possible join type. It is used when all parts of an index are used by the join and the index is a `PRIMARY KEY` or `UNIQUE NOT NULL` index.

  `eq_ref` can be used for indexed columns that are compared using the `=` operator. The comparison value can be a constant or an expression that uses columns from tables that are read before this table. In the following examples, MySQL can use an `eq_ref` join to process `ref_table`:

  ```
  SELECT * FROM ref_table,other_table
    WHERE ref_table.key_column=other_table.column;

  SELECT * FROM ref_table,other_table
    WHERE ref_table.key_column_part1=other_table.column
    AND ref_table.key_column_part2=1;
  ```

- `ref`

  All rows with matching index values are read from this table for each combination of rows from the previous tables. `ref` is used if the join uses only a leftmost prefix of the key or if the key is not a `PRIMARY KEY` or `UNIQUE` index (in other words, if the join cannot select a single row based on the key value). If the key that is used matches only a few rows, this is a good join type.

  `ref` can be used for indexed columns that are compared using the `=` or `<=>` operator. In the following examples, MySQL can use a `ref` join to process `ref_table`:

```
SELECT * FROM ref_table WHERE key_column=expr;

SELECT * FROM ref_table,other_table
  WHERE ref_table.key_column=other_table.column;

SELECT * FROM ref_table,other_table
  WHERE ref_table.key_column_part1=other_table.column
  AND ref_table.key_column_part2=1;
```

- `fulltext`

  The join is performed using a `FULLTEXT` index.

- `ref_or_null`

  This join type is like `ref`, but with the addition that MySQL does an extra search for rows that contain `NULL` values. This join type optimization is used most often in resolving subqueries. In the following examples, MySQL can use a `ref_or_null` join to process `ref_table`:

```
SELECT * FROM ref_table
  WHERE key_column=expr OR key_column IS NULL;
```

  See Section 8.2.1.6, "IS NULL Optimization".

- `index_merge`

  This join type indicates that the Index Merge optimization is used. In this case, the `key` column in the output row contains a list of indexes used, and `key_len` contains a list of the longest key parts for the indexes used. For more information, see Section 8.2.1.4, "Index Merge Optimization".

- `unique_subquery`

  This type replaces `eq_ref` for some `IN` subqueries of the following form:

```
value IN (SELECT primary_key FROM single_table WHERE some_expr)
```

  `unique_subquery` is just an index lookup function that replaces the subquery completely for better efficiency.

- `index_subquery`

  This join type is similar to `unique_subquery`. It replaces `IN` subqueries, but it works for nonunique indexes in subqueries of the following form:

```
value IN (SELECT key_column FROM single_table WHERE some_expr)
```

- `range`

  Only rows that are in a given range are retrieved, using an index to select the rows. The `key` column in the output row indicates which index is used. The `key_len` contains the longest key part that was used. The `ref` column is `NULL` for this type.

  `range` can be used when a key column is compared to a constant using any of the `=`, `<>`, `>`, `>=`, `<`, `<=`, `IS NULL`, `<=>`, `BETWEEN`, or `IN()` operators:

```
SELECT * FROM tbl_name
  WHERE key_column = 10;

SELECT * FROM tbl_name
  WHERE key_column BETWEEN 10 and 20;

SELECT * FROM tbl_name
  WHERE key_column IN (10,20,30);

SELECT * FROM tbl_name
  WHERE key_part1= 10 AND key_part2 IN (10,20,30);
```

- `index`

  The `index` join type is the same as `ALL`, except that the index tree is scanned. This occurs two ways:

  - If the index is a covering index for the queries and can be used to satisfy all data required from the table, only the index tree is scanned. In this case, the `Extra` column says `Using index`. An index-only scan usually is faster than `ALL` because the size of the index usually is smaller than the table data.

  - A full table scan is performed using reads from the index to look up data rows in index order. `Uses index` does not appear in the `Extra` column.

  MySQL can use this join type when the query uses only columns that are part of a single index.

- `ALL`

  A full table scan is done for each combination of rows from the previous tables. This is normally not good if the table is the first table not marked `const`, and usually *very* bad in all other cases. Normally, you can avoid `ALL` by adding indexes that enable row retrieval from the table based on constant values or column values from earlier tables.

EXPLAIN Extra Information

The `Extra` column of `EXPLAIN` output contains additional information about how MySQL resolves the query. The following list explains the values that can appear in this column. If you want to make your queries as fast as possible, look out for `Extra` values of `Using filesort` and `Using temporary`.

- `Child of 'table' pushed join@1`

  This table is referenced as the child of `table` in a join that can be pushed down to the NDB kernel. Applies only in MySQL Cluster NDB 7.2.0 and later, when pushed-down joins are enabled. See the description of the `ndb_join_pushdown` server system variable for more information and examples.

- `const row not found`

  For a query such as `SELECT ... FROM tbl_name`, the table was empty.

- `Distinct`

  MySQL is looking for distinct values, so it stops searching for more rows for the current row combination after it has found the first matching row.

- `Full scan on NULL key`

  This occurs for subquery optimization as a fallback strategy when the optimizer cannot use an index-lookup access method.

- `Impossible HAVING`

The `HAVING` clause is always false and cannot select any rows.

- `Impossible WHERE`

  The `WHERE` clause is always false and cannot select any rows.

- `Impossible WHERE noticed after reading const tables`

  MySQL has read all `const` (and `system`) tables and notice that the `WHERE` clause is always false.

- `No matching min/max row`

  No row satisfies the condition for a query such as `SELECT MIN(...) FROM ... WHERE condition`.

- `no matching row in const table`

  For a query with a join, there was an empty table or a table with no rows satisfying a unique index condition.

- `No tables used`

  The query has no `FROM` clause, or has a `FROM DUAL` clause.

- `Not exists`

  MySQL was able to do a `LEFT JOIN` optimization on the query and does not examine more rows in this table for the previous row combination after it finds one row that matches the `LEFT JOIN` criteria. Here is an example of the type of query that can be optimized this way:

  ```
  SELECT * FROM t1 LEFT JOIN t2 ON t1.id=t2.id
    WHERE t2.id IS NULL;
  ```

  Assume that `t2.id` is defined as `NOT NULL`. In this case, MySQL scans `t1` and looks up the rows in `t2` using the values of `t1.id`. If MySQL finds a matching row in `t2`, it knows that `t2.id` can never be `NULL`, and does not scan through the rest of the rows in `t2` that have the same `id` value. In other words, for each row in `t1`, MySQL needs to do only a single lookup in `t2`, regardless of how many rows actually match in `t2`.

- `Parent of N pushed join@1`

  This table is referenced as the parent of the table in row *N* of the current `EXPLAIN` output in a join that can be pushed down to the NDB kernel. Applies only in MySQL Cluster NDB 7.2.0 and later when pushed-down joins are enabled. See the description of the `ndb_join_pushdown` server system variable for more information and examples.

- `Range checked for each record (index map: N)`

  MySQL found no good index to use, but found that some of indexes might be used after column values from preceding tables are known. For each row combination in the preceding tables, MySQL checks whether it is possible to use a `range` or `index_merge` access method to retrieve rows. This is not very fast, but is faster than performing a join with no index at all. The applicability criteria are as described in Section 8.2.1.3, "Range Optimization", and Section 8.2.1.4, "Index Merge Optimization", with the exception that all column values for the preceding table are known and considered to be constants.

  Indexes are numbered beginning with 1, in the same order as shown by `SHOW INDEX` for the table. The index map value *N* is a bitmask value that indicates which indexes are candidates. For example, a value of `0x19` (binary 11001) means that indexes 1, 4, and 5 will be considered.

- Scanned *N* databases

  This indicates how many directory scans the server performs when processing a query for INFORMATION_SCHEMA tables, as described in Section 8.2.4, "INFORMATION_SCHEMA Optimization". The value of *N* can be 0, 1, or all.

- Select tables optimized away

  The optimizer determined 1) that at most one row should be returned, and 2) that to produce this row, a deterministic set of rows must be read. When the rows to be read can be read during the optimization phase (for example, by reading index rows), there is no need to read any tables during query execution.

  The first condition is fulfilled when the query is implicitly grouped (contains an aggregate function but no GROUP BY clause). The second condition is fulfilled when one row lookup is performed per index used. The number of indexes read determines the number of rows to read.

  Consider the following implicitly grouped query:

  ```
  SELECT MIN(c1), MIN(c2) FROM t1;
  ```

  Suppose that MIN(c1) can be retrieved by reading one index row and MIN(c2) can be retrieved by reading one row from a different index. That is, for each column c1 and c2, there exists an index where the column is the first column of the index. In this case, one row is returned, produced by reading two deterministic rows.

  This Extra value does not occur if the rows to read are not deterministic. Consider this query:

  ```
  SELECT MIN(c2) FROM t1 WHERE c1 <= 10;
  ```

  Suppose that (c1, c2) is a covering index. Using this index, all rows with c1 <= 10 must be scanned to find the minimum c2 value. By contrast, consider this query:

  ```
  SELECT MIN(c2) FROM t1 WHERE c1 = 10;
  ```

  In this case, the first index row with c1 = 10 contains the minimum c2 value. Only one row must be read to produce the returned row.

  For storage engines that maintain an exact row count per table (such as MyISAM, but not InnoDB), this Extra value can occur for COUNT(*) queries for which the WHERE clause is missing or always true and there is no GROUP BY clause. (This is an instance of an implicitly grouped query where the storage engine influences whether a deterministic number of rows can be read.)

- Skip_open_table, Open_frm_only, Open_trigger_only, Open_full_table

  These values indicate file-opening optimizations that apply to queries for INFORMATION_SCHEMA tables, as described in Section 8.2.4, "INFORMATION_SCHEMA Optimization".

  - Skip_open_table: Table files do not need to be opened. The information has already become available within the query by scanning the database directory.

  - Open_frm_only: Only the table's .frm file need be opened.

  - Open_trigger_only: Only the table's .TRG file need be opened.

- `Open_full_table`: The unoptimized information lookup. The `.frm`, `.MYD`, and `.MYI` files must be opened.

- `unique row not found`

  For a query such as `SELECT ... FROM` *tbl_name*, no rows satisfy the condition for a `UNIQUE` index or `PRIMARY KEY` on the table.

- `Using filesort`

  MySQL must do an extra pass to find out how to retrieve the rows in sorted order. The sort is done by going through all rows according to the join type and storing the sort key and pointer to the row for all rows that match the `WHERE` clause. The keys then are sorted and the rows are retrieved in sorted order. See Section 8.2.1.11, "ORDER BY Optimization".

- `Using index`

  The column information is retrieved from the table using only information in the index tree without having to do an additional seek to read the actual row. This strategy can be used when the query uses only columns that are part of a single index.

  For `InnoDB` tables that have a user-defined clustered index, that index can be used even when `Using index` is absent from the `Extra` column. This is the case if `type` is `index` and `key` is `PRIMARY`.

- `Using index for group-by`

  Similar to the `Using index` table access method, `Using index for group-by` indicates that MySQL found an index that can be used to retrieve all columns of a `GROUP BY` or `DISTINCT` query without any extra disk access to the actual table. Additionally, the index is used in the most efficient way so that for each group, only a few index entries are read. For details, see Section 8.2.1.12, "GROUP BY Optimization".

- `Using join buffer`

  Tables from earlier joins are read in portions into the join buffer, and then their rows are used from the buffer to perform the join with the current table.

- `Using sort_union(...)`, `Using union(...)`, `Using intersect(...)`

  These indicate how index scans are merged for the `index_merge` join type. See Section 8.2.1.4, "Index Merge Optimization".

- `Using temporary`

  To resolve the query, MySQL needs to create a temporary table to hold the result. This typically happens if the query contains `GROUP BY` and `ORDER BY` clauses that list columns differently.

- `Using where`

  A `WHERE` clause is used to restrict which rows to match against the next table or send to the client. Unless you specifically intend to fetch or examine all rows from the table, you may have something wrong in your query if the `Extra` value is not `Using where` and the table join type is `ALL` or `index`. Even if you are using an index for all parts of a `WHERE` clause, you may see `Using where` if the column can be `NULL`.

- `Using where with pushed condition`

This item applies to `NDB` tables *only*. It means that MySQL Cluster is using the Condition Pushdown optimization to improve the efficiency of a direct comparison between a nonindexed column and a constant. In such cases, the condition is "pushed down" to the cluster's data nodes and is evaluated on all data nodes simultaneously. This eliminates the need to send nonmatching rows over the network, and can speed up such queries by a factor of 5 to 10 times over cases where Condition Pushdown could be but is not used. For more information, see Section 8.2.1.5, "Engine Condition Pushdown Optimization".

EXPLAIN Output Interpretation

You can get a good indication of how good a join is by taking the product of the values in the `rows` column of the `EXPLAIN` output. This should tell you roughly how many rows MySQL must examine to execute the query. If you restrict queries with the `max_join_size` system variable, this row product also is used to determine which multiple-table `SELECT` statements to execute and which to abort. See Section 8.12.2, "Tuning Server Parameters".

The following example shows how a multiple-table join can be optimized progressively based on the information provided by `EXPLAIN`.

Suppose that you have the `SELECT` statement shown here and that you plan to examine it using `EXPLAIN`:

```
EXPLAIN SELECT tt.TicketNumber, tt.TimeIn,
               tt.ProjectReference, tt.EstimatedShipDate,
               tt.ActualShipDate, tt.ClientID,
               tt.ServiceCodes, tt.RepetitiveID,
               tt.CurrentProcess, tt.CurrentDPPerson,
               tt.RecordVolume, tt.DPPrinted, et.COUNTRY,
               et_1.COUNTRY, do.CUSTNAME
        FROM tt, et, et AS et_1, do
        WHERE tt.SubmitTime IS NULL
          AND tt.ActualPC = et.EMPLOYID
          AND tt.AssignedPC = et_1.EMPLOYID
          AND tt.ClientID = do.CUSTNMBR;
```

For this example, make the following assumptions:

- The columns being compared have been declared as follows.

Table	Column	Data Type
tt	ActualPC	CHAR(10)
tt	AssignedPC	CHAR(10)
tt	ClientID	CHAR(10)
et	EMPLOYID	CHAR(15)
do	CUSTNMBR	CHAR(15)

- The tables have the following indexes.

Table	Index
tt	ActualPC
tt	AssignedPC
tt	ClientID
et	EMPLOYID (primary key)
do	CUSTNMBR (primary key)

- The `tt.ActualPC` values are not evenly distributed.

Initially, before any optimizations have been performed, the `EXPLAIN` statement produces the following information:

```
table type possible_keys key  key_len ref  rows  Extra
et    ALL  PRIMARY       NULL NULL    NULL 74
do    ALL  PRIMARY       NULL NULL    NULL 2135
et_1  ALL  PRIMARY       NULL NULL    NULL 74
tt    ALL  AssignedPC,   NULL NULL    NULL 3872
           ClientID,
           ActualPC
      Range checked for each record (index map: 0x23)
```

Because `type` is `ALL` for each table, this output indicates that MySQL is generating a Cartesian product of all the tables; that is, every combination of rows. This takes quite a long time, because the product of the number of rows in each table must be examined. For the case at hand, this product is 74 × 2135 × 74 × 3872 = 45,268,558,720 rows. If the tables were bigger, you can only imagine how long it would take.

One problem here is that MySQL can use indexes on columns more efficiently if they are declared as the same type and size. In this context, `VARCHAR` and `CHAR` are considered the same if they are declared as the same size. `tt.ActualPC` is declared as `CHAR(10)` and `et.EMPLOYID` is `CHAR(15)`, so there is a length mismatch.

To fix this disparity between column lengths, use `ALTER TABLE` to lengthen `ActualPC` from 10 characters to 15 characters:

```
mysql> ALTER TABLE tt MODIFY ActualPC VARCHAR(15);
```

Now `tt.ActualPC` and `et.EMPLOYID` are both `VARCHAR(15)`. Executing the `EXPLAIN` statement again produces this result:

```
table type    possible_keys key     key_len ref         rows    Extra
tt    ALL     AssignedPC,   NULL    NULL    NULL        3872    Using
              ClientID,                                         where
              ActualPC
do    ALL     PRIMARY       NULL    NULL    NULL        2135
      Range checked for each record (index map: 0x1)
et_1  ALL     PRIMARY       NULL    NULL    NULL        74
      Range checked for each record (index map: 0x1)
et    eq_ref  PRIMARY       PRIMARY 15      tt.ActualPC 1
```

This is not perfect, but is much better: The product of the `rows` values is less by a factor of 74. This version executes in a couple of seconds.

A second alteration can be made to eliminate the column length mismatches for the `tt.AssignedPC = et_1.EMPLOYID` and `tt.ClientID = do.CUSTNMBR` comparisons:

```
mysql> ALTER TABLE tt MODIFY AssignedPC VARCHAR(15),
    ->                 MODIFY ClientID   VARCHAR(15);
```

After that modification, `EXPLAIN` produces the output shown here:

```
table type possible_keys key      key_len ref         rows Extra
et    ALL  PRIMARY       NULL     NULL    NULL        74
tt    ref  AssignedPC,   ActualPC 15      et.EMPLOYID 52   Using
           ClientID,                                       where
           ActualPC
```

```
et_1  eq_ref PRIMARY      PRIMARY  15      tt.AssignedPC 1
do    eq_ref PRIMARY      PRIMARY  15      tt.ClientID   1
```

At this point, the query is optimized almost as well as possible. The remaining problem is that, by default, MySQL assumes that values in the `tt.ActualPC` column are evenly distributed, and that is not the case for the `tt` table. Fortunately, it is easy to tell MySQL to analyze the key distribution:

```
mysql> ANALYZE TABLE tt;
```

With the additional index information, the join is perfect and `EXPLAIN` produces this result:

```
table type    possible_keys key     key_len ref          rows Extra
tt    ALL     AssignedPC    NULL    NULL    NULL         3872 Using
              ClientID,                                       where
              ActualPC
et    eq_ref  PRIMARY       PRIMARY 15      tt.ActualPC  1
et_1  eq_ref  PRIMARY       PRIMARY 15      tt.AssignedPC 1
do    eq_ref  PRIMARY       PRIMARY 15      tt.ClientID  1
```

The `rows` column in the output from `EXPLAIN` is an educated guess from the MySQL join optimizer. You should check whether the numbers are even close to the truth by comparing the `rows` product with the actual number of rows that the query returns. If the numbers are quite different, you might get better performance by using `STRAIGHT_JOIN` in your `SELECT` statement and trying to list the tables in a different order in the `FROM` clause.

It is possible in some cases to execute statements that modify data when `EXPLAIN SELECT` is used with a subquery; for more information, see Section 13.2.9.8, "Subqueries in the FROM Clause".

8.8.3 EXPLAIN EXTENDED Output Format

When `EXPLAIN` is used with the `EXTENDED` keyword, the output includes a `filtered` column not otherwise displayed. This column indicates the estimated percentage of table rows that will be filtered by the table condition. In addition, the statement produces extra information that can be viewed by issuing a `SHOW WARNINGS` statement following the `EXPLAIN` statement. The `Message` value in `SHOW WARNINGS` output displays how the optimizer qualifies table and column names in the `SELECT` statement, what the `SELECT` looks like after the application of rewriting and optimization rules, and possibly other notes about the optimization process.

Here is an example of extended output:

```
mysql> EXPLAIN EXTENDED
    -> SELECT t1.a, t1.a IN (SELECT t2.a FROM t2) FROM t1\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
         type: index
possible_keys: NULL
          key: PRIMARY
      key_len: 4
          ref: NULL
         rows: 4
     filtered: 100.00
        Extra: Using index
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: index_subquery
possible_keys: a
```

```
        key: a
    key_len: 5
        ref: func
       rows: 2
   filtered: 100.00
      Extra: Using index
2 rows in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Note
   Code: 1003
Message: select `test`.`t1`.`a` AS `a`,
        <in_optimizer>(`test`.`t1`.`a`,
        <exists>(<index_lookup>(<cache>(`test`.`t1`.`a`)
        in t2 on a checking NULL having
        <is_not_null_test>(`test`.`t2`.`a`)))) AS `t1.a
        IN (SELECT t2.a FROM t2)` from `test`.`t1`
1 row in set (0.00 sec)
```

Because the statement displayed by `SHOW WARNINGS` may contain special markers to provide information about query rewriting or optimizer actions, the statement is not necessarily valid SQL and is not intended to be executed. The output may also include rows with `Message` values that provide additional non-SQL explanatory notes about actions taken by the optimizer.

The following list describes special markers that can appear in `EXTENDED` output displayed by `SHOW WARNINGS`:

- `<cache>(expr)`

  The expression (such as a scalar subquery) is executed once and the resulting value is saved in memory for later use.

- `<exists>(query fragment)`

  The subquery predicate is converted to an `EXISTS` predicate and the subquery is transformed so that it can be used together with the `EXISTS` predicate.

- `<in_optimizer>(query fragment)`

  This is an internal optimizer object with no user significance.

- `<index_lookup>(query fragment)`

  The query fragment is processed using an index lookup to find qualifying rows.

- `<is_not_null_test>(expr)`

  A test to verify that the expression does not evaluate to `NULL`.

- `<primary_index_lookup>(query fragment)`

  The query fragment is processed using a primary key lookup to find qualifying rows.

- `<ref_null_helper>(expr)`

  This is an internal optimizer object with no user significance.

When some tables are of `const` or `system` type, expressions involving columns from these tables are evaluated early by the optimizer and are not part of the displayed statement. However, with `FORMAT=JSON`, some `const` table accesses are displayed as a `ref` access that uses a const value.

8.8.4 Estimating Query Performance

In most cases, you can estimate query performance by counting disk seeks. For small tables, you can usually find a row in one disk seek (because the index is probably cached). For bigger tables, you can estimate that, using B-tree indexes, you need this many seeks to find a row: `log(row_count) / log(index_block_length / 3 * 2 / (index_length + data_pointer_length)) + 1`.

In MySQL, an index block is usually 1,024 bytes and the data pointer is usually four bytes. For a 500,000-row table with a key value length of three bytes (the size of `MEDIUMINT`), the formula indicates `log(500,000)/log(1024/3*2/(3+4)) + 1` = 4 seeks.

This index would require storage of about 500,000 * 7 * 3/2 = 5.2MB (assuming a typical index buffer fill ratio of 2/3), so you probably have much of the index in memory and so need only one or two calls to read data to find the row.

For writes, however, you need four seek requests to find where to place a new index value and normally two seeks to update the index and write the row.

The preceding discussion does not mean that your application performance slowly degenerates by log N. As long as everything is cached by the OS or the MySQL server, things become only marginally slower as the table gets bigger. After the data gets too big to be cached, things start to go much slower until your applications are bound only by disk seeks (which increase by log N). To avoid this, increase the key cache size as the data grows. For `MyISAM` tables, the key cache size is controlled by the `key_buffer_size` system variable. See Section 8.12.2, "Tuning Server Parameters".

8.9 Controlling the Query Optimizer

MySQL provides optimizer control through system variables that affect how query plans are evaluated, switchable optimizations, and index hints.

8.9.1 Controlling Query Plan Evaluation

The task of the query optimizer is to find an optimal plan for executing an SQL query. Because the difference in performance between "good" and "bad" plans can be orders of magnitude (that is, seconds versus hours or even days), most query optimizers, including that of MySQL, perform a more or less exhaustive search for an optimal plan among all possible query evaluation plans. For join queries, the number of possible plans investigated by the MySQL optimizer grows exponentially with the number of tables referenced in a query. For small numbers of tables (typically less than 7 to 10) this is not a problem. However, when larger queries are submitted, the time spent in query optimization may easily become the major bottleneck in the server's performance.

A more flexible method for query optimization enables the user to control how exhaustive the optimizer is in its search for an optimal query evaluation plan. The general idea is that the fewer plans that are investigated by the optimizer, the less time it spends in compiling a query. On the other hand, because the optimizer skips some plans, it may miss finding an optimal plan.

The behavior of the optimizer with respect to the number of plans it evaluates can be controlled using two system variables:

- The `optimizer_prune_level` variable tells the optimizer to skip certain plans based on estimates of the number of rows accessed for each table. Our experience shows that this kind of "educated guess" rarely misses optimal plans, and may dramatically reduce query compilation times. That is why this option is on (`optimizer_prune_level=1`) by default. However, if you believe that the optimizer missed a better query plan, this option can be switched off (`optimizer_prune_level=0`) with the risk that query compilation may take much longer. Note that, even with the use of this heuristic, the optimizer still explores a roughly exponential number of plans.

- The `optimizer_search_depth` variable tells how far into the "future" of each incomplete plan the optimizer should look to evaluate whether it should be expanded further. Smaller values of `optimizer_search_depth` may result in orders of magnitude smaller query compilation times. For example, queries with 12, 13, or more tables may easily require hours and even days to compile if `optimizer_search_depth` is close to the number of tables in the query. At the same time, if compiled with `optimizer_search_depth` equal to 3 or 4, the optimizer may compile in less than a minute for the same query. If you are unsure of what a reasonable value is for `optimizer_search_depth`, this variable can be set to 0 to tell the optimizer to determine the value automatically.

8.9.2 Controlling Switchable Optimizations

The `optimizer_switch` system variable enables control over optimizer behavior. Its value is a set of flags, each of which has a value of `on` or `off` to indicate whether the corresponding optimizer behavior is enabled or disabled. This variable has global and session values and can be changed at runtime. The global default can be set at server startup.

To see the current set of optimizer flags, select the variable value:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                    index_merge_sort_union=on,
                    index_merge_intersection=on
```

To change the value of `optimizer_switch`, assign a value consisting of a comma-separated list of one or more commands:

```
SET [GLOBAL|SESSION] optimizer_switch='command[,command]...';
```

Each `command` value should have one of the forms shown in the following table.

Command Syntax	Meaning
`default`	Reset every optimization to its default value
`opt_name=default`	Set the named optimization to its default value
`opt_name=off`	Disable the named optimization
`opt_name=on`	Enable the named optimization

The order of the commands in the value does not matter, although the `default` command is executed first if present. Setting an `opt_name` flag to `default` sets it to whichever of `on` or `off` is its default value. Specifying any given `opt_name` more than once in the value is not permitted and causes an error. Any errors in the value cause the assignment to fail with an error, leaving the value of `optimizer_switch` unchanged.

The following table lists the permissible `opt_name` flag names.

Flag Name	Meaning	Default
`index_merge`	Controls all Index Merge optimizations	ON
`index_merge_intersection`	Controls the Index Merge Intersection Access optimization	ON
`index_merge_sort_union`	Controls the Index Merge Sort-Union Access optimization	ON
`index_merge_union`	Controls the Index Merge Union Access optimization	ON

For information about Index Merge, see Section 8.2.1.4, "Index Merge Optimization".

When you assign a value to `optimizer_switch`, flags that are not mentioned keep their current values. This makes it possible to enable or disable specific optimizer behaviors in a single statement without affecting other behaviors. The statement does not depend on what other optimizer flags exist and what their values are. Suppose that all Index Merge optimizations are enabled:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                    index_merge_sort_union=on,
                    index_merge_intersection=on
```

If the server is using the Index Merge Union or Index Merge Sort-Union access methods for certain queries and you want to check whether the optimizer will perform better without them, set the variable value like this:

```
mysql> SET optimizer_switch='index_merge_union=off,index_merge_sort_union=off';

mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=off,
                    index_merge_sort_union=off,
                    index_merge_intersection=on
```

8.9.3 Index Hints

Index hints give the optimizer information about how to choose indexes during query processing. Index hints are specified following a table name. (For the general syntax for specifying tables in a `SELECT` statement, see Section 13.2.8.2, "JOIN Syntax".) The syntax for referring to an individual table, including index hints, looks like this:

```
tbl_name [[AS] alias] [index_hint_list]

index_hint_list:
    index_hint [, index_hint] ...

index_hint:
    USE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] ([index_list])
  | IGNORE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)
  | FORCE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)

index_list:
    index_name [, index_name] ...
```

The `USE INDEX (index_list)` hint tells MySQL to use only one of the named indexes to find rows in the table. The alternative syntax `IGNORE INDEX (index_list)` tells MySQL to not use some particular index or indexes. These hints are useful if `EXPLAIN` shows that MySQL is using the wrong index from the list of possible indexes.

The `FORCE INDEX` hint acts like `USE INDEX (index_list)`, with the addition that a table scan is assumed to be *very* expensive. In other words, a table scan is used only if there is no way to use one of the named indexes to find rows in the table.

Each hint requires the names of *indexes*, not the names of columns. To refer to a primary key, use the name `PRIMARY`. To see the index names for a table, use `SHOW INDEX`.

An *index_name* value need not be a full index name. It can be an unambiguous prefix of an index name. If a prefix is ambiguous, an error occurs.

Prior to MySQL 5.1.17, `USE INDEX`, `IGNORE INDEX`, and `FORCE INDEX` affect only which indexes are used when MySQL decides how to find rows in the table and how to process joins. They do not affect whether an index is used when resolving an `ORDER BY` or `GROUP BY` clause.

Examples:

```
SELECT * FROM table1 USE INDEX (col1_index,col2_index)
  WHERE col1=1 AND col2=2 AND col3=3;

SELECT * FROM table1 IGNORE INDEX (col3_index)
  WHERE col1=1 AND col2=2 AND col3=3;
```

As of MySQL 5.1.17, the syntax for index hints is extended in the following ways:

- It is syntactically valid to omit *index_list* for `USE INDEX`, which means "use no indexes." Omitting *index_list* for `FORCE INDEX` or `IGNORE INDEX` is a syntax error.

- You can specify the scope of an index hint by adding a `FOR` clause to the hint. This provides more fine-grained control over the optimizer's selection of an execution plan for various phases of query processing. To affect only the indexes used when MySQL decides how to find rows in the table and how to process joins, use `FOR JOIN`. To influence index usage for sorting or grouping rows, use `FOR ORDER BY` or `FOR GROUP BY`.

- You can specify multiple index hints:

  ```
  SELECT * FROM t1 USE INDEX (i1) IGNORE INDEX FOR ORDER BY (i2) ORDER BY a;
  ```

  It is not an error to name the same index in several hints (even within the same hint):

  ```
  SELECT * FROM t1 USE INDEX (i1) USE INDEX (i1,i1);
  ```

  However, it is an error to mix `USE INDEX` and `FORCE INDEX` for the same table:

  ```
  SELECT * FROM t1 USE INDEX FOR JOIN (i1) FORCE INDEX FOR JOIN (i2);
  ```

The default scope of index hints also is changed as of MySQL 5.1.17. Formerly, index hints applied only to how indexes are used for retrieval of records and not during resolution of `ORDER BY` or `GROUP BY` clauses. As of 5.1.17, if an index hint includes no `FOR` clause, the hint by default applies to all parts of the statement. For example, this hint:

```
IGNORE INDEX (i1)
```

is equivalent to this combination of hints:

```
IGNORE INDEX FOR JOIN (i1)
IGNORE INDEX FOR ORDER BY (i1)
IGNORE INDEX FOR GROUP BY (i1)
```

To cause the server to use the older behavior for hint scope when no `FOR` clause is present (so that hints apply only to row retrieval), enable the `old` system variable at server startup. Take care about enabling this variable in a replication setup. With statement-based binary logging, having different modes for the master and slaves might lead to replication errors.

When index hints are processed, they are collected in a single list by type (`USE`, `FORCE`, `IGNORE`) and by scope (`FOR JOIN`, `FOR ORDER BY`, `FOR GROUP BY`). For example:

```
SELECT * FROM t1
  USE INDEX () IGNORE INDEX (i2) USE INDEX (i1) USE INDEX (i2);
```

is equivalent to:

```
SELECT * FROM t1
   USE INDEX (i1,i2) IGNORE INDEX (i2);
```

The index hints then are applied for each scope in the following order:

1. `{USE|FORCE} INDEX` is applied if present. (If not, the optimizer-determined set of indexes is used.)

2. `IGNORE INDEX` is applied over the result of the previous step. For example, the following two queries are equivalent:

   ```
   SELECT * FROM t1 USE INDEX (i1) IGNORE INDEX (i2) USE INDEX (i2);

   SELECT * FROM t1 USE INDEX (i1);
   ```

For `FULLTEXT` searches, index hints do not work before MySQL 5.1.31. As of 5.1.31, index hints work as follows:

- For natural language mode searches, index hints are silently ignored. For example, `IGNORE INDEX(i1)` is ignored with no warning and the index is still used.

- For boolean mode searches, index hints with `FOR ORDER BY` or `FOR GROUP BY` are silently ignored. Index hints with `FOR JOIN` or no `FOR` modifier are honored. In contrast to how hints apply for non-`FULLTEXT` searches, the hint is used for all phases of query execution (finding rows and retrieval, grouping, and ordering). This is true even if the hint is given for a non-`FULLTEXT` index.

  For example, the following two queries are equivalent:

  ```
  SELECT * FROM t
    USE INDEX (index1)
    IGNORE INDEX (index1) FOR ORDER BY
    IGNORE INDEX (index1) FOR GROUP BY
    WHERE ... IN BOOLEAN MODE ... ;

  SELECT * FROM t
    USE INDEX (index1)
    WHERE ... IN BOOLEAN MODE ... ;
  ```

8.10 Buffering and Caching

MySQL uses several strategies that cache information in memory buffers to increase performance.

8.10.1 The MyISAM Key Cache

To minimize disk I/O, the `MyISAM` storage engine exploits a strategy that is used by many database management systems. It employs a cache mechanism to keep the most frequently accessed table blocks in memory:

- For index blocks, a special structure called the *key cache* (or *key buffer*) is maintained. The structure contains a number of block buffers where the most-used index blocks are placed.

- For data blocks, MySQL uses no special cache. Instead it relies on the native operating system file system cache.

This section first describes the basic operation of the `MyISAM` key cache. Then it discusses features that improve key cache performance and that enable you to better control cache operation:

- Multiple sessions can access the cache concurrently.

- You can set up multiple key caches and assign table indexes to specific caches.

To control the size of the key cache, use the `key_buffer_size` system variable. If this variable is set equal to zero, no key cache is used. The key cache also is not used if the `key_buffer_size` value is too small to allocate the minimal number of block buffers (8).

When the key cache is not operational, index files are accessed using only the native file system buffering provided by the operating system. (In other words, table index blocks are accessed using the same strategy as that employed for table data blocks.)

An index block is a contiguous unit of access to the `MyISAM` index files. Usually the size of an index block is equal to the size of nodes of the index B-tree. (Indexes are represented on disk using a B-tree data structure. Nodes at the bottom of the tree are leaf nodes. Nodes above the leaf nodes are nonleaf nodes.)

All block buffers in a key cache structure are the same size. This size can be equal to, greater than, or less than the size of a table index block. Usually one these two values is a multiple of the other.

When data from any table index block must be accessed, the server first checks whether it is available in some block buffer of the key cache. If it is, the server accesses data in the key cache rather than on disk. That is, it reads from the cache or writes into it rather than reading from or writing to disk. Otherwise, the server chooses a cache block buffer containing a different table index block (or blocks) and replaces the data there by a copy of required table index block. As soon as the new index block is in the cache, the index data can be accessed.

If it happens that a block selected for replacement has been modified, the block is considered "dirty." In this case, prior to being replaced, its contents are flushed to the table index from which it came.

Usually the server follows an *LRU (Least Recently Used)* strategy: When choosing a block for replacement, it selects the least recently used index block. To make this choice easier, the key cache module maintains all used blocks in a special list (*LRU chain*) ordered by time of use. When a block is accessed, it is the most recently used and is placed at the end of the list. When blocks need to be replaced, blocks at the beginning of the list are the least recently used and become the first candidates for eviction.

The `InnoDB` storage engine also uses an LRU algorithm, to manage its buffer pool. See Section 8.10.2, "The InnoDB Buffer Pool".

8.10.1.1 Shared Key Cache Access

Threads can access key cache buffers simultaneously, subject to the following conditions:

- A buffer that is not being updated can be accessed by multiple sessions.

- A buffer that is being updated causes sessions that need to use it to wait until the update is complete.

- Multiple sessions can initiate requests that result in cache block replacements, as long as they do not interfere with each other (that is, as long as they need different index blocks, and thus cause different cache blocks to be replaced).

Shared access to the key cache enables the server to improve throughput significantly.

8.10.1.2 Multiple Key Caches

Shared access to the key cache improves performance but does not eliminate contention among sessions entirely. They still compete for control structures that manage access to the key cache buffers. To reduce key cache access contention further, MySQL also provides multiple key caches. This feature enables you to assign different table indexes to different key caches.

Where there are multiple key caches, the server must know which cache to use when processing queries for a given `MyISAM` table. By default, all `MyISAM` table indexes are cached in the default key cache. To assign table indexes to a specific key cache, use the `CACHE INDEX` statement (see Section 13.7.6.2, "CACHE INDEX Syntax"). For example, the following statement assigns indexes from the tables `t1`, `t2`, and `t3` to the key cache named `hot_cache`:

```
mysql> CACHE INDEX t1, t2, t3 IN hot_cache;
+---------+--------------------+----------+----------+
| Table   | Op                 | Msg_type | Msg_text |
+---------+--------------------+----------+----------+
| test.t1 | assign_to_keycache | status   | OK       |
| test.t2 | assign_to_keycache | status   | OK       |
| test.t3 | assign_to_keycache | status   | OK       |
+---------+--------------------+----------+----------+
```

The key cache referred to in a `CACHE INDEX` statement can be created by setting its size with a `SET GLOBAL` parameter setting statement or by using server startup options. For example:

```
mysql> SET GLOBAL keycache1.key_buffer_size=128*1024;
```

To destroy a key cache, set its size to zero:

```
mysql> SET GLOBAL keycache1.key_buffer_size=0;
```

You cannot destroy the default key cache. Any attempt to do this is ignored:

```
mysql> SET GLOBAL key_buffer_size = 0;

mysql> SHOW VARIABLES LIKE 'key_buffer_size';
+-----------------+---------+
| Variable_name   | Value   |
+-----------------+---------+
| key_buffer_size | 8384512 |
+-----------------+---------+
```

Key cache variables are structured system variables that have a name and components. For `keycache1.key_buffer_size`, `keycache1` is the cache variable name and `key_buffer_size` is the cache component. See Section 5.1.5.1, "Structured System Variables", for a description of the syntax used for referring to structured key cache system variables.

By default, table indexes are assigned to the main (default) key cache created at the server startup. When a key cache is destroyed, all indexes assigned to it are reassigned to the default key cache.

For a busy server, you can use a strategy that involves three key caches:

- A "hot" key cache that takes up 20% of the space allocated for all key caches. Use this for tables that are heavily used for searches but that are not updated.

- A "cold" key cache that takes up 20% of the space allocated for all key caches. Use this cache for medium-sized, intensively modified tables, such as temporary tables.

- A "warm" key cache that takes up 60% of the key cache space. Employ this as the default key cache, to be used by default for all other tables.

One reason the use of three key caches is beneficial is that access to one key cache structure does not block access to the others. Statements that access tables assigned to one cache do not compete with statements that access tables assigned to another cache. Performance gains occur for other reasons as well:

- The hot cache is used only for retrieval queries, so its contents are never modified. Consequently, whenever an index block needs to be pulled in from disk, the contents of the cache block chosen for replacement need not be flushed first.

- For an index assigned to the hot cache, if there are no queries requiring an index scan, there is a high probability that the index blocks corresponding to nonleaf nodes of the index B-tree remain in the cache.

- An update operation most frequently executed for temporary tables is performed much faster when the updated node is in the cache and need not be read in from disk first. If the size of the indexes of the temporary tables are comparable with the size of cold key cache, the probability is very high that the updated node is in the cache.

The `CACHE INDEX` statement sets up an association between a table and a key cache, but the association is lost each time the server restarts. If you want the association to take effect each time the server starts, one way to accomplish this is to use an option file: Include variable settings that configure your key caches, and an `init-file` option that names a file containing `CACHE INDEX` statements to be executed. For example:

```
key_buffer_size = 4G
hot_cache.key_buffer_size = 2G
cold_cache.key_buffer_size = 2G
init_file=/path/to/data-directory/mysqld_init.sql
```

The statements in `mysqld_init.sql` are executed each time the server starts. The file should contain one SQL statement per line. The following example assigns several tables each to `hot_cache` and `cold_cache`:

```
CACHE INDEX db1.t1, db1.t2, db2.t3 IN hot_cache
CACHE INDEX db1.t4, db2.t5, db2.t6 IN cold_cache
```

8.10.1.3 Midpoint Insertion Strategy

By default, the key cache management system uses a simple LRU strategy for choosing key cache blocks to be evicted, but it also supports a more sophisticated method called the *midpoint insertion strategy.*

When using the midpoint insertion strategy, the LRU chain is divided into two parts: a hot sublist and a warm sublist. The division point between two parts is not fixed, but the key cache management system takes care that the warm part is not "too short," always containing at least `key_cache_division_limit` percent of the key cache blocks. `key_cache_division_limit` is a component of structured key cache variables, so its value is a parameter that can be set per cache.

When an index block is read from a table into the key cache, it is placed at the end of the warm sublist. After a certain number of hits (accesses of the block), it is promoted to the hot sublist. At present, the number of hits required to promote a block (3) is the same for all index blocks.

A block promoted into the hot sublist is placed at the end of the list. The block then circulates within this sublist. If the block stays at the beginning of the sublist for a long enough time, it is demoted to the warm

sublist. This time is determined by the value of the `key_cache_age_threshold` component of the key cache.

The threshold value prescribes that, for a key cache containing N blocks, the block at the beginning of the hot sublist not accessed within the last N `* key_cache_age_threshold / 100` hits is to be moved to the beginning of the warm sublist. It then becomes the first candidate for eviction, because blocks for replacement always are taken from the beginning of the warm sublist.

The midpoint insertion strategy enables you to keep more-valued blocks always in the cache. If you prefer to use the plain LRU strategy, leave the `key_cache_division_limit` value set to its default of 100.

The midpoint insertion strategy helps to improve performance when execution of a query that requires an index scan effectively pushes out of the cache all the index blocks corresponding to valuable high-level B-tree nodes. To avoid this, you must use a midpoint insertion strategy with the `key_cache_division_limit` set to much less than 100. Then valuable frequently hit nodes are preserved in the hot sublist during an index scan operation as well.

8.10.1.4 Index Preloading

If there are enough blocks in a key cache to hold blocks of an entire index, or at least the blocks corresponding to its nonleaf nodes, it makes sense to preload the key cache with index blocks before starting to use it. Preloading enables you to put the table index blocks into a key cache buffer in the most efficient way: by reading the index blocks from disk sequentially.

Without preloading, the blocks are still placed into the key cache as needed by queries. Although the blocks will stay in the cache, because there are enough buffers for all of them, they are fetched from disk in random order, and not sequentially.

To preload an index into a cache, use the `LOAD INDEX INTO CACHE` statement. For example, the following statement preloads nodes (index blocks) of indexes of the tables `t1` and `t2`:

```
mysql> LOAD INDEX INTO CACHE t1, t2 IGNORE LEAVES;
+---------+--------------+----------+----------+
| Table   | Op           | Msg_type | Msg_text |
+---------+--------------+----------+----------+
| test.t1 | preload_keys | status   | OK       |
| test.t2 | preload_keys | status   | OK       |
+---------+--------------+----------+----------+
```

The `IGNORE LEAVES` modifier causes only blocks for the nonleaf nodes of the index to be preloaded. Thus, the statement shown preloads all index blocks from `t1`, but only blocks for the nonleaf nodes from `t2`.

If an index has been assigned to a key cache using a `CACHE INDEX` statement, preloading places index blocks into that cache. Otherwise, the index is loaded into the default key cache.

8.10.1.5 Key Cache Block Size

It is possible to specify the size of the block buffers for an individual key cache using the `key_cache_block_size` variable. This permits tuning of the performance of I/O operations for index files.

The best performance for I/O operations is achieved when the size of read buffers is equal to the size of the native operating system I/O buffers. But setting the size of key nodes equal to the size of the I/O buffer does not always ensure the best overall performance. When reading the big leaf nodes, the server pulls in a lot of unnecessary data, effectively preventing reading other leaf nodes.

To control the size of blocks in the `.MYI` index file of `MyISAM` tables, use the `--myisam-block-size` option at server startup.

8.10.1.6 Restructuring a Key Cache

A key cache can be restructured at any time by updating its parameter values. For example:

```
mysql> SET GLOBAL cold_cache.key_buffer_size=4*1024*1024;
```

If you assign to either the `key_buffer_size` or `key_cache_block_size` key cache component a value that differs from the component's current value, the server destroys the cache's old structure and creates a new one based on the new values. If the cache contains any dirty blocks, the server saves them to disk before destroying and re-creating the cache. Restructuring does not occur if you change other key cache parameters.

When restructuring a key cache, the server first flushes the contents of any dirty buffers to disk. After that, the cache contents become unavailable. However, restructuring does not block queries that need to use indexes assigned to the cache. Instead, the server directly accesses the table indexes using native file system caching. File system caching is not as efficient as using a key cache, so although queries execute, a slowdown can be anticipated. After the cache has been restructured, it becomes available again for caching indexes assigned to it, and the use of file system caching for the indexes ceases.

8.10.2 The InnoDB Buffer Pool

`InnoDB` maintains a buffer pool for caching data and indexes in memory. `InnoDB` manages the pool as a list, using a least recently used (LRU) algorithm incorporating a midpoint insertion strategy. When room is needed to add a new block to the pool, `InnoDB` evicts the least recently used block and adds the new block to the middle of the list. The midpoint insertion strategy in effect causes the list to be treated as two sublists:

- At the head, a sublist of "new" (or "young") blocks that have been recently used.

- At the tail, a sublist of "old" blocks that are less recently used.

As a result of the algorithm, the new sublist contains blocks that are heavily used by queries. The old sublist contains less-used blocks, and candidates for eviction are taken from this sublist.

The LRU algorithm operates as follows by default:

- 3/8 of the buffer pool is devoted to the old sublist.

- The midpoint of the list is the boundary where the tail of the new sublist meets the head of the old sublist.

- When `InnoDB` reads a block into the buffer pool, it initially inserts it at the midpoint (the head of the old sublist). A block can be read in as a result of two types of read requests: Because it is required (for example, to satisfy query execution), or as part of read-ahead performed in anticipation that it will be required.

- The first access to a block in the old sublist makes it "young", causing it to move to the head of the buffer pool (the head of the new sublist). If the block was read in because it was required, the first access occurs immediately and the block is made young. If the block was read in due to read-ahead, the first access does not occur immediately (and might not occur at all before the block is evicted).

- As long as no accesses occur for a block in the pool, it "ages" by moving toward the tail of the list. Blocks in both the new and old sublists age as other blocks are made new. Blocks in the old sublist also age as

blocks are inserted at the midpoint. Eventually, a block that remains unused for long enough reaches the tail of the old sublist and is evicted.

In the default operation of the buffer pool, a block when read in is loaded at the midpoint and then moved immediately to the head of the new sublist as soon as an access occurs. In the case of a table scan (such as performed for a `mysqldump` operation), each block read by the scan ends up moving to the head of the new sublist because multiple rows are accessed from each block. This occurs even for a one-time scan, where the blocks are not otherwise used by other queries. Blocks may also be loaded by the read-ahead background thread and then moved to the head of the new sublist by a single access. These effects can be disadvantageous because they push blocks that are in heavy use by other queries out of the new sublist to the old sublist where they become subject to eviction.

Several `InnoDB` system variables control the size of the buffer pool and let you tune the LRU algorithm:

- `innodb_buffer_pool_size`

  Specifies the size of the buffer pool. If your buffer pool is small and you have sufficient memory, making the pool larger can improve performance by reducing the amount of disk I/O needed as queries access `InnoDB` tables.

- `innodb_old_blocks_pct`

  Specifies the approximate percentage of the buffer pool that `InnoDB` uses for the old block sublist. The range of values is 5 to 95. The default value is 37 (that is, 3/8 of the pool).

- `innodb_old_blocks_time`

  Specifies how long in milliseconds (ms) a block inserted into the old sublist must stay there after its first access before it can be moved to the new sublist. The default value is 0: A block inserted into the old sublist moves to the new sublist when Innodb has evicted 1/4 of the inserted block's pages from the buffer pool, no matter how soon after insertion the access occurs. If the value is greater than 0, blocks remain in the old sublist until an access occurs at least that many ms after the first access. For example, a value of 1000 causes blocks to stay in the old sublist for 1 second after the first access before they become eligible to move to the new sublist.

`innodb_old_blocks_pct` and `innodb_old_blocks_time` are available as of MySQL 5.1.41, but only for `InnoDB Plugin`, not the built-in version of `InnoDB`.

By setting `innodb_old_blocks_time` greater than 0, you can prevent one-time table scans from flooding the new sublist with blocks used only for the scan. Rows in a block read in for a scan are accessed rapidly many times in succession, but the block is unused after that. If `innodb_old_blocks_time` is set to a value greater than the block scan time, the block is not moved to the new sublist during the table scan. Instead, it remains in the old sublist and ages to the tail of the list to be evicted quickly. This way, blocks used only for a one-time scan do not act to the detriment of heavily used blocks in the new sublist.

`innodb_old_blocks_time` can be set at runtime, so you can change it temporarily while performing operations such as table scans and dumps to prevent them from flooding the new sublist:

```
SET GLOBAL innodb_old_blocks_time = 1000;
... perform queries that scan tables ...
SET GLOBAL innodb_old_blocks_time = 0;
```

This strategy does not apply if your intent is to fill the buffer pool with a table's content. For example, you might perform a table or index scan at server startup or during benchmarking or testing specifically to "warm up" the buffer pool. In this case, leaving `innodb_old_blocks_time` set to 0 accomplishes the goal of loading the scanned blocks into the new sublist.

The output from the InnoDB Standard Monitor contains several fields in the `BUFFER POOL AND MEMORY` section that pertain to operation of the buffer pool LRU algorithm:

- `Old database pages`: The number of pages in the old sublist of the buffer pool.

- `Pages made young, not young`: The number of old pages that were moved to the head of the buffer pool (the new sublist), and the number of pages that have remained in the old sublist without being made new.

- `youngs/s non-youngs/s`: The number of accesses to old pages that have resulted in making them young or not. This metric differs from that of the previous item in two ways. First, it relates only to old pages. Second, it is based on number of accesses to pages and not the number of pages. (There can be multiple accesses to a given page, all of which are counted.)

- `young-making rate`: Hits that cause blocks to move to the head of the buffer pool.

- `not`: Hits that do not cause blocks to move to the head of the buffer pool (due to the delay not being met).

The `young-making` rate and `not` rate will not normally add up to the overall buffer pool hit rate. Hits for blocks in the old sublist cause them to move to the new sublist, but hits to blocks in the new sublist cause them to move to the head of the list only if they are a certain distance from the head.

The preceding information from the Monitor can help you make LRU tuning decisions:

- If you see very low `youngs/s` values when you do not have large scans going on, that indicates that you might need to either reduce the delay time, or increase the percentage of the buffer pool used for the old sublist. Increasing the percentage makes the old sublist larger, so blocks in that sublist take longer to move to the tail and be evicted. This increases the likelihood that they will be accessed again and be made young.

- If you do not see a lot of `non-youngs/s` when you are doing large table scans (and lots of `youngs/s`), you will want to tune your delay value to be larger.

For more information about InnoDB Monitors, see Section 14.6.9, "InnoDB Monitors".

The `MyISAM` storage engine also uses an LRU algorithm, to manage its key cache. See Section 8.10.1, "The MyISAM Key Cache".

8.10.3 The MySQL Query Cache

The query cache stores the text of a `SELECT` statement together with the corresponding result that was sent to the client. If an identical statement is received later, the server retrieves the results from the query cache rather than parsing and executing the statement again. The query cache is shared among sessions, so a result set generated by one client can be sent in response to the same query issued by another client.

The query cache can be useful in an environment where you have tables that do not change very often and for which the server receives many identical queries. This is a typical situation for many Web servers that generate many dynamic pages based on database content.

The query cache does not return stale data. When tables are modified, any relevant entries in the query cache are flushed.

Note

The query cache does not work in an environment where you have multiple `mysqld` servers updating the same `MyISAM` tables.

> **Note**
>
> As of MySQL 5.1.17, the query cache is used for prepared statements under the conditions described in Section 8.10.3.1, "How the Query Cache Operates". Before 5.1.17, the query cache is not used for prepared statements.

> **Note**
>
> As of MySQL 5.1.63, the query cache is not supported for partitioned tables, and is automatically disabled for queries involving partitioned tables. The query cache cannot be enabled for such queries. (Bug #53775)

Some performance data for the query cache follows. These results were generated by running the MySQL benchmark suite on a Linux Alpha 2×500MHz system with 2GB RAM and a 64MB query cache.

- If all the queries you are performing are simple (such as selecting a row from a table with one row), but still differ so that the queries cannot be cached, the overhead for having the query cache active is 13%. This could be regarded as the worst case scenario. In real life, queries tend to be much more complicated, so the overhead normally is significantly lower.

- Searches for a single row in a single-row table are 238% faster with the query cache than without it. This can be regarded as close to the minimum speedup to be expected for a query that is cached.

To disable the query cache at server startup, set the `query_cache_size` system variable to 0. By disabling the query cache code, there is no noticeable overhead. If you build MySQL from source, query cache capabilities can be excluded from the server entirely by invoking `configure` with the `--without-query-cache` option.

The query cache offers the potential for substantial performance improvement, but you should not assume that it will do so under all circumstances. With some query cache configurations or server workloads, you might actually see a performance decrease:

- Be cautious about sizing the query cache excessively large, which increases the overhead required to maintain the cache, possibly beyond the benefit of enabling it. Sizes in tens of megabytes are usually beneficial. Sizes in the hundreds of megabytes might not be.

- Server workload has a significant effect on query cache efficiency. A query mix consisting almost entirely of a fixed set of `SELECT` statements is much more likely to benefit from enabling the cache than a mix in which frequent `INSERT` statements cause continual invalidation of results in the cache. In some cases, a workaround is to use the `SQL_NO_CACHE` option to prevent results from even entering the cache for `SELECT` statements that use frequently modified tables. (See Section 8.10.3.2, "Query Cache SELECT Options".)

To verify that enabling the query cache is beneficial, test the operation of your MySQL server with the cache enabled and disabled. Then retest periodically because query cache efficiency may change as server workload changes.

8.10.3.1 How the Query Cache Operates

This section describes how the query cache works when it is operational. Section 8.10.3.3, "Query Cache Configuration", describes how to control whether it is operational.

Incoming queries are compared to those in the query cache before parsing, so the following two queries are regarded as different by the query cache:

```
SELECT * FROM tbl_name
Select * from tbl_name
```

Queries must be *exactly* the same (byte for byte) to be seen as identical. In addition, query strings that are identical may be treated as different for other reasons. Queries that use different databases, different protocol versions, or different default character sets are considered different queries and are cached separately.

The cache is not used for queries of the following types:

- Queries that are a subquery of an outer query

- Queries executed within the body of a stored function, trigger, or event

Before a query result is fetched from the query cache, MySQL checks whether the user has `SELECT` privilege for all databases and tables involved. If this is not the case, the cached result is not used.

If a query result is returned from query cache, the server increments the `Qcache_hits` status variable, not `Com_select`. See Section 8.10.3.4, "Query Cache Status and Maintenance".

If a table changes, all cached queries that use the table become invalid and are removed from the cache. This includes queries that use `MERGE` tables that map to the changed table. A table can be changed by many types of statements, such as `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE TABLE`, `ALTER TABLE`, `DROP TABLE`, or `DROP DATABASE`.

The query cache also works within transactions when using `InnoDB` tables.

The result from a `SELECT` query on a view is cached.

The query cache works for `SELECT SQL_CALC_FOUND_ROWS ...` queries and stores a value that is returned by a following `SELECT FOUND_ROWS()` query. `FOUND_ROWS()` returns the correct value even if the preceding query was fetched from the cache because the number of found rows is also stored in the cache. The `SELECT FOUND_ROWS()` query itself cannot be cached.

Before MySQL 5.1.17, prepared statements do not use the query cache. Beginning with 5.1.17, prepared statements use the query cache under certain conditions, which differ depending on the preparation method:

- Statements that are issued using the binary protocol using `mysql_stmt_prepare()` and `mysql_stmt_execute()`. See Section 21.8.8, "C API Prepared Statements".

  For a prepared statement executed using the binary protocol, comparison with statements in the query cache is based on the text of the statement after expansion of `?` parameter markers. The statement is compared only with other cached statements that were executed using the binary protocol. That is, for query cache purposes, statements issued using the binary protocol are distinct from statements issued using the text protocol.

- Statements that are issued using the text (nonbinary) protocol using `PREPARE` and `EXECUTE`. See Section 13.5, "SQL Syntax for Prepared Statements". These are denoted SQL PS statements here.

  Before MySQL 5.1.21, for a prepared statement executed using `PREPARE` and `EXECUTE`, it is not cached if it contains any `?` parameter markers. In that case, the statement after parameter expansion contains references to user variables, which prevents caching, even for nonprepared statements. If the statement contains no parameter markers, the statement is compared with statements in the query cache that were executed using the text protocol (that is, it is compared with other SQL PS statements and nonprepared statements). As of MySQL 5.1.21, this limitation is lifted and prepared statements that contain parameter markers can be cached because expansion directly substitutes the user variable values.

A query cannot be cached if it contains any of the functions shown in the following table.

BENCHMARK()	CONNECTION_ID()	CONVERT_TZ()
CURDATE()	CURRENT_DATE()	CURRENT_TIME()
CURRENT_TIMESTAMP()	CURRENT_USER()	CURTIME()
DATABASE()	ENCRYPT() with one parameter	FOUND_ROWS()
GET_LOCK()	IS_FREE_LOCK()	IS_USED_LOCK()
LAST_INSERT_ID()	LOAD_FILE()	MASTER_POS_WAIT()
NOW()	RAND()	RELEASE_ALL_LOCKS()
RELEASE_LOCK()	SLEEP()	SYSDATE()
UNIX_TIMESTAMP() with no parameters	USER()	UUID()
UUID_SHORT()		

A query also is not cached under these conditions:

- It refers to user-defined functions (UDFs) or stored functions.

- It refers to user variables or local stored program variables.

- It refers to tables in the `mysql` or `INFORMATION_SCHEMA` system database.

- (*MySQL 5.1.63 and later.*) It refers to any partitioned tables.

- It is of any of the following forms:

```
SELECT ... LOCK IN SHARE MODE
SELECT ... FOR UPDATE
SELECT ... INTO OUTFILE ...
SELECT ... INTO DUMPFILE ...
SELECT * FROM ... WHERE autoincrement_col IS NULL
```

  The last form is not cached because it is used as the ODBC workaround for obtaining the last insert ID value. See the Connector/ODBC section of Chapter 21, *Connectors and APIs*.

  Statements within transactions that use `SERIALIZABLE` isolation level also cannot be cached because they use `LOCK IN SHARE MODE` locking.

- It uses `TEMPORARY` tables.

- It does not use any tables.

- It generates warnings.

- The user has a column-level privilege for any of the involved tables.

8.10.3.2 Query Cache SELECT Options

Two query cache-related options may be specified in `SELECT` statements:

- `SQL_CACHE`

  The query result is cached if it is cacheable and the value of the `query_cache_type` system variable is `ON` or `DEMAND`.

- SQL_NO_CACHE

  The server does not use the query cache. It neither checks the query cache to see whether the result is already cached, nor does it cache the query result. (Due to a limitation in the parser, a space character must precede and follow the SQL_NO_CACHE keyword; a nonspace such as a newline causes the server to check the query cache to see whether the result is already cached.)

Examples:

```
SELECT SQL_CACHE id, name FROM customer;
SELECT SQL_NO_CACHE id, name FROM customer;
```

8.10.3.3 Query Cache Configuration

The have_query_cache server system variable indicates whether the query cache is available:

```
mysql> SHOW VARIABLES LIKE 'have_query_cache';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| have_query_cache | YES   |
+------------------+-------+
```

When using a standard MySQL binary, this value is always YES, even if query caching is disabled.

Several other system variables control query cache operation. These can be set in an option file or on the command line when starting mysqld. The query cache system variables all have names that begin with query_cache_. They are described briefly in Section 5.1.4, "Server System Variables", with additional configuration information given here.

To set the size of the query cache, set the query_cache_size system variable. Setting it to 0 disables the query cache. The default size is 0, so the query cache is disabled by default.

Be careful not to set the size of the cache too large. Due to the need for threads to lock the cache during updates, you may see lock contention issues with a very large cache.

> **Note**
>
> When using the Windows Configuration Wizard to install or configure MySQL, the default value for query_cache_size will be configured automatically for you based on the different configuration types available. When using the Windows Configuration Wizard, the query cache may be enabled (that is, set to a nonzero value) due to the selected configuration. The query cache is also controlled by the setting of the query_cache_type variable. You should check the values of these variables as set in your my.ini file after configuration has taken place.

When you set query_cache_size to a nonzero value, keep in mind that the query cache needs a minimum size of about 40KB to allocate its structures. (The exact size depends on system architecture.) If you set the value too small, you'll get a warning, as in this example:

```
mysql> SET GLOBAL query_cache_size = 40000;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
```

```
   Code: 1282
Message: Query cache failed to set size 39936;
         new query cache size is 0

mysql> SET GLOBAL query_cache_size = 41984;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'query_cache_size';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| query_cache_size | 41984 |
+------------------+-------+
```

For the query cache to actually be able to hold any query results, its size must be set larger:

```
mysql> SET GLOBAL query_cache_size = 1000000;
Query OK, 0 rows affected (0.04 sec)

mysql> SHOW VARIABLES LIKE 'query_cache_size';
+------------------+--------+
| Variable_name    | Value  |
+------------------+--------+
| query_cache_size | 999424 |
+------------------+--------+
1 row in set (0.00 sec)
```

The `query_cache_size` value is aligned to the nearest 1024 byte block. The value reported may therefore be different from the value that you assign.

If the query cache size is greater than 0, the `query_cache_type` variable influences how it works. This variable can be set to the following values:

- A value of `0` or `OFF` prevents caching or retrieval of cached results.

- A value of `1` or `ON` enables caching except of those statements that begin with `SELECT SQL_NO_CACHE`.

- A value of `2` or `DEMAND` causes caching of only those statements that begin with `SELECT SQL_CACHE`.

Setting the `GLOBAL query_cache_type` value determines query cache behavior for all clients that connect after the change is made. Individual clients can control cache behavior for their own connection by setting the `SESSION query_cache_type` value. For example, a client can disable use of the query cache for its own queries like this:

```
mysql> SET SESSION query_cache_type = OFF;
```

If you set `query_cache_type` at server startup (rather than at runtime with a `SET` statement), only the numeric values are permitted.

To control the maximum size of individual query results that can be cached, set the `query_cache_limit` system variable. The default value is 1MB.

> **Note**
>
> You can set the maximum size that can be specified for the query cache at runtime with the `SET` statement by using the `--maximum-query_cache_size=32M` option on the command line or in the configuration file.

When a query is to be cached, its result (the data sent to the client) is stored in the query cache during result retrieval. Therefore the data usually is not handled in one big chunk. The query cache allocates

blocks for storing this data on demand, so when one block is filled, a new block is allocated. Because memory allocation operation is costly (timewise), the query cache allocates blocks with a minimum size given by the `query_cache_min_res_unit` system variable. When a query is executed, the last result block is trimmed to the actual data size so that unused memory is freed. Depending on the types of queries your server executes, you might find it helpful to tune the value of `query_cache_min_res_unit`:

- The default value of `query_cache_min_res_unit` is 4KB. This should be adequate for most cases.

- If you have a lot of queries with small results, the default block size may lead to memory fragmentation, as indicated by a large number of free blocks. Fragmentation can force the query cache to prune (delete) queries from the cache due to lack of memory. In this case, you should decrease the value of `query_cache_min_res_unit`. The number of free blocks and queries removed due to pruning are given by the values of the `Qcache_free_blocks` and `Qcache_lowmem_prunes` status variables.

- If most of your queries have large results (check the `Qcache_total_blocks` and `Qcache_queries_in_cache` status variables), you can increase performance by increasing `query_cache_min_res_unit`. However, be careful to not make it too large (see the previous item).

8.10.3.4 Query Cache Status and Maintenance

To check whether the query cache is present in your MySQL server, use the following statement:

```
mysql> SHOW VARIABLES LIKE 'have_query_cache';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| have_query_cache | YES   |
+------------------+-------+
```

You can defragment the query cache to better utilize its memory with the `FLUSH QUERY CACHE` statement. The statement does not remove any queries from the cache.

The `RESET QUERY CACHE` statement removes all query results from the query cache. The `FLUSH TABLES` statement also does this.

To monitor query cache performance, use `SHOW STATUS` to view the cache status variables:

```
mysql> SHOW STATUS LIKE 'Qcache%';
+-------------------------+--------+
| Variable_name           | Value  |
+-------------------------+--------+
| Qcache_free_blocks      | 36     |
| Qcache_free_memory      | 138488 |
| Qcache_hits             | 79570  |
| Qcache_inserts          | 27087  |
| Qcache_lowmem_prunes    | 3114   |
| Qcache_not_cached       | 22989  |
| Qcache_queries_in_cache | 415    |
| Qcache_total_blocks     | 912    |
+-------------------------+--------+
```

Descriptions of each of these variables are given in Section 5.1.6, "Server Status Variables". Some uses for them are described here.

The total number of `SELECT` queries is given by this formula:

```
  Com_select
+ Qcache_hits
+ queries with errors found by parser
```

The `Com_select` value is given by this formula:

```
  Qcache_inserts
+ Qcache_not_cached
+ queries with errors found during the column-privileges check
```

The query cache uses variable-length blocks, so `Qcache_total_blocks` and `Qcache_free_blocks` may indicate query cache memory fragmentation. After `FLUSH QUERY CACHE`, only a single free block remains.

Every cached query requires a minimum of two blocks (one for the query text and one or more for the query results). Also, every table that is used by a query requires one block. However, if two or more queries use the same table, only one table block needs to be allocated.

The information provided by the `Qcache_lowmem_prunes` status variable can help you tune the query cache size. It counts the number of queries that have been removed from the cache to free up memory for caching new queries. The query cache uses a least recently used (LRU) strategy to decide which queries to remove from the cache. Tuning information is given in Section 8.10.3.3, "Query Cache Configuration".

8.11 Optimizing Locking Operations

When your database is busy with multiple sessions reading and writing data, the mechanism that controls access to data files and memory areas can become a consideration for performance tuning. Otherwise, sessions can spend time waiting for access to resources when they could be running concurrently.

MySQL manages contention for table contents using locking:

- Internal locking is performed within the MySQL server itself to manage contention for table contents by multiple threads. This type of locking is internal because it is performed entirely by the server and involves no other programs. See Section 8.11.1, "Internal Locking Methods".

- External locking occurs when the server and other programs lock `MyISAM` table files to coordinate among themselves which program can access the tables at which time. See Section 8.11.4, "External Locking".

8.11.1 Internal Locking Methods

This section discusses internal locking; that is, locking performed within the MySQL server itself to manage contention for table contents by multiple sessions. This type of locking is internal because it is performed entirely by the server and involves no other programs. External locking occurs when the server and other programs lock `MyISAM` table files to coordinate among themselves which program can access the tables at which time. See Section 8.11.4, "External Locking".

MySQL uses row-level locking for `InnoDB` tables to support simultaneous write access by multiple sessions, making them suitable for multi-user, highly concurrent, and OLTP applications. MySQL uses table-level locking for `MyISAM`, `MEMORY`, and `MERGE` tables, permitting only one session to update those tables at a time. This locking level makes these storage engines more suitable for read-only, read-mostly, or single-user applications.

Considerations for Table Locking

Table locking in MySQL is deadlock-free for storage engines that use table-level locking. Deadlock avoidance is managed by always requesting all needed locks at once at the beginning of a query and always locking the tables in the same order.

MySQL grants table write locks as follows:

1. If there are no locks on the table, put a write lock on it.

2. Otherwise, put the lock request in the write lock queue.

MySQL grants table read locks as follows:

1. If there are no write locks on the table, put a read lock on it.

2. Otherwise, put the lock request in the read lock queue.

Table updates are given higher priority than table retrievals. Therefore, when a lock is released, the lock is made available to the requests in the write lock queue and then to the requests in the read lock queue. This ensures that updates to a table are not "starved" even when there is heavy `SELECT` activity for the table. However, if there are many updates for a table, `SELECT` statements wait until there are no more updates.

For information on altering the priority of reads and writes, see Section 8.11.2, "Table Locking Issues".

You can analyze the table lock contention on your system by checking the `Table_locks_immediate` and `Table_locks_waited` status variables, which indicate the number of times that requests for table locks could be granted immediately and the number that had to wait, respectively:

```
mysql> SHOW STATUS LIKE 'Table%';
+-----------------------+---------+
| Variable_name         | Value   |
+-----------------------+---------+
| Table_locks_immediate | 1151552 |
| Table_locks_waited    | 15324   |
+-----------------------+---------+
```

The `MyISAM` storage engine supports concurrent inserts to reduce contention between readers and writers for a given table: If a `MyISAM` table has no free blocks in the middle of the data file, rows are always inserted at the end of the data file. In this case, you can freely mix concurrent `INSERT` and `SELECT` statements for a `MyISAM` table without locks. That is, you can insert rows into a `MyISAM` table at the same time other clients are reading from it. Holes can result from rows having been deleted from or updated in the middle of the table. If there are holes, concurrent inserts are disabled but are enabled again automatically when all holes have been filled with new data. This behavior is altered by the `concurrent_insert` system variable. See Section 8.11.3, "Concurrent Inserts".

If you acquire a table lock explicitly with `LOCK TABLES`, you can request a `READ LOCAL` lock rather than a `READ` lock to enable other sessions to perform concurrent inserts while you have the table locked.

To perform many `INSERT` and `SELECT` operations on a table `t1` when concurrent inserts are not possible, you can insert rows into a temporary table `temp_t1` and update the real table with the rows from the temporary table:

```
mysql> LOCK TABLES t1 WRITE, temp_t1 WRITE;
mysql> INSERT INTO t1 SELECT * FROM temp_t1;
mysql> DELETE FROM temp_t1;
mysql> UNLOCK TABLES;
```

`InnoDB` uses row locks. Deadlocks are possible for `InnoDB` because it automatically acquires locks during the processing of SQL statements, not at the start of the transaction.

Considerations for Row Locking

Advantages of row-level locking:

- Fewer lock conflicts when different sessions access different rows

- Fewer changes for rollbacks

- Possible to lock a single row for a long time

Disadvantages of row-level locking:

- Requires more memory than table-level locks

- Slower than table-level locks when used on a large part of the table because you must acquire many more locks

- Slower than other locks if you often do `GROUP BY` operations on a large part of the data or if you must scan the entire table frequently

Choosing the Type of Locking

Generally, table locks are superior to row-level locks in the following cases:

- Most statements for the table are reads

- Statements for the table are a mix of reads and writes, where writes are updates or deletes for a single row that can be fetched with one key read:

```
UPDATE tbl_name SET column=value WHERE unique_key_col=key_value;
DELETE FROM tbl_name WHERE unique_key_col=key_value;
```

- `SELECT` combined with concurrent `INSERT` statements, and very few `UPDATE` or `DELETE` statements

- Many scans or `GROUP BY` operations on the entire table without any writers

With higher-level locks, you can more easily tune applications by supporting locks of different types, because the lock overhead is less than for row-level locks.

Options other than row-level locking:

- Versioning (such as that used in MySQL for concurrent inserts) where it is possible to have one writer at the same time as many readers. This means that the database or table supports different views for the data depending on when access begins. Other common terms for this are "time travel," "copy on write," or "copy on demand."

- Copy on demand is in many cases superior to row-level locking. However, in the worst case, it can use much more memory than using normal locks.

- Instead of using row-level locks, you can employ application-level locks, such as those provided by `GET_LOCK()` and `RELEASE_LOCK()` in MySQL. These are advisory locks, so they work only with applications that cooperate with each other. See Section 12.16, "Miscellaneous Functions".

8.11.2 Table Locking Issues

To achieve a very high lock speed, MySQL uses table locking (instead of page, row, or column locking) for all storage engines except `InnoDB` and `NDB`.

For `InnoDB` tables, MySQL uses table locking only if you explicitly lock the table with `LOCK TABLES`. For this storage engine, avoid using `LOCK TABLES` at all, because `InnoDB` uses automatic row-level locking to ensure transaction isolation.

For large tables, table locking is often better than row locking, but there are some disadvantages:

- Table locking enables many sessions to read from a table at the same time, but if a session wants to write to a table, it must first get exclusive access. During the update, all other sessions that want to access this particular table must wait until the update is done.

- Table locking causes problems in cases such as when a session is waiting because the disk is full and free space needs to become available before the session can proceed. In this case, all sessions that want to access the problem table are also put in a waiting state until more disk space is made available.

Table locking is also disadvantageous under the following scenario:

- A session issues a `SELECT` that takes a long time to run.

- Another session then issues an `UPDATE` on the same table. This session waits until the `SELECT` is finished.

- Another session issues another `SELECT` statement on the same table. Because `UPDATE` has higher priority than `SELECT`, this `SELECT` waits for the `UPDATE` to finish, *after* waiting for the first `SELECT` to finish.

The following items describe some ways to avoid or reduce contention caused by table locking:

- Try to get the `SELECT` statements to run faster so that they lock tables for a shorter time. You might have to create some summary tables to do this.

- Start `mysqld` with `--low-priority-updates`. For storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`), this gives all statements that update (modify) a table lower priority than `SELECT` statements. In this case, the second `SELECT` statement in the preceding scenario would execute before the `UPDATE` statement, and would not need to wait for the first `SELECT` to finish.

- To specify that all updates issued in a specific connection should be done with low priority, set the `low_priority_updates` server system variable equal to 1.

- To give a specific `INSERT`, `UPDATE`, or `DELETE` statement lower priority, use the `LOW_PRIORITY` attribute.

- To give a specific `SELECT` statement higher priority, use the `HIGH_PRIORITY` attribute. See Section 13.2.8, "SELECT Syntax".

- Start `mysqld` with a low value for the `max_write_lock_count` system variable to force MySQL to temporarily elevate the priority of all `SELECT` statements that are waiting for a table after a specific number of inserts to the table occur. This permits `READ` locks after a certain number of `WRITE` locks.

- If you have problems with `INSERT` combined with `SELECT`, consider switching to `MyISAM` tables, which support concurrent `SELECT` and `INSERT` statements. (See Section 8.11.3, "Concurrent Inserts".)

- If you mix inserts and deletes on the same table, `INSERT DELAYED` may be of great help. See Section 13.2.5.2, "INSERT DELAYED Syntax".

- If you have problems with mixed `SELECT` and `DELETE` statements, the `LIMIT` option to `DELETE` may help. See Section 13.2.2, "DELETE Syntax".

- Using `SQL_BUFFER_RESULT` with `SELECT` statements can help to make the duration of table locks shorter. See Section 13.2.8, "SELECT Syntax".

- You could change the locking code in `mysys/thr_lock.c` to use a single queue. In this case, write locks and read locks would have the same priority, which might help some applications.

Here are some tips concerning table locks in MySQL:

- Concurrent users are not a problem if you do not mix updates with selects that need to examine many rows in the same table.

- You can use `LOCK TABLES` to increase speed, because many updates within a single lock is much faster than updating without locks. Splitting table contents into separate tables may also help.

- If you encounter speed problems with table locks in MySQL, you may be able to improve performance by converting some of your tables to `InnoDB`. See Section 14.6, "The InnoDB Storage Engine".

8.11.3 Concurrent Inserts

The `MyISAM` storage engine supports concurrent inserts to reduce contention between readers and writers for a given table: If a `MyISAM` table has no holes in the data file (deleted rows in the middle), an `INSERT` statement can be executed to add rows to the end of the table at the same time that `SELECT` statements are reading rows from the table. If there are multiple `INSERT` statements, they are queued and performed in sequence, concurrently with the `SELECT` statements. The results of a concurrent `INSERT` may not be visible immediately.

The `concurrent_insert` system variable can be set to modify the concurrent-insert processing. By default, the variable is set to 1 and concurrent inserts are handled as just described. If `concurrent_insert` is set to 0, concurrent inserts are disabled. If the variable is set to 2, concurrent inserts at the end of the table are permitted even for tables that have deleted rows. See also the description of the `concurrent_insert` system variable.

Under circumstances where concurrent inserts can be used, there is seldom any need to use the `DELAYED` modifier for `INSERT` statements. See Section 13.2.5.2, "INSERT DELAYED Syntax".

If you are using the binary log, concurrent inserts are converted to normal inserts for `CREATE ... SELECT` or `INSERT ... SELECT` statements. This is done to ensure that you can re-create an exact copy of your tables by applying the log during a backup operation. See Section 5.4.4, "The Binary Log". In addition, for those statements a read lock is placed on the selected-from table such that inserts into that table are blocked. The effect is that concurrent inserts for that table must wait as well.

With `LOAD DATA INFILE`, if you specify `CONCURRENT` with a `MyISAM` table that satisfies the condition for concurrent inserts (that is, it contains no free blocks in the middle), other sessions can retrieve data from the table while `LOAD DATA` is executing. Use of the `CONCURRENT` option affects the performance of `LOAD DATA` a bit, even if no other session is using the table at the same time.

If you specify `HIGH_PRIORITY`, it overrides the effect of the `--low-priority-updates` option if the server was started with that option. It also causes concurrent inserts not to be used.

For `LOCK TABLE`, the difference between `READ LOCAL` and `READ` is that `READ LOCAL` permits nonconflicting `INSERT` statements (concurrent inserts) to execute while the lock is held. However, this cannot be used if you are going to manipulate the database using processes external to the server while you hold the lock.

8.11.4 External Locking

External locking is the use of file system locking to manage contention for `MyISAM` database tables by multiple processes. External locking is used in situations where a single process such as the MySQL server cannot be assumed to be the only process that requires access to tables. Here are some examples:

- If you run multiple servers that use the same database directory (not recommended), each server must have external locking enabled.

- If you use `myisamchk` to perform table maintenance operations on `MyISAM` tables, you must either ensure that the server is not running, or that the server has external locking enabled so that it locks table files as necessary to coordinate with `myisamchk` for access to the tables. The same is true for use of `myisampack` to pack `MyISAM` tables.

  If the server is run with external locking enabled, you can use `myisamchk` at any time for read operations such a checking tables. In this case, if the server tries to update a table that `myisamchk` is using, the server will wait for `myisamchk` to finish before it continues.

  If you use `myisamchk` for write operations such as repairing or optimizing tables, or if you use `myisampack` to pack tables, you *must* always ensure that the `mysqld` server is not using the table. If you do not stop `mysqld`, you should at least do a `mysqladmin flush-tables` before you run `myisamchk`. Your tables *may become corrupted* if the server and `myisamchk` access the tables simultaneously.

With external locking in effect, each process that requires access to a table acquires a file system lock for the table files before proceeding to access the table. If all necessary locks cannot be acquired, the process is blocked from accessing the table until the locks can be obtained (after the process that currently holds the locks releases them).

External locking affects server performance because the server must sometimes wait for other processes before it can access tables.

External locking is unnecessary if you run a single server to access a given data directory (which is the usual case) and if no other programs such as `myisamchk` need to modify tables while the server is running. If you only *read* tables with other programs, external locking is not required, although `myisamchk` might report warnings if the server changes tables while `myisamchk` is reading them.

With external locking disabled, to use `myisamchk`, you must either stop the server while `myisamchk` executes or else lock and flush the tables before running `myisamchk`. (See Section 8.12.1, "System Factors and Startup Parameter Tuning".) To avoid this requirement, use the `CHECK TABLE` and `REPAIR TABLE` statements to check and repair `MyISAM` tables.

For `mysqld`, external locking is controlled by the value of the `skip_external_locking` system variable. When this variable is enabled, external locking is disabled, and vice versa. External locking is disabled by default.

Use of external locking can be controlled at server startup by using the `--external-locking` or `--skip-external-locking` option.

If you do use external locking option to enable updates to `MyISAM` tables from many MySQL processes, you must ensure that the following conditions are satisfied:

- You should not use the query cache for queries that use tables that are updated by another process.

- You should not start the server with the `--delay-key-write=ALL` option or use the `DELAY_KEY_WRITE=1` table option for any shared tables. Otherwise, index corruption can occur.

The easiest way to satisfy these conditions is to always use `--external-locking` together with `--delay-key-write=OFF` and `--query-cache-size=0`. (This is not done by default because in many setups it is useful to have a mixture of the preceding options.)

8.12 Optimizing the MySQL Server

8.12.1 System Factors and Startup Parameter Tuning

We start with system-level factors, because some of these decisions must be made very early to achieve large performance gains. In other cases, a quick look at this section may suffice. However, it is always nice to have a sense of how much can be gained by changing factors that apply at this level.

Before using MySQL in production, we advise you to test it on your intended platform.

Other tips:

- If you have enough RAM, you could remove all swap devices. Some operating systems use a swap device in some contexts even if you have free memory.

- Avoid external locking for `MyISAM` tables. The default is for external locking to be disabled. The `--external-locking` and `--skip-external-locking` options explicitly enable and disable external locking.

  Disabling external locking does not affect MySQL's functionality as long as you run only one server. Just remember to take down the server (or lock and flush the relevant tables) before you run `myisamchk`. On some systems it is mandatory to disable external locking because it does not work, anyway.

  The only case in which you cannot disable external locking is when you run multiple MySQL *servers* (not clients) on the same data, or if you run `myisamchk` to check (not repair) a table without telling the server to flush and lock the tables first. Note that using multiple MySQL servers to access the same data concurrently is generally *not* recommended, except when using MySQL Cluster.

  The `LOCK TABLES` and `UNLOCK TABLES` statements use internal locking, so you can use them even if external locking is disabled.

8.12.2 Tuning Server Parameters

You can determine the default buffer sizes used by the `mysqld` server using this command:

```
shell> mysqld --verbose --help
```

This command produces a list of all `mysqld` options and configurable system variables. The output includes the default variable values and looks something like this:

```
abort-slave-event-count         0
allow-suspicious-udfs           FALSE
auto-increment-increment        1
auto-increment-offset           1
automatic-sp-privileges         TRUE
back_log                        50
basedir                         /home/jon/bin/mysql-5.1/
...
tmpdir                          (No default value)
tmp_table_size                  16777216
transaction_alloc_block_size    8192
transaction_prealloc_size       4096
updatable_views_with_limit      1
use-symbolic-links              TRUE
verbose                         TRUE
wait_timeout                    28800
warnings                        1
```

For a `mysqld` server that is currently running, you can see the current values of its system variables by connecting to it and issuing this statement:

```
mysql> SHOW VARIABLES;
```

You can also see some statistical and status indicators for a running server by issuing this statement:

```
mysql> SHOW STATUS;
```

System variable and status information also can be obtained using `mysqladmin`:

```
shell> mysqladmin variables
shell> mysqladmin extended-status
```

For a full description of all system and status variables, see Section 5.1.4, "Server System Variables", and Section 5.1.6, "Server Status Variables".

MySQL uses algorithms that are very scalable, so you can usually run with very little memory. However, normally better performance results from giving MySQL more memory.

When tuning a MySQL server, the two most important variables to configure are `key_buffer_size` and `table_open_cache`. You should first feel confident that you have these set appropriately before trying to change any other variables.

The following examples indicate some typical variable values for different runtime configurations.

• If you have at least 1-2GB of memory and many tables and want maximum performance with a moderate number of clients, use something like this:

```
shell> mysqld_safe --key_buffer_size=384M --table_cache=4000 \
          --sort_buffer_size=4M --read_buffer_size=1M &
```

• If you have only 256MB of memory and only a few tables, but you still do a lot of sorting, you can use something like this:

```
shell> mysqld_safe --key_buffer_size=64M --sort_buffer_size=1M
```

If there are very many simultaneous connections, swapping problems may occur unless `mysqld` has been configured to use very little memory for each connection. `mysqld` performs better if you have enough memory for all connections.

• With little memory and lots of connections, use something like this:

```
shell> mysqld_safe --key_buffer_size=512K --sort_buffer_size=100K \
          --read_buffer_size=100K &
```

Or even this:

```
shell> mysqld_safe --key_buffer_size=512K --sort_buffer_size=16K \
          --table_open_cache=32 --read_buffer_size=8K \
          --net_buffer_length=1K &
```

If you are performing GROUP BY or ORDER BY operations on tables that are much larger than your available memory, increase the value of `read_rnd_buffer_size` to speed up the reading of rows following sorting operations.

You can make use of the example option files included with your MySQL distribution; see Section 5.1.2, "Server Configuration Defaults".

If you specify an option on the command line for `mysqld` or `mysqld_safe`, it remains in effect only for that invocation of the server. To use the option every time the server runs, put it in an option file.

To see the effects of a parameter change, do something like this:

```
shell> mysqld --key_buffer_size=128M --verbose --help
```

The variable values are listed near the end of the output. Make sure that the `--verbose` and `--help` options are last. Otherwise, the effect of any options listed after them on the command line are not reflected in the output.

For information on tuning the `InnoDB` storage engine, see Section 8.6, "Optimizing for InnoDB Tables".

8.12.3 Optimizing Disk I/O

This section describes ways to configure storage devices when you can devote more and faster storage hardware to the database server.

- Disk seeks are a huge performance bottleneck. This problem becomes more apparent when the amount of data starts to grow so large that effective caching becomes impossible. For large databases where you access data more or less randomly, you can be sure that you need at least one disk seek to read and a couple of disk seeks to write things. To minimize this problem, use disks with low seek times.

- Increase the number of available disk spindles (and thereby reduce the seek overhead) by either symlinking files to different disks or striping the disks:

  - Using symbolic links

    This means that, for `MyISAM` tables, you symlink the index file and data files from their usual location in the data directory to another disk (that may also be striped). This makes both the seek and read times better, assuming that the disk is not used for other purposes as well. See Section 8.12.4, "Using Symbolic Links".

  - Striping

    Striping means that you have many disks and put the first block on the first disk, the second block on the second disk, and the N-th block on the (N MOD $number\_of\_disks$) disk, and so on. This means if your normal data size is less than the stripe size (or perfectly aligned), you get much better performance. Striping is very dependent on the operating system and the stripe size, so benchmark your application with different stripe sizes. See Section 8.13.3, "Using Your Own Benchmarks".

    The speed difference for striping is *very* dependent on the parameters. Depending on how you set the striping parameters and number of disks, you may get differences measured in orders of magnitude. You have to choose to optimize for random or sequential access.

- For reliability, you may want to use RAID 0+1 (striping plus mirroring), but in this case, you need 2 × N drives to hold N drives of data. This is probably the best option if you have the money for it. However, you may also have to invest in some volume-management software to handle it efficiently.

- A good option is to vary the RAID level according to how critical a type of data is. For example, store semi-important data that can be regenerated on a RAID 0 disk, but store really important data such as host information and logs on a RAID 0+1 or RAID N disk. RAID N can be a problem if you have many writes, due to the time required to update the parity bits.

- On Linux, you can get much better performance by using `hdparm` to configure your disk's interface. (Up to 100% under load is not uncommon.) The following `hdparm` options should be quite good for MySQL, and probably for many other applications:

```
hdparm -m 16 -d 1
```

Performance and reliability when using this command depend on your hardware, so we strongly suggest that you test your system thoroughly after using `hdparm`. Please consult the `hdparm` manual page for more information. If `hdparm` is not used wisely, file system corruption may result, so back up everything before experimenting!

- You can also set the parameters for the file system that the database uses:

  If you do not need to know when files were last accessed (which is not really useful on a database server), you can mount your file systems with the `-o noatime` option. That skips updates to the last access time in inodes on the file system, which avoids some disk seeks.

  On many operating systems, you can set a file system to be updated asynchronously by mounting it with the `-o async` option. If your computer is reasonably stable, this should give you better performance without sacrificing too much reliability. (This flag is on by default on Linux.)

8.12.4 Using Symbolic Links

You can move databases or tables from the database directory to other locations and replace them with symbolic links to the new locations. You might want to do this, for example, to move a database to a file system with more free space or increase the speed of your system by spreading your tables to different disks.

The recommended way to do this is to symlink entire database directories to a different disk. Symlink `MyISAM` tables only as a last resort.

To determine the location of your data directory, use this statement:

```
SHOW VARIABLES LIKE 'datadir';
```

8.12.4.1 Using Symbolic Links for Databases on Unix

On Unix, the way to symlink a database is first to create a directory on some disk where you have free space and then to create a soft link to it from the MySQL data directory.

```
shell> mkdir /dr1/databases/test
shell> ln -s /dr1/databases/test /path/to/datadir
```

MySQL does not support linking one directory to multiple databases. Replacing a database directory with a symbolic link works as long as you do not make a symbolic link between databases. Suppose that you have a database `db1` under the MySQL data directory, and then make a symlink `db2` that points to `db1`:

```
shell> cd /path/to/datadir
shell> ln -s db1 db2
```

The result is that, or any table `tbl_a` in `db1`, there also appears to be a table `tbl_a` in `db2`. If one client updates `db1.tbl_a` and another client updates `db2.tbl_a`, problems are likely to occur.

8.12.4.2 Using Symbolic Links for MyISAM Tables on Unix

Symlinks are fully supported only for `MyISAM` tables. For files used by tables for other storage engines, you may get strange problems if you try to use symbolic links.

Do not symlink tables on systems that do not have a fully operational `realpath()` call. (Linux and Solaris support `realpath()`). To determine whether your system supports symbolic links, check the value of the `have_symlink` system variable using this statement:

```
SHOW VARIABLES LIKE 'have_symlink';
```

The handling of symbolic links for `MyISAM` tables works as follows:

- In the data directory, you always have the table format (`.frm`) file, the data (`.MYD`) file, and the index (`.MYI`) file. The data file and index file can be moved elsewhere and replaced in the data directory by symlinks. The format file cannot.

- You can symlink the data file and the index file independently to different directories.

- To instruct a running MySQL server to perform the symlinking, use the `DATA DIRECTORY` and `INDEX DIRECTORY` options to `CREATE TABLE`. See Section 13.1.17, "CREATE TABLE Syntax". Alternatively, if `mysqld` is not running, symlinking can be accomplished manually using `ln -s` from the command line.

  > **Note**
  >
  > Beginning with MySQL 5.1.24, the path used with either or both of the `DATA DIRECTORY` and `INDEX DIRECTORY` options may not include the MySQL `data` directory. (Bug #32167)

- `myisamchk` does not replace a symlink with the data file or index file. It works directly on the file to which the symlink points. Any temporary files are created in the directory where the data file or index file is located. The same is true for the `ALTER TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements.

- > **Note**
  >
  > When you drop a table that is using symlinks, *both the symlink and the file to which the symlink points are dropped*. This is an extremely good reason *not* to run `mysqld` as the system `root` or permit system users to have write access to MySQL database directories.

- If you rename a table with `ALTER TABLE ... RENAME` or `RENAME TABLE` and you do not move the table to another database, the symlinks in the database directory are renamed to the new names and the data file and index file are renamed accordingly.

- If you use `ALTER TABLE ... RENAME` or `RENAME TABLE` to move a table to another database, the table is moved to the other database directory. If the table name changed, the symlinks in the new database directory are renamed to the new names and the data file and index file are renamed accordingly.

- If you are not using symlinks, start `mysqld` with the `--skip-symbolic-links` option to ensure that no one can use `mysqld` to drop or rename a file outside of the data directory.

These table symlink operations are not supported:

- `ALTER TABLE` ignores the `DATA DIRECTORY` and `INDEX DIRECTORY` table options.

- `BACKUP TABLE` and `RESTORE TABLE` do not respect symbolic links.

- As indicated previously, only the data and index files can be symbolic links. The `.frm` file must *never* be a symbolic link. Attempting to do this (for example, to make one table name a synonym for another) produces incorrect results. Suppose that you have a database `db1` under the MySQL data directory, a table `tbl1` in this database, and in the `db1` directory you make a symlink `tbl2` that points to `tbl1`:

```
shell> cd /path/to/datadir/db1
shell> ln -s tbl1.frm tbl2.frm
shell> ln -s tbl1.MYD tbl2.MYD
shell> ln -s tbl1.MYI tbl2.MYI
```

Problems result if one thread reads `db1.tbl1` and another thread updates `db1.tbl2`:

- The query cache is "fooled" (it has no way of knowing that `tbl1` has not been updated, so it returns outdated results).

- `ALTER` statements on `tbl2` fail.

8.12.4.3 Using Symbolic Links for Databases on Windows

On Windows, symbolic links can be used for database directories. This enables you to put a database directory at a different location (for example, on a different disk) by setting up a symbolic link to it. Use of database symlinks on Windows is similar to their use on Unix, although the procedure for setting up the link differs.

Suppose that you want to place the database directory for a database named `mydb` at `D:\data\mydb`. To do this, create a symbolic link in the MySQL data directory that points to `D:\data\mydb`. However, before creating the symbolic link, make sure that the `D:\data\mydb` directory exists by creating it if necessary. If you already have a database directory named `mydb` in the data directory, move it to `D:\data`. Otherwise, the symbolic link will be ineffective. To avoid problems, make sure that the server is not running when you move the database directory.

On Windows, create a symbolic link to a MySQL database by creating a `.sym` file in the data directory that contains the path to the destination directory. The file should be named *db_name*`.sym`, where *db_name* is the database name.

Support for database symbolic links on Windows using `.sym` files is enabled by default. If you do not need `.sym` file symbolic links, you can disable support for them by starting `mysqld` with the `--skip-symbolic-links` option. To determine whether your system supports `.sym` file symbolic links, check the value of the `have_symlink` system variable using this statement:

```
SHOW VARIABLES LIKE 'have_symlink';
```

To create a `.sym` file symlink, use this procedure:

1. Change location into the data directory:

   ```
   C:\> cd \path\to\datadir
   ```

2. In the data directory, create a text file named `mydb.sym` that contains this path name: `D:\data\mydb\`

   Note

   The path name to the new database and tables should be absolute. If you specify a relative path, the location will be relative to the `mydb.sym` file.

After this, all tables created in the database `mydb` are created in `D:\data\mydb`.

The following limitations apply to the use of `.sym` files for database symbolic linking on Windows:

- The symbolic link is not used if a directory with the same name as the database exists in the MySQL data directory.

- The `--innodb_file_per_table` option cannot be used.

- If you run `mysqld` as a service, you cannot use a mapped drive to a remote server as the destination of the symbolic link. As a workaround, you can use the full path (`\\servername\path\`).

8.12.5 Optimizing Memory Use

8.12.5.1 How MySQL Uses Memory

MySQL allocates buffers and caches to improve performance of database operations. You can improve MySQL performance by increasing the values of certain cache and buffer-related system variables. You can also modify these variables to run MySQL on systems with limited memory.

The following list describes some of the ways that MySQL uses memory. Where applicable, relevant system variables are referenced. Some items are storage engine specific.

- The `InnoDB` buffer pool is a memory area that holds cached `InnoDB` data for tables, indexes, and other auxiliary buffers. For efficiency of high-volume read operations, the buffer pool is divided into pages that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache, using a variation of the LRU algorithm. For more information, see Section 8.10.2, "The InnoDB Buffer Pool".

  The size of the buffer pool is important for system performance.

  - Typically, it is recommended that `innodb_buffer_pool_size` is configured to 50 to 75 percent of system memory.

  - `InnoDB` allocates memory for the entire buffer pool at server startup. Memory allocation is performed by `malloc()` operations. Buffer pool size is defined by the `innodb_buffer_pool_size` configuration option.

  - A buffer pool that is too small may cause excessive churning as pages are flushed from the buffer pool only to be required again a short time later.

  - A buffer pool that is too large may cause swapping due to competition for memory.

- All threads share the `MyISAM` key buffer; its size is determined by the `key_buffer_size` variable. Other buffers used by the server are allocated as needed. See Section 8.12.2, "Tuning Server Parameters".

  For each `MyISAM` table that is opened, the index file is opened once; the data file is opened once for each concurrently running thread. For each concurrent thread, a table structure, column structures for each column, and a buffer of size $3 * N$ are allocated (where N is the maximum row length, not counting `BLOB` columns). A `BLOB` column requires five to eight bytes plus the length of the `BLOB` data. The `MyISAM` storage engine maintains one extra row buffer for internal use.

- Each thread that is used to manage client connections uses some thread-specific space. The following list indicates these and which variables control their size:

  - A stack (variable `thread_stack`)

  - A connection buffer (variable `net_buffer_length`)

  - A result buffer (variable `net_buffer_length`)

The connection buffer and result buffer each begin with a size equal to `net_buffer_length` bytes, but are dynamically enlarged up to `max_allowed_packet` bytes as needed. The result buffer shrinks to `net_buffer_length` bytes after each SQL statement. While a statement is running, a copy of the current statement string is also allocated.

- All threads share the same base memory.

- When a thread is no longer needed, the memory allocated to it is released and returned to the system unless the thread goes back into the thread cache. In that case, the memory remains allocated.

- Before MySQL 5.1.4, only compressed `MyISAM` tables are memory mapped. As of MySQL 5.1.4, the `myisam_use_mmap` system variable can be set to 1 to enable memory-mapping for all `MyISAM` tables.

- Each request that performs a sequential scan of a table allocates a *read buffer* (variable `read_buffer_size`).

- When reading rows in an arbitrary sequence (for example, following a sort), a *random-read buffer* (variable `read_rnd_buffer_size`) may be allocated to avoid disk seeks.

- All joins are executed in a single pass, and most joins can be done without even using a temporary table. Most temporary tables are memory-based hash tables. Temporary tables with a large row length (calculated as the sum of all column lengths) or that contain `BLOB` columns are stored on disk.

  If an internal in-memory temporary table becomes too large, MySQL handles this automatically by changing the table from in-memory to on-disk format, to be handled by the `MyISAM` storage engine. You can increase the permissible temporary table size as described in Section 8.4.4, "Internal Temporary Table Use in MySQL".

- Most requests that perform a sort allocate a sort buffer and zero to two temporary files depending on the result set size. See Section B.5.3.5, "Where MySQL Stores Temporary Files".

- Almost all parsing and calculating is done in thread-local and reusable memory pools. No memory overhead is needed for small items, so the normal slow memory allocation and freeing is avoided. Memory is allocated only for unexpectedly large strings.

- For each table having `BLOB` columns, a buffer is enlarged dynamically to read in larger `BLOB` values. If you scan a table, a buffer as large as the largest `BLOB` value is allocated.

- MySQL requires memory and descriptors for the table cache. Handler structures for all in-use tables are saved in the table cache and managed as "First In, First Out" (FIFO). The initial table cache size is defined by the `table_open_cache` system variable; see Section 8.4.3.1, "How MySQL Opens and Closes Tables".

  MySQL also requires memory for the table definition cache. The `table_definition_cache` system variable defines the number of table definitions (from `.frm` files) that can be stored in the table definition cache. If you use a large number of tables, you can create a large table definition cache to speed up the opening of tables. The table definition cache takes less space and does not use file descriptors, unlike the table cache.

- A `FLUSH TABLES` statement or `mysqladmin flush-tables` command closes all tables that are not in use at once and marks all in-use tables to be closed when the currently executing thread finishes. This effectively frees most in-use memory. `FLUSH TABLES` does not return until all tables have been closed.

- The server caches information in memory as a result of `GRANT`, `CREATE USER`, `CREATE SERVER`, and `INSTALL PLUGIN` statements. This memory is not released by the corresponding `REVOKE`, `DROP USER`, `DROP SERVER`, and `UNINSTALL PLUGIN` statements, so for a server that executes many

instances of the statements that cause caching, there will be an increase in memory use. This cached memory can be freed with `FLUSH PRIVILEGES`.

`ps` and other system status programs may report that `mysqld` uses a lot of memory. This may be caused by thread stacks on different memory addresses. For example, the Solaris version of `ps` counts the unused memory between stacks as used memory. To verify this, check available swap with `swap -s`. We test `mysqld` with several memory-leakage detectors (both commercial and Open Source), so there should be no memory leaks.

8.12.5.2 Enabling Large Page Support

Some hardware/operating system architectures support memory pages greater than the default (usually 4KB). The actual implementation of this support depends on the underlying hardware and operating system. Applications that perform a lot of memory accesses may obtain performance improvements by using large pages due to reduced Translation Lookaside Buffer (TLB) misses.

In MySQL, large pages can be used by InnoDB, to allocate memory for its buffer pool and additional memory pool.

MySQL supports only the Linux implementation of large page support (which is called HugeTLB in Linux).

Before large pages can be used on Linux, the kernel must be enabled to support them and it is necessary to configure the HugeTLB memory pool. For reference, the HugeTBL API is documented in the `Documentation/vm/hugetlbpage.txt` file of your Linux sources.

The kernel for some recent systems such as Red Hat Enterprise Linux appear to have the large pages feature enabled by default. To check whether this is true for your kernel, use the following command and look for output lines containing "huge":

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

The nonempty command output indicates that large page support is present, but the zero values indicate that no pages are configured for use.

If your kernel needs to be reconfigured to support large pages, consult the `hugetlbpage.txt` file for instructions.

Assuming that your Linux kernel has large page support enabled, configure it for use by MySQL using the following commands. Normally, you put these in an `rc` file or equivalent startup file that is executed during the system boot sequence, so that the commands execute each time the system starts. The commands should execute early in the boot sequence, before the MySQL server starts. Be sure to change the allocation numbers and the group number as appropriate for your system.

```
# Set the number of pages to be used.
# Each page is normally 2MB, so a value of 20 = 40MB.
# This command actually allocates memory, so this much
# memory must be available.
echo 20 > /proc/sys/vm/nr_hugepages

# Set the group number that is permitted to access this
# memory (102 in this case). The mysql user must be a
# member of this group.
```

```
echo 102 > /proc/sys/vm/hugetlb_shm_group

# Increase the amount of shmem permitted per segment
# (12G in this case).
echo 1560281088 > /proc/sys/kernel/shmmax

# Increase total amount of shared memory.  The value
# is the number of pages. At 4KB/page, 4194304 = 16GB.
echo 4194304 > /proc/sys/kernel/shmall
```

For MySQL usage, you normally want the value of `shmmax` to be close to the value of `shmall`.

To verify the large page configuration, check `/proc/meminfo` again as described previously. Now you should see some nonzero values:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:       20
HugePages_Free:        20
HugePages_Rsvd:         0
HugePages_Surp:         0
Hugepagesize:        4096 kB
```

The final step to make use of the `hugetlb_shm_group` is to give the `mysql` user an "unlimited" value for the memlock limit. This can by done either by editing `/etc/security/limits.conf` or by adding the following command to your `mysqld_safe` script:

```
ulimit -l unlimited
```

Adding the `ulimit` command to `mysqld_safe` causes the `root` user to set the memlock limit to `unlimited` before switching to the `mysql` user. (This assumes that `mysqld_safe` is started by `root`.)

Large page support in MySQL is disabled by default. To enable it, start the server with the `--large-pages` option. For example, you can use the following lines in your server's `my.cnf` file:

```
[mysqld]
large-pages
```

With this option, `InnoDB` uses large pages automatically for its buffer pool and additional memory pool. If `InnoDB` cannot do this, it falls back to use of traditional memory and writes a warning to the error log:
`Warning: Using conventional memory pool`

To verify that large pages are being used, check `/proc/meminfo` again:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:       20
HugePages_Free:        20
HugePages_Rsvd:         2
HugePages_Surp:         0
Hugepagesize:        4096 kB
```

8.12.6 Optimizing Network Use

8.12.6.1 How MySQL Uses Threads for Client Connections

Connection manager threads handle client connection requests on the network interfaces that the server listens to. On all platforms, one manager thread handles TCP/IP connection requests. On Unix, this manager thread also handles Unix socket file connection requests. On Windows, a manager thread

handles shared-memory connection requests, and another handles named-pipe connection requests. The server does not create threads to handle interfaces that it does not listen to. For example, a Windows server that does not have support for named-pipe connections enabled does not create a thread to handle them.

Connection manager threads associate each client connection with a thread dedicated to it that handles authentication and request processing for that connection. Manager threads create a new thread when necessary but try to avoid doing so by consulting the thread cache first to see whether it contains a thread that can be used for the connection. When a connection ends, its thread is returned to the thread cache if the cache is not full.

In this connection thread model, there are as many threads as there are clients currently connected, which has some disadvantages when server workload must scale to handle large numbers of connections. For example, thread creation and disposal becomes expensive. Also, each thread requires server and kernel resources, such as stack space. To accommodate a large number of simultaneous connections, the stack size per thread must be kept small, leading to a situation where it is either too small or the server consumes large amounts of memory. Exhaustion of other resources can occur as well, and scheduling overhead can become significant.

To control and monitor how the server manages threads that handle client connections, several system and status variables are relevant. (See Section 5.1.4, "Server System Variables", and Section 5.1.6, "Server Status Variables".)

The thread cache has a size determined by the `thread_cache_size` system variable. The default value is 0 (no caching), which causes a thread to be set up for each new connection and disposed of when the connection terminates. Set `thread_cache_size` to N to enable N inactive connection threads to be cached. `thread_cache_size` can be set at server startup or changed while the server runs. A connection thread becomes inactive when the client connection with which it was associated terminates.

To monitor the number of threads in the cache and how many threads have been created because a thread could not be taken from the cache, monitor the `Threads_cached` and `Threads_created` status variables.

You can set `max_connections` at server startup or at runtime to control the maximum number of clients that can connect simultaneously.

When the thread stack is too small, this limits the complexity of the SQL statements which the server can handle, the recursion depth of stored procedures, and other memory-consuming actions. To set a stack size of N bytes for each thread, start the server with `--thread_stack=`N.

8.12.6.2 DNS Lookup Optimization and the Host Cache

The MySQL server maintains a host cache in memory that contains information about clients: IP address, host name, and error information. The server uses this cache for nonlocal TCP connections. It does not use the cache for TCP connections established using the loopback interface address (`127.0.0.1`), or for connections established using a Unix socket file, named pipe, or shared memory.

For each new client connection, the server uses the client IP address to check whether the client host name is in the host cache. If not, the server attempts to resolve the host name. First, it resolves the IP address to a host name and resolves that host name back to an IP address. Then it compares the result to the original IP address to ensure that they are the same. The server stores information about the result of this operation in the host cache. If the cache is full, the least recently used entry is discarded.

The server performs host name resolution using the thread-safe `gethostbyaddr_r()` and `gethostbyname_r()` calls if the operating system supports them. Otherwise, the thread performing the lookup locks a mutex and calls `gethostbyaddr()` and `gethostbyname()` instead. In this case, no

other thread can resolve host names that are not in the host cache until the thread holding the mutex lock releases it.

The server uses the host cache for several purposes:

- By caching the results of IP-to-host name lookups, the server avoids doing a DNS lookup for each client connection. Instead, for a given host, it needs to perform a lookup only for the first connection from that host.

- The cache contains information about errors that occur during the connection process. Some errors are considered "blocking." If too many of these occur successively from a given host without a successful connection, the server blocks further connections from that host. The `max_connect_errors` system variable determines the number of permitted errors before blocking occurs. See Section B.5.2.6, "Host 'host_name' is blocked".

To unblock blocked hosts, flush the host cache by issuing a `FLUSH HOSTS` statement or executing a `mysqladmin flush-hosts` command.

It is possible for a blocked host to become unblocked even without `FLUSH HOSTS` if activity from other hosts has occurred since the last connection attempt from the blocked host. This can occur because the server discards the least recently used cache entry to make room for a new entry if the cache is full when a connection arrives from a client IP not in the cache. If the discarded entry is for a blocked host, that host becomes unblocked.

The host cache is enabled by default. To disable it, start the server with the `--skip-host-cache` option.

To disable DNS host name lookups, start the server with the `--skip-name-resolve` option. In this case, the server uses only IP addresses and not host names to match connecting hosts to rows in the MySQL grant tables. Only accounts specified in those tables using IP addresses can be used. (Be sure that an account exists that specifies an IP address or you may not be able to connect.)

If you have a very slow DNS and many hosts, you might be able to improve performance either by disabling DNS lookups with `--skip-name-resolve` or by increasing the `HOST_CACHE_SIZE` define (default value: 128) and recompiling the server

To disallow TCP/IP connections entirely, start the server with the `--skip-networking` option.

Some connection errors are not associated with TCP connections, occur very early in the connection process (even before an IP address is known), or are not specific to any particular IP address (such as out-of-memory conditions).

8.13 Measuring Performance (Benchmarking)

To measure performance, consider the following factors:

- Whether you are measuring the speed of a single operation on a quiet system, or how a set of operations (a "workload") works over a period of time. With simple tests, you usually test how changing one aspect (a configuration setting, the set of indexes on a table, the SQL clauses in a query) affects performance. Benchmarks are typically long-running and elaborate performance tests, where the results could dictate high-level choices such as hardware and storage configuration, or how soon to upgrade to a new MySQL version.

- For benchmarking, sometimes you must simulate a heavy database workload to get an accurate picture.

- Performance can vary depending on so many different factors that a difference of a few percentage points might not be a decisive victory. The results might shift the opposite way when you test in a different environment.

- Certain MySQL features help or do not help performance depending on the workload. For completeness, always test performance with those features turned on and turned off. The two most important features to try with each workload are the MySQL query cache, and the adaptive hash index for `InnoDB` tables.

This section progresses from simple and direct measurement techniques that a single developer can do, to more complicated ones that require additional expertise to perform and interpret the results.

8.13.1 Measuring the Speed of Expressions and Functions

To measure the speed of a specific MySQL expression or function, invoke the `BENCHMARK()` function using the `mysql` client program. Its syntax is `BENCHMARK(loop_count,expression)`. The return value is always zero, but `mysql` prints a line displaying approximately how long the statement took to execute. For example:

```
mysql> SELECT BENCHMARK(1000000,1+1);
+------------------------+
| BENCHMARK(1000000,1+1) |
+------------------------+
|                      0 |
+------------------------+
1 row in set (0.32 sec)
```

This result was obtained on a Pentium II 400MHz system. It shows that MySQL can execute 1,000,000 simple addition expressions in 0.32 seconds on that system.

The built-in MySQL functions are typically highly optimized, but there may be some exceptions. `BENCHMARK()` is an excellent tool for finding out if some function is a problem for your queries.

8.13.2 The MySQL Benchmark Suite

This benchmark suite is meant to tell any user what operations a given SQL implementation performs well or poorly. You can get a good idea for how the benchmarks work by looking at the code and results in the `sql-bench` directory in any MySQL source distribution.

To use the benchmark suite, the following requirements must be satisfied:

- The benchmark suite is provided with MySQL source distributions. You can either download a released distribution from http://dev.mysql.com/downloads/, or use the current development source tree. (See Section 2.11.3, "Installing MySQL Using a Development Source Tree".)

- The benchmark scripts are written in Perl and use the Perl DBI module to access database servers, so DBI must be installed. You also need the server-specific DBD drivers for each of the servers you want to test. For example, to test MySQL, PostgreSQL, and DB2, you must have the `DBD::mysql`, `DBD::Pg`, and `DBD::DB2` modules installed. See Section 2.15, "Perl Installation Notes".

After you obtain a MySQL source distribution, you can find the benchmark suite located in its `sql-bench` directory. To run the benchmark tests, build MySQL, and then change location into the `sql-bench` directory and execute the `run-all-tests` script:

```
shell> cd sql-bench
shell> perl run-all-tests --server=server_name
```

server_name should be the name of one of the supported servers. To get a list of all options and supported servers, invoke this command:

```
shell> perl run-all-tests --help
```

The `crash-me` script also is located in the `sql-bench` directory. `crash-me` tries to determine what features a database system supports and what its capabilities and limitations are by actually running queries. For example, it determines:

- What data types are supported

- How many indexes are supported

- What functions are supported

- How big a query can be

- How big a `VARCHAR` column can be

For more information about benchmark results, visit http://www.mysql.com/why-mysql/benchmarks/.

8.13.3 Using Your Own Benchmarks

Benchmark your application and database to find out where the bottlenecks are. After fixing one bottleneck (or by replacing it with a "dummy" module), you can proceed to identify the next bottleneck. Even if the overall performance for your application currently is acceptable, you should at least make a plan for each bottleneck and decide how to solve it if someday you really need the extra performance.

For examples of portable benchmark programs, look at those in the MySQL benchmark suite. See Section 8.13.2, "The MySQL Benchmark Suite". You can take any program from this suite and modify it for your own needs. By doing this, you can try different solutions to your problem and test which really is fastest for you.

Another free benchmark suite is the Open Source Database Benchmark, available at http://osdb.sourceforge.net/.

It is very common for a problem to occur only when the system is very heavily loaded. We have had many customers who contact us when they have a (tested) system in production and have encountered load problems. In most cases, performance problems turn out to be due to issues of basic database design (for example, table scans are not good under high load) or problems with the operating system or libraries. Most of the time, these problems would be much easier to fix if the systems were not already in production.

To avoid problems like this, benchmark your whole application under the worst possible load:

- The `mysqlslap` program can be helpful for simulating a high load produced by multiple clients issuing queries simultaneously. See Section 4.5.7, "`mysqlslap` — Load Emulation Client".

- You can also try benchmarking packages such as SysBench and DBT2, available at https://launchpad.net/sysbench, and http://osdldbt.sourceforge.net/#dbt2.

These programs or packages can bring a system to its knees, so be sure to use them only on your development systems.

8.14 Examining Thread Information

When you are attempting to ascertain what your MySQL server is doing, it can be helpful to examine the process list, which is the set of threads currently executing within the server. Process list information is available from these sources:

- The `SHOW [FULL] PROCESSLIST` statement: Section 13.7.5.31, "SHOW PROCESSLIST Syntax"

- The `SHOW PROFILE` statement: Section 13.7.5.33, "SHOW PROFILES Syntax"

- The `INFORMATION_SCHEMA PROCESSLIST` table: Section 20.13, "The INFORMATION_SCHEMA PROCESSLIST Table"

- The `mysqladmin processlist` command: Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server"

You can always view information about your own threads. To view information about threads being executed for other accounts, you must have the `PROCESS` privilege.

Each process list entry contains several pieces of information:

- `Id` is the connection identifier for the client associated with the thread.

- `User` and `Host` indicate the account associated with the thread.

- `db` is the default database for the thread, or `NULL` if none is selected.

- `Command` and `State` indicate what the thread is doing.

  Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.

- `Time` indicates how long the thread has been in its current state. The thread's notion of the current time may be altered in some cases: The thread can change the time with `SET TIMESTAMP = value`. For a thread running on a slave that is processing events from the master, the thread time is set to the time found in the events and thus reflects current time on the master and not the slave.

- `Info` contains the text of the statement being executed by the thread, or `NULL` if it is not executing one. By default, this value contains only the first 100 characters of the statement. To see the complete statements, use `SHOW FULL PROCESSLIST`.

The following sections list the possible `Command` values, and `State` values grouped by category. The meaning for some of these values is self-evident. For others, additional description is provided.

8.14.1 Thread Command Values

A thread can have any of the following `Command` values:

- `Binlog Dump`

  This is a thread on a master server for sending binary log contents to a slave server.

- `Change user`

  The thread is executing a change-user operation.

- `Close stmt`

  The thread is closing a prepared statement.

- `Connect`

  A replication slave is connected to its master.

- `Connect Out`

  A replication slave is connecting to its master.

- `Create DB`

  The thread is executing a create-database operation.

- `Daemon`

  This thread is internal to the server, not a thread that services a client connection.

- `Debug`

  The thread is generating debugging information.

- `Delayed insert`

  The thread is a delayed-insert handler.

- `Drop DB`

  The thread is executing a drop-database operation.

- `Error`

- `Execute`

  The thread is executing a prepared statement.

- `Fetch`

  The thread is fetching the results from executing a prepared statement.

- `Field List`

  The thread is retrieving information for table columns.

- `Init DB`

  The thread is selecting a default database.

- `Kill`

  The thread is killing another thread.

- `Long Data`

  The thread is retrieving long data in the result of executing a prepared statement.

- `Ping`

  The thread is handling a server-ping request.

- `Prepare`

  The thread is preparing a prepared statement.

- `Processlist`

  The thread is producing information about server threads.

- `Query`

The thread is executing a statement.

- `Quit`

  The thread is terminating.

- `Refresh`

  The thread is flushing table, logs, or caches, or resetting status variable or replication server information.

- `Register Slave`

  The thread is registering a slave server.

- `Reset stmt`

  The thread is resetting a prepared statement.

- `Set option`

  The thread is setting or resetting a client statement-execution option.

- `Shutdown`

  The thread is shutting down the server.

- `Sleep`

  The thread is waiting for the client to send a new statement to it.

- `Statistics`

  The thread is producing server-status information.

- `Table Dump`

  The thread is sending table contents to a slave server.

- `Time`

  Unused.

8.14.2 General Thread States

The following list describes thread `State` values that are associated with general query processing and not more specialized activities such as replication. Many of these are useful only for finding bugs in the server.

- `After create`

  This occurs when the thread creates a table (including internal temporary tables), at the end of the function that creates the table. This state is used even if the table could not be created due to some error.

- `Analyzing`

  The thread is calculating a `MyISAM` table key distributions (for example, for `ANALYZE TABLE`).

- `checking permissions`

The thread is checking whether the server has the required privileges to execute the statement.

- `Checking table`

  The thread is performing a table check operation.

- `cleaning up`

  The thread has processed one command and is preparing to free memory and reset certain state variables.

- `closing tables`

  The thread is flushing the changed table data to disk and closing the used tables. This should be a fast operation. If not, you should verify that you do not have a full disk and that the disk is not in very heavy use.

- `converting HEAP to MyISAM`

  The thread is converting an internal temporary table from a `MEMORY` table to an on-disk `MyISAM` table.

- `copy to tmp table`

  The thread is processing an `ALTER TABLE` statement. This state occurs after the table with the new structure has been created but before rows are copied into it.

- `Copying to group table`

  If a statement has different `ORDER BY` and `GROUP BY` criteria, the rows are sorted by group and copied to a temporary table.

- `Copying to tmp table`

  The server is copying to a temporary table in memory.

- `Copying to tmp table on disk`

  The server is copying to a temporary table on disk. The temporary result set has become too large (see Section 8.4.4, "Internal Temporary Table Use in MySQL"). Consequently, the thread is changing the temporary table from in-memory to disk-based format to save memory.

- `Creating index`

  The thread is processing `ALTER TABLE ... ENABLE KEYS` for a `MyISAM` table.

- `Creating sort index`

  The thread is processing a `SELECT` that is resolved using an internal temporary table.

- `creating table`

  The thread is creating a table. This includes creation of temporary tables.

- `Creating tmp table`

  The thread is creating a temporary table in memory or on disk. If the table is created in memory but later is converted to an on-disk table, the state during that operation will be `Copying to tmp table on disk`.

- `deleting from main table`

  The server is executing the first part of a multiple-table delete. It is deleting only from the first table, and saving columns and offsets to be used for deleting from the other (reference) tables.

- `deleting from reference tables`

  The server is executing the second part of a multiple-table delete and deleting the matched rows from the other tables.

- `discard_or_import_tablespace`

  The thread is processing an `ALTER TABLE ... DISCARD TABLESPACE` or `ALTER TABLE ... IMPORT TABLESPACE` statement.

- `end`

  This occurs at the end but before the cleanup of `ALTER TABLE`, `CREATE VIEW`, `DELETE`, `INSERT`, `SELECT`, or `UPDATE` statements.

- `executing`

  The thread has begun executing a statement.

- `Execution of init_command`

  The thread is executing statements in the value of the `init_command` system variable.

- `freeing items`

  The thread has executed a command. Some freeing of items done during this state involves the query cache. This state is usually followed by `cleaning up`.

- `Flushing tables`

  The thread is executing `FLUSH TABLES` and is waiting for all threads to close their tables.

- `FULLTEXT initialization`

  The server is preparing to perform a natural-language full-text search.

- `init`

  This occurs before the initialization of `ALTER TABLE`, `DELETE`, `INSERT`, `SELECT`, or `UPDATE` statements. Actions taken by the server in this state include flushing the binary log, the `InnoDB` log, and some query cache cleanup operations.

  For the `end` state, the following operations could be happening:

  - Removing query cache entries after data in a table is changed

  - Writing an event to the binary log

  - Freeing memory buffers, including for blobs

- `Killed`

  Someone has sent a `KILL` statement to the thread and it should abort next time it checks the kill flag. The flag is checked in each major loop in MySQL, but in some cases it might still take a short time for

the thread to die. If the thread is locked by some other thread, the kill takes effect as soon as the other thread releases its lock.

- `Locked`

  The query is locked by another query.

- `logging slow query`

  The thread is writing a statement to the slow-query log.

- `login`

  The initial state for a connection thread until the client has been authenticated successfully.

- `manage keys`

  The server is enabling or disabling a table index.

- `NULL`

  This state is used for the `SHOW PROCESSLIST` state.

- `Opening tables`, `Opening table`

  The thread is trying to open a table. This is should be very fast procedure, unless something prevents opening. For example, an `ALTER TABLE` or a `LOCK TABLE` statement can prevent opening a table until the statement is finished. It is also worth checking that your `table_open_cache` value is large enough.

- `optimizing`

  The server is performing initial optimizations for a query.

- `preparing`

  This state occurs during query optimization.

- `Purging old relay logs`

  The thread is removing unneeded relay log files.

- `query end`

  This state occurs after processing a query but before the `freeing items` state.

- `Reading from net`

  The server is reading a packet from the network.

- `Removing duplicates`

  The query was using `SELECT DISTINCT` in such a way that MySQL could not optimize away the distinct operation at an early stage. Because of this, MySQL requires an extra stage to remove all duplicated rows before sending the result to the client.

- `removing tmp table`

  The thread is removing an internal temporary table after processing a `SELECT` statement. This state is not used if no temporary table was created.

- rename

  The thread is renaming a table.

- rename result table

  The thread is processing an ALTER TABLE statement, has created the new table, and is renaming it to replace the original table.

- Reopen tables

  The thread got a lock for the table, but noticed after getting the lock that the underlying table structure changed. It has freed the lock, closed the table, and is trying to reopen it.

- Repair by sorting

  The repair code is using a sort to create indexes.

- Repair done

  The thread has completed a multi-threaded repair for a MyISAM table.

- Repair with keycache

  The repair code is using creating keys one by one through the key cache. This is much slower than Repair by sorting.

- Rolling back

  The thread is rolling back a transaction.

- Saving state

  For MyISAM table operations such as repair or analysis, the thread is saving the new table state to the .MYI file header. State includes information such as number of rows, the AUTO_INCREMENT counter, and key distributions.

- Searching rows for update

  The thread is doing a first phase to find all matching rows before updating them. This has to be done if the UPDATE is changing the index that is used to find the involved rows.

- Sending data

  The thread is reading and processing rows for a SELECT statement, and sending data to the client. Because operations occurring during this state tend to perform large amounts of disk access (reads), it is often the longest-running state over the lifetime of a given query.

- setup

  The thread is beginning an ALTER TABLE operation.

- Sorting for group

  The thread is doing a sort to satisfy a GROUP BY.

- Sorting for order

  The thread is doing a sort to satisfy an ORDER BY.

- `Sorting index`

  The thread is sorting index pages for more efficient access during a `MyISAM` table optimization operation.

- `Sorting result`

  For a `SELECT` statement, this is similar to `Creating sort index`, but for nontemporary tables.

- `statistics`

  The server is calculating statistics to develop a query execution plan. If a thread is in this state for a long time, the server is probably disk-bound performing other work.

- `System lock`

  The thread is going to request or is waiting for an internal or external system lock for the table. For example, this can occur when `InnoDB` waits for a table-level lock during execution of `LOCK TABLES`. If this state is being caused by requests for external locks and you are not using multiple `mysqld` servers that are accessing the same `MyISAM` tables, you can disable external system locks with the `--skip-external-locking` option. However, external locking is disabled by default, so it is likely that this option will have no effect.

- `Table lock`

  The next thread state after `System lock`. After acquiring a system lock, the thread is going to request an internal table lock (a `THR_LOCK` lock).

  For more information about table lock indicators, see Section 8.11.1, "Internal Locking Methods".

- `update`

  The thread is getting ready to start updating the table.

- `Updating`

  The thread is searching for rows to update and is updating them.

- `updating main table`

  The server is executing the first part of a multiple-table update. It is updating only the first table, and saving columns and offsets to be used for updating the other (reference) tables.

- `updating reference tables`

  The server is executing the second part of a multiple-table update and updating the matched rows from the other tables.

- `User lock`

  The thread is going to request or is waiting for an advisory lock requested with a `GET_LOCK()` call. For `SHOW PROFILE`, this state means the thread is requesting the lock (not waiting for it).

- `User sleep`

  The thread has invoked a `SLEEP()` call.

- `Waiting for release of readlock`

The thread is waiting for a global read lock obtained by another thread (with `FLUSH TABLES WITH READ LOCK`) to be released.

- `Waiting for tables`, `Waiting for table`

  The thread got a notification that the underlying structure for a table has changed and it needs to reopen the table to get the new structure. However, to reopen the table, it must wait until all other threads have closed the table in question.

  This notification takes place if another thread has used `FLUSH TABLES` or one of the following statements on the table in question: `FLUSH TABLES tbl_name`, `ALTER TABLE`, `RENAME TABLE`, `REPAIR TABLE`, `ANALYZE TABLE`, or `OPTIMIZE TABLE`.

- `Waiting on cond`

  A generic state in which the thread is waiting for a condition to become true. No specific state information is available.

- `Waiting to get readlock`

  The thread has issued a `FLUSH TABLES WITH READ LOCK` statement to obtain a global read lock and is waiting to obtain the lock.

- `Writing to net`

  The server is writing a packet to the network.

8.14.3 Delayed-Insert Thread States

These thread states are associated with processing for `DELAYED` inserts (see Section 13.2.5.2, "INSERT DELAYED Syntax"). Some states are associated with connection threads that process `INSERT DELAYED` statements from clients. Other states are associated with delayed-insert handler threads that insert the rows. There is a delayed-insert handler thread for each table for which `INSERT DELAYED` statements are issued.

States associated with a connection thread that processes an `INSERT DELAYED` statement from the client:

- `allocating local table`

  The thread is preparing to feed rows to the delayed-insert handler thread.

- `Creating delayed handler`

  The thread is creating a handler for `DELAYED` inserts.

- `got handler lock`

  This occurs before the `allocating local table` state and after the `waiting for handler lock` state, when the connection thread gets access to the delayed-insert handler thread.

- `got old table`

  This occurs after the `waiting for handler open` state. The delayed-insert handler thread has signaled that it has ended its initialization phase, which includes opening the table for delayed inserts.

- `storing row into queue`

The thread is adding a new row to the list of rows that the delayed-insert handler thread must insert.

- `waiting for delay_list`

  This occurs during the initialization phase when the thread is trying to find the delayed-insert handler thread for the table, and before attempting to gain access to the list of delayed-insert threads.

- `waiting for handler insert`

  An `INSERT DELAYED` handler has processed all pending inserts and is waiting for new ones.

- `waiting for handler lock`

  This occurs before the `allocating local table` state when the connection thread waits for access to the delayed-insert handler thread.

- `waiting for handler open`

  This occurs after the `Creating delayed handler` state and before the `got old table` state. The delayed-insert handler thread has just been started, and the connection thread is waiting for it to initialize.

States associated with a delayed-insert handler thread that inserts the rows:

- `insert`

  The state that occurs just before inserting rows into the table.

- `reschedule`

  After inserting a number of rows, the delayed-insert thread sleeps to let other threads do work.

- `upgrading lock`

  A delayed-insert handler is trying to get a lock for the table to insert rows.

- `Waiting for INSERT`

  A delayed-insert handler is waiting for a connection thread to add rows to the queue (see `storing row into queue`).

8.14.4 Query Cache Thread States

These thread states are associated with the query cache (see Section 8.10.3, "The MySQL Query Cache").

- `checking privileges on cached query`

  The server is checking whether the user has privileges to access a cached query result.

- `checking query cache for query`

  The server is checking whether the current query is present in the query cache.

- `invalidating query cache entries`

  Query cache entries are being marked invalid because the underlying tables have changed.

- `sending cached result to client`

The server is taking the result of a query from the query cache and sending it to the client.

- `storing result in query cache`

The server is storing the result of a query in the query cache.

8.14.5 Replication Master Thread States

The following list shows the most common states you may see in the `State` column for the master's `Binlog Dump` thread. If you see no `Binlog Dump` threads on a master server, this means that replication is not running—that is, that no slaves are currently connected.

- `Sending binlog event to slave`

Binary logs consist of *events*, where an event is usually an update plus some other information. The thread has read an event from the binary log and is now sending it to the slave.

- `Finished reading one binlog; switching to next binlog`

The thread has finished reading a binary log file and is opening the next one to send to the slave.

- `Has sent all binlog to slave; waiting for binlog to be updated`

The thread has read all outstanding updates from the binary logs and sent them to the slave. The thread is now idle, waiting for new events to appear in the binary log resulting from new updates occurring on the master.

- `Waiting to finalize termination`

A very brief state that occurs as the thread is stopping.

8.14.6 Replication Slave I/O Thread States

The following list shows the most common states you see in the `State` column for a slave server I/O thread. This state also appears in the `Slave_IO_State` column displayed by `SHOW SLAVE STATUS`, so you can get a good view of what is happening by using that statement.

- `Waiting for master update`

The initial state before `Connecting to master`.

- `Connecting to master`

The thread is attempting to connect to the master.

- `Checking master version`

A state that occurs very briefly, after the connection to the master is established.

- `Registering slave on master`

A state that occurs very briefly after the connection to the master is established.

- `Requesting binlog dump`

A state that occurs very briefly, after the connection to the master is established. The thread sends to the master a request for the contents of its binary logs, starting from the requested binary log file name and position.

- `Waiting to reconnect after a failed binlog dump request`

  If the binary log dump request failed (due to disconnection), the thread goes into this state while it sleeps, then tries to reconnect periodically. The interval between retries can be specified using the `CHANGE MASTER TO` statement or the `--master-connect-retry` option.

- `Reconnecting after a failed binlog dump request`

  The thread is trying to reconnect to the master.

- `Waiting for master to send event`

  The thread has connected to the master and is waiting for binary log events to arrive. This can last for a long time if the master is idle. If the wait lasts for `slave_net_timeout` seconds, a timeout occurs. At that point, the thread considers the connection to be broken and makes an attempt to reconnect.

- `Queueing master event to the relay log`

  The thread has read an event and is copying it to the relay log so that the SQL thread can process it.

- `Waiting to reconnect after a failed master event read`

  An error occurred while reading (due to disconnection). The thread is sleeping for the number of seconds set by the `CHANGE MASTER TO` statement or `--master-connect-retry` option (default 60) before attempting to reconnect.

- `Reconnecting after a failed master event read`

  The thread is trying to reconnect to the master. When connection is established again, the state becomes `Waiting for master to send event`.

- `Waiting for the slave SQL thread to free enough relay log space`

  You are using a nonzero `relay_log_space_limit` value, and the relay logs have grown large enough that their combined size exceeds this value. The I/O thread is waiting until the SQL thread frees enough space by processing relay log contents so that it can delete some relay log files.

- `Waiting for slave mutex on exit`

  A state that occurs briefly as the thread is stopping.

8.14.7 Replication Slave SQL Thread States

The following list shows the most common states you may see in the `State` column for a slave server SQL thread:

- `Waiting for the next event in relay log`

  The initial state before `Reading event from the relay log`.

- `Reading event from the relay log`

  The thread has read an event from the relay log so that the event can be processed.

- `Has read all relay log; waiting for the slave I/O thread to update it`

  The thread has processed all events in the relay log files, and is now waiting for the I/O thread to write new events to the relay log.

- `Making temp file`

  The thread is executing a `LOAD DATA INFILE` statement and is creating a temporary file containing the data from which the slave will read rows.

- `Waiting for slave mutex on exit`

  A very brief state that occurs as the thread is stopping.

The `State` column for the I/O thread may also show the text of a statement. This indicates that the thread has read an event from the relay log, extracted the statement from it, and is executing it.

8.14.8 Replication Slave Connection Thread States

These thread states occur on a replication slave but are associated with connection threads, not with the I/O or SQL threads.

- `Changing master`

  The thread is processing a `CHANGE MASTER TO` statement.

- `Creating table from master dump`

  The slave is creating a table using the `CREATE TABLE` statement contained in the dump from the master. Used for `LOAD TABLE FROM MASTER` and `LOAD DATA FROM MASTER`.

- `Killing slave`

  The thread is processing a `STOP SLAVE` statement.

- `Opening master dump table`

  This state occurs after `Creating table from master dump`.

- `Reading master dump table data`

  This state occurs after `Opening master dump table`.

- `Rebuilding the index on master dump table`

  This state occurs after `Reading master dump table data`.

- `starting slave`

  The thread is starting the slave threads after processing a successful `LOAD DATA FROM MASTER` load operation.

8.14.9 MySQL Cluster Thread States

- `Committing events to binlog`

- `Opening mysql.ndb_apply_status`

- `Processing events`

  The thread is processing events for binary logging.

- `Processing events from schema table`

The thread is doing the work of schema replication.

- `Shutting down`

- `Syncing ndb table schema operation and binlog`

  This is used to have a correct binary log of schema operations for NDB.

- `Waiting for event from ndbcluster`

  The server is acting as an SQL node in a MySQL Cluster, and is connected to a cluster management node.

- `Waiting for first event from ndbcluster`

- `Waiting for ndbcluster binlog update to reach current position`

- `Waiting for ndbcluster to start`

- `Waiting for schema epoch`

  The thread is waiting for a schema epoch (that is, a global checkpoint).

8.14.10 Event Scheduler Thread States

These states occur for the Event Scheduler thread, threads that are created to execute scheduled events, or threads that terminate the scheduler.

- `Clearing`

  The scheduler thread or a thread that was executing an event is terminating and is about to end.

- `Initialized`

  The scheduler thread or a thread that will execute an event has been initialized.

- `Waiting for next activation`

  The scheduler has a nonempty event queue but the next activation is in the future.

- `Waiting for scheduler to stop`

  The thread issued `SET GLOBAL event_scheduler=OFF` and is waiting for the scheduler to stop.

- `Waiting on empty queue`

  The scheduler's event queue is empty and it is sleeping.

Chapter 9 Language Structure

Table of Contents

This chapter discusses the rules for writing the following elements of SQL statements when using MySQL:

- Literal values such as strings and numbers

- Identifiers such as database, table, and column names

- Keywords and reserved words

- User-defined and system variables

- Comments

9.1 Literal Values

This section describes how to write literal values in MySQL. These include strings, numbers, hexadecimal values, boolean values, and `NULL`. The section also covers the various nuances and "gotchas" that you may run into when dealing with these basic types in MySQL.

9.1.1 String Literals

A string is a sequence of bytes or characters, enclosed within either single quote ("`'`") or double quote ("`"`") characters. Examples:

```
'a string'
"another string"
```

Quoted strings placed next to each other are concatenated to a single string. The following lines are equivalent:

```
'a string'
'a' ' ' 'string'
```

If the `ANSI_QUOTES` SQL mode is enabled, string literals can be quoted only within single quotation marks because a string quoted within double quotation marks is interpreted as an identifier.

A *binary string* is a string of bytes that has no character set or collation. A *nonbinary string* is a string of characters that has a character set and collation. For both types of strings, comparisons are based on the numeric values of the string unit. For binary strings, the unit is the byte. For nonbinary strings the unit is the character and some character sets support multibyte characters. Character value ordering is a function of the string collation.

String literals may have an optional character set introducer and `COLLATE` clause:

```
[_charset_name]'string' [COLLATE collation_name]
```

Examples:

```
SELECT _latin1'string';
SELECT _latin1'string' COLLATE latin1_danish_ci;
```

You can use `N'literal'` (or `n'literal'`) to create a string in the national character set. These statements are equivalent:

```
SELECT N'some text';
SELECT n'some text';
SELECT _utf8'some text';
```

For more information about these forms of string syntax, see Section 10.1.3.5, "Character String Literal Character Set and Collation", and Section 10.1.3.6, "National Character Set".

Within a string, certain sequences have special meaning unless the `NO_BACKSLASH_ESCAPES` SQL mode is enabled. Each of these sequences begins with a backslash ("\"), known as the *escape character*. MySQL recognizes the escape sequences shown in Table 9.1, "Special Character Escape Sequences". For all other escape sequences, backslash is ignored. That is, the escaped character is interpreted as if it was not escaped. For example, "\x" is just "x". These sequences are case sensitive. For example, "\b" is interpreted as a backspace, but "\B" is interpreted as "B". Escape processing is done according to the character set indicated by the `character_set_connection` system variable. This is true even for strings that are preceded by an introducer that indicates a different character set, as discussed in Section 10.1.3.5, "Character String Literal Character Set and Collation".

Table 9.1 Special Character Escape Sequences

Escape Sequence	Character Represented by Sequence
\0	An ASCII NUL (X'00') character
\'	A single quote ("'") character
\"	A double quote (""") character
\b	A backspace character
\n	A newline (linefeed) character
\r	A carriage return character
\t	A tab character
\Z	ASCII 26 (Control+Z); see note following the table
\\	A backslash ("\") character
\%	A "%" character; see note following the table

Escape Sequence	Character Represented by Sequence
_	A "_" character; see note following the table

The ASCII 26 character can be encoded as "\Z" to enable you to work around the problem that ASCII 26 stands for END-OF-FILE on Windows. ASCII 26 within a file causes problems if you try to use `mysql db_name < file_name`.

The "\%" and "_" sequences are used to search for literal instances of "%" and "_" in pattern-matching contexts where they would otherwise be interpreted as wildcard characters. See the description of the `LIKE` operator in Section 12.5.1, "String Comparison Functions". If you use "\%" or "_" outside of pattern-matching contexts, they evaluate to the strings "\%" and "_", not to "%" and "_".

There are several ways to include quote characters within a string:

• A "'" inside a string quoted with "'" may be written as "''".

• A """ inside a string quoted with """ may be written as """"".

• Precede the quote character by an escape character ("\").

• A "'" inside a string quoted with """ needs no special treatment and need not be doubled or escaped. In the same way, """ inside a string quoted with "'" needs no special treatment.

The following `SELECT` statements demonstrate how quoting and escaping work:

```
mysql> SELECT 'hello', '"hello"', '""hello""', 'hel''lo', '\'hello';
+-------+---------+-----------+--------+--------+
| hello | "hello" | ""hello"" | hel'lo | 'hello |
+-------+---------+-----------+--------+--------+

mysql> SELECT "hello", "'hello'", "''hello''", "hel""lo", "\"hello";
+-------+---------+-----------+--------+--------+
| hello | 'hello' | ''hello'' | hel"lo | "hello |
+-------+---------+-----------+--------+--------+

mysql> SELECT 'This\nIs\nFour\nLines';
+--------------------+
| This
Is
Four
Lines |
+--------------------+

mysql> SELECT 'disappearing\ backslash';
+------------------------+
| disappearing backslash |
+------------------------+
```

If you want to insert binary data into a string column (such as a `BLOB` column), you should represent certain characters by escape sequences. Backslash ("\") and the quote character used to quote the string must be escaped. In certain client environments, it may also be necessary to escape `NUL` or Control+Z. The `mysql` client truncates quoted strings containing `NUL` characters if they are not escaped, and Control +Z may be taken for END-OF-FILE on Windows if not escaped. For the escape sequences that represent each of these characters, see Table 9.1, "Special Character Escape Sequences".

When writing application programs, any string that might contain any of these special characters must be properly escaped before the string is used as a data value in an SQL statement that is sent to the MySQL server. You can do this in two ways:

- Process the string with a function that escapes the special characters. In a C program, you can use the `mysql_real_escape_string()` C API function to escape characters. See Section 21.8.7.53, "mysql_real_escape_string()". Within SQL statements that construct other SQL statements, you can use the `QUOTE()` function. The Perl DBI interface provides a `quote` method to convert special characters to the proper escape sequences. See Section 21.10, "MySQL Perl API". Other language interfaces may provide a similar capability.

- As an alternative to explicitly escaping special characters, many MySQL APIs provide a placeholder capability that enables you to insert special markers into a statement string, and then bind data values to them when you issue the statement. In this case, the API takes care of escaping special characters in the values for you.

9.1.2 Number Literals

Number literals include exact-value (integer and `DECIMAL`) literals and approximate-value (floating-point) literals.

Integers are represented as a sequence of digits. Numbers may include "." as a decimal separator. Numbers may be preceded by "−" or "+" to indicate a negative or positive value, respectively. Numbers represented in scientific notation with a mantissa and exponent are approximate-value numbers.

Exact-value numeric literals have an integer part or fractional part, or both. They may be signed. Examples: `1`, `.2`, `3.4`, `−5`, `−6.78`, `+9.10`.

Approximate-value numeric literals are represented in scientific notation with a mantissa and exponent. Either or both parts may be signed. Examples: `1.2E3`, `1.2E-3`, `−1.2E3`, `−1.2E-3`.

Two numbers that look similar may be treated differently. For example, `2.34` is an exact-value (fixed-point) number, whereas `2.34E0` is an approximate-value (floating-point) number.

The `DECIMAL` data type is a fixed-point type and calculations are exact. In MySQL, the `DECIMAL` type has several synonyms: `NUMERIC`, `DEC`, `FIXED`. The integer types also are exact-value types. For more information about exact-value calculations, see Section 12.18, "Precision Math".

The `FLOAT` and `DOUBLE` data types are floating-point types and calculations are approximate. In MySQL, types that are synonymous with `FLOAT` or `DOUBLE` are `DOUBLE PRECISION` and `REAL`.

An integer may be used in a floating-point context; it is interpreted as the equivalent floating-point number.

9.1.3 Date and Time Literals

Date and time values can be represented in several formats, such as quoted strings or as numbers, depending on the exact type of the value and other factors. For example, in contexts where MySQL expects a date, it interprets any of `'2015-07-21'`, `'20150721'`, and `20150721` as a date.

This section describes the acceptable formats for date and time literals. For more information about the temporal data types, such as the range of permitted values, consult these sections:

- Section 11.1.2, "Date and Time Type Overview"

- Section 11.3, "Date and Time Types"

Standard SQL and ODBC Date and Time Literals.   Standard SQL permits temporal literals to be specified using a type keyword and a string. The space between the keyword and string is optional.

```
DATE 'str'
```

```
TIME 'str'
TIMESTAMP 'str'
```

MySQL recognizes those constructions and also the corresponding ODBC syntax:

```
{ d 'str' }
{ t 'str' }
{ ts 'str' }
```

However, MySQL ignores the type keyword and each of the preceding constructions produces the string value `'str'`, with a type of `VARCHAR`.

String and Numeric Literals in Date and Time Context. MySQL recognizes `DATE` values in these formats:

- As a string in either `'YYYY-MM-DD'` or `'YY-MM-DD'` format. A "relaxed" syntax is permitted: Any punctuation character may be used as the delimiter between date parts. For example, `'2012-12-31'`, `'2012/12/31'`, `'2012^12^31'`, and `'2012@12@31'` are equivalent.

- As a string with no delimiters in either `'YYYYMMDD'` or `'YYMMDD'` format, provided that the string makes sense as a date. For example, `'20070523'` and `'070523'` are interpreted as `'2007-05-23'`, but `'071332'` is illegal (it has nonsensical month and day parts) and becomes `'0000-00-00'`.

- As a number in either `YYYYMMDD` or `YYMMDD` format, provided that the number makes sense as a date. For example, `19830905` and `830905` are interpreted as `'1983-09-05'`.

MySQL recognizes `DATETIME` and `TIMESTAMP` values in these formats:

- As a string in either `'YYYY-MM-DD HH:MM:SS'` or `'YY-MM-DD HH:MM:SS'` format. A "relaxed" syntax is permitted here, too: Any punctuation character may be used as the delimiter between date parts or time parts. For example, `'2012-12-31 11:30:45'`, `'2012^12^31 11+30+45'`, `'2012/12/31 11*30*45'`, and `'2012@12@31 11^30^45'` are equivalent.

  The date and time parts can be separated by `T` rather than a space. For example, `'2012-12-31 11:30:45'` `'2012-12-31T11:30:45'` are equivalent.

- As a string with no delimiters in either `'YYYYMMDDHHMMSS'` or `'YYMMDDHHMMSS'` format, provided that the string makes sense as a date. For example, `'20070523091528'` and `'070523091528'` are interpreted as `'2007-05-23 09:15:28'`, but `'071122129015'` is illegal (it has a nonsensical minute part) and becomes `'0000-00-00 00:00:00'`.

- As a number in either `YYYYMMDDHHMMSS` or `YYMMDDHHMMSS` format, provided that the number makes sense as a date. For example, `19830905132800` and `830905132800` are interpreted as `'1983-09-05 13:28:00'`.

A `DATETIME` or `TIMESTAMP` value can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `DATETIME` or `TIMESTAMP` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, "Fractional Seconds in Time Values".

Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:

- Year values in the range `70-99` are converted to `1970-1999`.

- Year values in the range `00-69` are converted to `2000-2069`.

See also Section 11.3.8, "Two-Digit Years in Dates".

For values specified as strings that include date part delimiters, it is unnecessary to specify two digits for month or day values that are less than 10. `'2015-6-9'` is the same as `'2015-06-09'`. Similarly, for values specified as strings that include time part delimiters, it is unnecessary to specify two digits for hour, minute, or second values that are less than 10. `'2015-10-30 1:2:3'` is the same as `'2015-10-30 01:02:03'`.

Values specified as numbers should be 6, 8, 12, or 14 digits long. If a number is 8 or 14 digits long, it is assumed to be in `YYYYMMDD` or `YYYYMMDDHHMMSS` format and that the year is given by the first 4 digits. If the number is 6 or 12 digits long, it is assumed to be in `YYMMDD` or `YYMMDDHHMMSS` format and that the year is given by the first 2 digits. Numbers that are not one of these lengths are interpreted as though padded with leading zeros to the closest length.

Values specified as nondelimited strings are interpreted according their length. For a string 8 or 14 characters long, the year is assumed to be given by the first 4 characters. Otherwise, the year is assumed to be given by the first 2 characters. The string is interpreted from left to right to find year, month, day, hour, minute, and second values, for as many parts as are present in the string. This means you should not use strings that have fewer than 6 characters. For example, if you specify `'9903'`, thinking that represents March, 1999, MySQL converts it to the "zero" date value. This occurs because the year and month values are `99` and `03`, but the day part is completely missing. However, you can explicitly specify a value of zero to represent missing month or day parts. For example, to insert the value `'1999-03-00'`, use `'990300'`.

MySQL recognizes `TIME` values in these formats:

- As a string in `'D HH:MM:SS'` format. You can also use one of the following "relaxed" syntaxes: `'HH:MM:SS'`, `'HH:MM'`, `'D HH:MM'`, `'D HH'`, or `'SS'`. Here `D` represents days and can have a value from 0 to 34.

- As a string with no delimiters in `'HHMMSS'` format, provided that it makes sense as a time. For example, `'101112'` is understood as `'10:11:12'`, but `'109712'` is illegal (it has a nonsensical minute part) and becomes `'00:00:00'`.

- As a number in `HHMMSS` format, provided that it makes sense as a time. For example, `101112` is understood as `'10:11:12'`. The following alternative formats are also understood: `SS`, `MMSS`, or `HHMMSS`.

A trailing fractional seconds part is recognized in the `'D HH:MM:SS.fraction'`, `'HH:MM:SS.fraction'`, `'HHMMSS.fraction'`, and `HHMMSS.fraction` time formats, where `fraction` is the fractional part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `TIME` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, "Fractional Seconds in Time Values".

For `TIME` values specified as strings that include a time part delimiter, it is unnecessary to specify two digits for hours, minutes, or seconds values that are less than 10. `'8:3:2'` is the same as `'08:03:02'`.

9.1.4 Hexadecimal Literals

MySQL supports hexadecimal values, written using `X'val'`, `x'val'`, or `0xval` format, where `val` contains hexadecimal digits (`0..9`, `A..F`). Lettercase of the digits does not matter. For values written using `X'val'` or `x'val'` format, `val` must contain an even number of digits. For values written using `0xval syntax`, values that contain an odd number of digits are treated as having an extra leading `0`. For example, `0x0a` and `0xaaa` are interpreted as `0x0a` and `0x0aaa`.

In numeric contexts, hexadecimal values act like integers (64-bit precision). In string contexts, they act like binary strings, where each pair of hex digits is converted to a character:

```
mysql> SELECT X'4D7953514C';
```

```
        -> 'MySQL'
mysql> SELECT x'0a'+0;
        -> 10
mysql> SELECT 0x5061756c;
        -> 'Paul'
```

The default type of a hexadecimal value is a string. If you want to ensure that the value is treated as a number, you can use `CAST(... AS UNSIGNED)`:

```
mysql> SELECT X'41', CAST(X'41' AS UNSIGNED);
        -> 'A', 65
```

The `X'hexstring'` and `x'val'` syntaxes are based on standard SQL. The `0x` syntax is based on ODBC. Hexadecimal strings are often used by ODBC to supply values for `BLOB` columns.

To convert a string or a number to a string in hexadecimal format, use the `HEX()` function:

```
mysql> SELECT HEX('cat');
        -> '636174'
mysql> SELECT X'636174';
        -> 'cat'
```

9.1.5 Boolean Literals

The constants `TRUE` and `FALSE` evaluate to `1` and `0`, respectively. The constant names can be written in any lettercase.

```
mysql> SELECT TRUE, true, FALSE, false;
        -> 1, 1, 0, 0
```

9.1.6 Bit-Field Literals

Bit-field values can be written using `b'value'` or `0bvalue` notation. `value` is a binary value written using zeros and ones.

Bit-field notation is convenient for specifying values to be assigned to `BIT` columns:

```
mysql> CREATE TABLE t (b BIT(8));
mysql> INSERT INTO t SET b = b'11111111';
mysql> INSERT INTO t SET b = b'1010';
mysql> INSERT INTO t SET b = b'0101';
```

Bit values are returned as binary values. To display them in printable form, add 0 or use a conversion function such as `BIN()`. High-order 0 bits are not displayed in the converted value.

```
mysql> SELECT b+0, BIN(b+0), OCT(b+0), HEX(b+0) FROM t;
+------+----------+----------+----------+
| b+0  | BIN(b+0) | OCT(b+0) | HEX(b+0) |
+------+----------+----------+----------+
|  255 | 11111111 | 377      | FF       |
|   10 | 1010     | 12       | A        |
|    5 | 101      | 5        | 5        |
+------+----------+----------+----------+
```

Bit values assigned to user variables are treated as binary strings. To assign a bit value as a number to a user variable, use `CAST()` or `+0`:

```
mysql> SET @v1 = 0b1000001;
mysql> SET @v2 = CAST(0b1000001 AS UNSIGNED), @v3 = 0b1000001+0;
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| A    |   65 |   65 |
+------+------+------+
```

9.1.7 NULL Values

The NULL value means "no data." NULL can be written in any lettercase. A synonym is \N (case sensitive).

For text file import or export operations performed with LOAD DATA INFILE or SELECT ... INTO OUTFILE, NULL is represented by the \N sequence. See Section 13.2.6, "LOAD DATA INFILE Syntax".

Be aware that the NULL value is different from values such as 0 for numeric types or the empty string for string types. For more information, see Section B.5.4.3, "Problems with NULL Values".

9.2 Schema Object Names

Certain objects within MySQL, including database, table, index, column, alias, view, stored procedure, partition, tablespace, and other object names are known as identifiers. This section describes the permissible syntax for identifiers in MySQL. Section 9.2.2, "Identifier Case Sensitivity", describes which types of identifiers are case sensitive and under what conditions.

An identifier may be quoted or unquoted. If an identifier contains special characters or is a reserved word, you *must* quote it whenever you refer to it. (Exception: A reserved word that follows a period in a qualified name must be an identifier, so it need not be quoted.) Reserved words are listed at Section 9.3, "Keywords and Reserved Words".

Identifiers are converted to Unicode internally. They may contain these characters:

- Permitted characters in unquoted identifiers:

  - ASCII: [0-9,a-z,A-Z$_] (basic Latin letters, digits 0-9, dollar, underscore)

  - Extended: U+0080 .. U+FFFF

- Permitted characters in quoted identifiers include the full Unicode Basic Multilingual Plane (BMP), except U+0000:

  - ASCII: U+0001 .. U+007F

  - Extended: U+0080 .. U+FFFF

- ASCII NUL (U+0000) and supplementary characters (U+10000 and higher) are not permitted in quoted or unquoted identifiers.

- Identifiers may begin with a digit but unless quoted may not consist solely of digits.

- Database, table, and column names cannot end with space characters.

- Before MySQL 5.1.6, database and table names cannot contain "/", "\", ".", or characters that are not permitted in file names.

The identifier quote character is the backtick ("`"):

```
mysql> SELECT * FROM `select` WHERE `select`.id > 100;
```

If the `ANSI_QUOTES` SQL mode is enabled, it is also permissible to quote identifiers within double quotation marks:

```
mysql> CREATE TABLE "test" (col INT);
ERROR 1064: You have an error in your SQL syntax...
mysql> SET sql_mode='ANSI_QUOTES';
mysql> CREATE TABLE "test" (col INT);
Query OK, 0 rows affected (0.00 sec)
```

The `ANSI_QUOTES` mode causes the server to interpret double-quoted strings as identifiers. Consequently, when this mode is enabled, string literals must be enclosed within single quotation marks. They cannot be enclosed within double quotation marks. The server SQL mode is controlled as described in Section 5.1.7, "Server SQL Modes".

Identifier quote characters can be included within an identifier if you quote the identifier. If the character to be included within the identifier is the same as that used to quote the identifier itself, then you need to double the character. The following statement creates a table named `` a`b `` that contains a column named `c"d`:

```
mysql> CREATE TABLE `a``b` (`c"d` INT);
```

In the select list of a query, a quoted column alias can be specified using identifier or string quoting characters:

```
mysql> SELECT 1 AS `one`, 2 AS 'two';
+-----+-----+
| one | two |
+-----+-----+
|   1 |   2 |
+-----+-----+
```

Elsewhere in the statement, quoted references to the alias must use identifier quoting or the reference is treated as a string literal.

It is recommended that you do not use names that begin with Me or MeN, where M and N are integers. For example, avoid using `1e` as an identifier, because an expression such as `1e+3` is ambiguous. Depending on context, it might be interpreted as the expression `1e + 3` or as the number `1e+3`.

Be careful when using `MD5()` to produce table names because it can produce names in illegal or ambiguous formats such as those just described.

A user variable cannot be used directly in an SQL statement as an identifier or as part of an identifier. See Section 9.4, "User-Defined Variables", for more information and examples of workarounds.

As of MySQL 5.1.6, special characters in database and table names are encoded in the corresponding file system names as described in Section 9.2.3, "Mapping of Identifiers to File Names". If you have databases or tables from an older version of MySQL that contain special characters and for which the underlying directory names or file names have not been updated to use the new encoding, the server displays their names with a prefix of `#mysql50#`. For information about referring to such names or converting them to the newer encoding, see that section.

The following table describes the maximum length for each type of identifier.

Identifier	Maximum Length (characters)
Database	64 (NDB storage engine: 63)
Table	64 (NDB storage engine: 63)

Identifier	Maximum Length (characters)
Column	64
Index	64
Constraint	64
Stored Program	64
View	64
Tablespace	64
Server	64
Log File Group	64
Alias	256 (see exception following table)
Compound Statement Label	16

As of MySQL 5.1.23, aliases for column names in `CREATE VIEW` statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters).

Identifiers are stored using Unicode (UTF-8). This applies to identifiers in table definitions that are stored in `.frm` files and to identifiers stored in the grant tables in the `mysql` database. The sizes of the identifier string columns in the grant tables are measured in characters. You can use multibyte characters without reducing the number of characters permitted for values stored in these columns. As indicated earlier, the permissible Unicode characters are those in the Basic Multilingual Plane (BMP). Supplementary characters are not permitted.

MySQL Cluster imposes a maximum length of 63 characters for names of databases and tables. See Section 17.1.6.5, "Limits Associated with Database Objects in MySQL Cluster".

9.2.1 Identifier Qualifiers

MySQL permits names that consist of a single identifier or multiple identifiers. The components of a multiple-part name must be separated by period ("`.`") characters. The initial parts of a multiple-part name act as qualifiers that affect the context within which the final identifier is interpreted.

In MySQL, you can refer to a table column using any of the following forms.

Column Reference	Meaning
`col_name`	The column `col_name` from whichever table used in the statement contains a column of that name.
`tbl_name.col_name`	The column `col_name` from table `tbl_name` of the default database.
`db_name.tbl_name.col_name`	The column `col_name` from table `tbl_name` of the database `db_name`.

The qualifier character is a separate token and need not be contiguous with the associated identifiers. For example, `tbl_name.col_name` and `tbl_name . col_name` are equivalent.

If any components of a multiple-part name require quoting, quote them individually rather than quoting the name as a whole. For example, write `` `my-table`.`my-column` ``, not `` `my-table.my-column` ``.

A reserved word that follows a period in a qualified name must be an identifier, so in that context it need not be quoted.

You need not specify a `tbl_name` or `db_name.tbl_name` prefix for a column reference in a statement unless the reference would be ambiguous. Suppose that tables `t1` and `t2` each contain a column `c`, and you retrieve `c` in a `SELECT` statement that uses both `t1` and `t2`. In this case, `c` is ambiguous because it is

not unique among the tables used in the statement. You must qualify it with a table name as `t1.c` or `t2.c` to indicate which table you mean. Similarly, to retrieve from a table `t` in database `db1` and from a table `t` in database `db2` in the same statement, you must refer to columns in those tables as `db1.t.col_name` and `db2.t.col_name`.

The syntax `.tbl_name` means the table `tbl_name` in the default database. This syntax is accepted for ODBC compatibility because some ODBC programs prefix table names with a "`.`" character.

9.2.2 Identifier Case Sensitivity

In MySQL, databases correspond to directories within the data directory. Each table within a database corresponds to at least one file within the database directory (and possibly more, depending on the storage engine). Triggers also correspond to files. Consequently, the case sensitivity of the underlying operating system plays a part in the case sensitivity of database, table, and trigger names. This means such names are not case sensitive in Windows, but are case sensitive in most varieties of Unix. One notable exception is OS X, which is Unix-based but uses a default file system type (HFS+) that is not case sensitive. However, OS X also supports UFS volumes, which are case sensitive just as on any Unix. See Section 1.8.1, "MySQL Extensions to Standard SQL". The `lower_case_table_names` system variable also affects how the server handles identifier case sensitivity, as described later in this section.

> **Note**
>
> Although database, table, and trigger names are not case sensitive on some platforms, you should not refer to one of these using different cases within the same statement. The following statement would not work because it refers to a table both as `my_table` and as `MY_TABLE`:
>
> ```
> mysql> SELECT * FROM my_table WHERE MY_TABLE.col=1;
> ```

Column, index, stored routine, and event names are not case sensitive on any platform, nor are column aliases.

However, names of logfile groups are case sensitive. This differs from standard SQL.

By default, table aliases are case sensitive on Unix, but not so on Windows or OS X. The following statement would not work on Unix, because it refers to the alias both as `a` and as `A`:

```
mysql> SELECT col_name FROM tbl_name AS a
    -> WHERE a.col_name = 1 OR A.col_name = 2;
```

However, this same statement is permitted on Windows. To avoid problems caused by such differences, it is best to adopt a consistent convention, such as always creating and referring to databases and tables using lowercase names. This convention is recommended for maximum portability and ease of use.

How table and database names are stored on disk and used in MySQL is affected by the `lower_case_table_names` system variable, which you can set when starting `mysqld`. `lower_case_table_names` can take the values shown in the following table. This variable does *not* affect case sensitivity of trigger identifiers. On Unix, the default value of `lower_case_table_names` is 0. On Windows, the default value is 1. On OS X, the default value is 2.

Value	Meaning
0	Table and database names are stored on disk using the lettercase specified in the `CREATE TABLE` or `CREATE DATABASE` statement. Name comparisons are case sensitive. You should *not* set this variable to 0 if you are running MySQL on a system that has case-insensitive file names (such as Windows or OS X). If you force this variable to 0 with `--lower-case-`

Value	Meaning
	`table-names=0` on a case-insensitive file system and access `MyISAM` tablenames using different lettercases, index corruption may result.
1	Table names are stored in lowercase on disk and name comparisons are not case sensitive. MySQL converts all table names to lowercase on storage and lookup. This behavior also applies to database names and table aliases.
2	Table and database names are stored on disk using the lettercase specified in the `CREATE TABLE` or `CREATE DATABASE` statement, but MySQL converts them to lowercase on lookup. Name comparisons are not case sensitive. This works *only* on file systems that are not case sensitive! `InnoDB` table names are stored in lowercase, as for `lower_case_table_names=1`.

If you are using MySQL on only one platform, you do not normally have to change the `lower_case_table_names` variable from its default value. However, you may encounter difficulties if you want to transfer tables between platforms that differ in file system case sensitivity. For example, on Unix, you can have two different tables named `my_table` and `MY_TABLE`, but on Windows these two names are considered identical. To avoid data transfer problems arising from lettercase of database or table names, you have two options:

- Use `lower_case_table_names=1` on all systems. The main disadvantage with this is that when you use `SHOW TABLES` or `SHOW DATABASES`, you do not see the names in their original lettercase.

- Use `lower_case_table_names=0` on Unix and `lower_case_table_names=2` on Windows. This preserves the lettercase of database and table names. The disadvantage of this is that you must ensure that your statements always refer to your database and table names with the correct lettercase on Windows. If you transfer your statements to Unix, where lettercase is significant, they do not work if the lettercase is incorrect.

  Exception: If you are using `InnoDB` tables and you are trying to avoid these data transfer problems, you should set `lower_case_table_names` to 1 on all platforms to force names to be converted to lowercase.

If you plan to set the `lower_case_table_names` system variable to 1 on Unix, you must first convert your old database and table names to lowercase before stopping `mysqld` and restarting it with the new variable setting. To do this for an individual table, use `RENAME TABLE`:

```
RENAME TABLE T1 TO t1;
```

To convert one or more entire databases, dump them before setting `lower_case_table_names`, then drop the databases, and reload them after setting `lower_case_table_names`:

1. Use `mysqldump` to dump each database:

   ```
   mysqldump --databases db1 > db1.sql
   mysqldump --databases db2 > db2.sql
   ...
   ```

   Do this for each database that must be recreated.

2. Use `DROP DATABASE` to drop each database.

3. Stop the server, set `lower_case_table_names`, and restart the server.

4. Reload the dump file for each database. Because `lower_case_table_names` is set, each database and table name will be converted to lowercase as it is recreated:

```
mysql < db1.sql
mysql < db2.sql
...
```

Object names may be considered duplicates if their uppercase forms are equal according to a binary collation. That is true for names of cursors, conditions, procedures, functions, savepoints, stored routine parameters, stored program local variables, and plugins. It is not true for names of columns, constraints, databases, partitions, statements prepared with `PREPARE`, tables, triggers, users, and user-defined variables.

File system case sensitivity can affect searches in string columns of `INFORMATION_SCHEMA` tables. For more information, see Section 10.1.7.9, "Collation and INFORMATION_SCHEMA Searches".

9.2.3 Mapping of Identifiers to File Names

There is a correspondence between database and table identifiers and names in the file system. For the basic structure, MySQL represents each database as a directory in the data directory, and each table by one or more files in the appropriate database directory. For the table format files (`.FRM`), the data is always stored in this structure and location.

For the data and index files, the exact representation on disk is storage engine specific. These files may be stored in the same location as the `FRM` files, or the information may be stored in a separate file. `InnoDB` data is stored in the InnoDB data files. If you are using tablespaces with `InnoDB`, then the specific tablespace files you create are used instead.

Before MySQL 5.1.6, there are some limitations on the characters that can be used in identifiers for database objects that correspond to file system objects. For example, path name separator characters are not permitted, and "`.`" is not permitted because it begins the extension for table files.

As of MySQL 5.1.6, any character is legal in database or table identifiers except ASCII NUL (`0x00`). MySQL encodes any characters that are problematic in the corresponding file system objects when it creates database directories or table files:

* Basic Latin letters (`a..zA..Z`), digits (`0..9`) and underscore (`_`) are encoded as is. Consequently, their case sensitivity directly depends on file system features.

* All other national letters from alphabets that have uppercase/lowercase mapping are encoded as shown in the following table. Values in the Code Range column are UCS-2 values.

Code Range	Pattern	Number	Used	Unused	Blocks
00C0..017F	[@][0..4][g..z]	5*20= 100	97	3	Latin-1 Supplement + Latin Extended-A
0370..03FF	[@][5..9][g..z]	5*20= 100	88	12	Greek and Coptic
0400..052F	[@][g..z][0..6]	20*7= 140	137	3	Cyrillic + Cyrillic Supplement
0530..058F	[@][g..z][7..8]	20*2= 40	38	2	Armenian
2160..217F	[@][g..z][9]	20*1= 20	16	4	Number Forms
0180..02AF	[@][g..z][a..k]	20*11=220	203	17	Latin Extended-B + IPA Extensions
1E00..1EFF	[@][g..z][l..r]	20*7= 140	136	4	Latin Extended Additional
1F00..1FFF	[@][g..z][s..z]	20*8= 160	144	16	Greek Extended

Code Range	Pattern	Number	Used	Unused	Blocks
....	[@][a..f][g..z]	6*20= 120	0	120	RESERVED
24B6..24E9	[@][@][a..z]	26	26	0	Enclosed Alphanumerics
FF21..FF5A	[@][a..z][@]	26	26	0	Halfwidth and Fullwidth forms

One of the bytes in the sequence encodes lettercase. For example: `LATIN CAPITAL LETTER A WITH GRAVE` is encoded as `@0G`, whereas `LATIN SMALL LETTER A WITH GRAVE` is encoded as `@0g`. Here the third byte (`G` or `g`) indicates lettercase. (On a case-insensitive file system, both letters will be treated as the same.)

For some blocks, such as Cyrillic, the second byte determines lettercase. For other blocks, such as Latin1 Supplement, the third byte determines lettercase. If two bytes in the sequence are letters (as in Greek Extended), the leftmost letter character stands for lettercase. All other letter bytes must be in lowercase.

- All nonletter characters except underscore (_), as well as letters from alphabets that do not have uppercase/lowercase mapping (such as Hebrew) are encoded using hexadecimal representation using lowercase letters for hex digits `a..f`:

```
0x003F -> @003f
0xFFFF -> @ffff
```

The hexadecimal values correspond to character values in the `ucs2` double-byte character set.

On Windows, some names such as `nul`, `prn`, and `aux` cannot be used as file names because they are reserved as device names. As of MySQL 5.1.10, these are permissible names in MySQL. They are encoded by appending `@@@` to the name when the server creates the corresponding file or directory. This occurs on all platforms for portability of the corresponding database object between platforms.

If you have databases or tables from a version of MySQL older than 5.1.6 that contain special characters and for which the underlying directory names or file names have not been updated to use the new encoding, the server displays their names with a prefix of `#mysql50#` in the output from `INFORMATION_SCHEMA` tables or `SHOW` statements. For example, if you have a table named `a@b` and its name encoding has not been updated, `SHOW TABLES` displays it like this:

```
mysql> SHOW TABLES;
+----------------+
| Tables_in_test |
+----------------+
| #mysql50#a@b   |
+----------------+
```

To refer to such a name for which the encoding has not been updated, you must supply the `#mysql50#` prefix:

```
mysql> SHOW COLUMNS FROM `a@b`;
ERROR 1146 (42S02): Table 'test.a@b' doesn't exist

mysql> SHOW COLUMNS FROM `#mysql50#a@b`;
+-------+---------+------+-----+---------+-------+
| Field | Type    | Null | Key | Default | Extra |
+-------+---------+------+-----+---------+-------+
| i     | int(11) | YES  |     | NULL    |       |
+-------+---------+------+-----+---------+-------+
```

To update old names to eliminate the need to use the special prefix to refer to them, re-encode them with `mysqlcheck`. The following command updates all names to the new encoding:

```
shell> mysqlcheck --check-upgrade --fix-db-names --fix-table-names --all-databases
```

To check only specific databases or tables, omit `--all-databases` and provide the appropriate database or table arguments. For information about `mysqlcheck` invocation syntax, see Section 4.5.3, "`mysqlcheck` — A Table Maintenance Program".

> **Note**
>
> The `#mysql50#` prefix is intended only to be used internally by the server. You should not create databases or tables with names that use this prefix.
>
> Also, `mysqlcheck` cannot fix names that contain literal instances of the `@` character that is used for encoding special characters. If you have databases or tables that contain this character, use `mysqldump` to dump them before upgrading to MySQL 5.1.6 or later, and then reload the dump file after upgrading.

9.2.4 Function Name Parsing and Resolution

MySQL 5.1 supports built-in (native) functions, user-defined functions (UDFs), and stored functions. This section describes how the server recognizes whether the name of a built-in function is used as a function call or as an identifier, and how the server determines which function to use in cases when functions of different types exist with a given name.

Built-In Function Name Parsing

The parser uses default rules for parsing names of built-in functions. These rules can be changed by enabling the `IGNORE_SPACE` SQL mode.

When the parser encounters a word that is the name of a built-in function, it must determine whether the name signifies a function call or is instead a nonexpression reference to an identifier such as a table or column name. For example, in the following statements, the first reference to `count` is a function call, whereas the second reference is a table name:

```
SELECT COUNT(*) FROM mytable;
CREATE TABLE count (i INT);
```

The parser should recognize the name of a built-in function as indicating a function call only when parsing what is expected to be an expression. That is, in nonexpression context, function names are permitted as identifiers.

However, some built-in functions have special parsing or implementation considerations, so the parser uses the following rules by default to distinguish whether their names are being used as function calls or as identifiers in nonexpression context:

- To use the name as a function call in an expression, there must be no whitespace between the name and the following "`(`" parenthesis character.

- Conversely, to use the function name as an identifier, it must not be followed immediately by a parenthesis.

The requirement that function calls be written with no whitespace between the name and the parenthesis applies only to the built-in functions that have special considerations. `COUNT` is one such name. The `sql_functions[]` array in the `sql/lex.h` source file lists the names of these special functions for which following whitespace determines their interpretation. Before MySQL 5.1, these are rather numerous

(about 200). In MySQL 5.1, parser improvements reduce to about 30 the number of affected function names. You may find it easiest to treat the no-whitespace requirement as applying to all function calls.

The following table names the functions that are affected by the `IGNORE_SPACE` setting and listed as special in the `sql/lex.h` source file. For versions older than MySQL 5.1.13, the list is much longer; check the `sql_functions[]` array in the `sql/lex.h` source file.

ADDDATE	BIT_AND	BIT_OR	BIT_XOR
CAST	COUNT	CURDATE	CURTIME
DATE_ADD	DATE_SUB	EXTRACT	GROUP_CONCAT
MAX	MID	MIN	NOW
POSITION	SESSION_USER	STD	STDDEV
STDDEV_POP	STDDEV_SAMP	SUBDATE	SUBSTR
SUBSTRING	SUM	SYSDATE	SYSTEM_USER
TRIM	VARIANCE	VAR_POP	VAR_SAMP

For functions not listed as special in `sql/lex.h`, whitespace does not matter. They are interpreted as function calls only when used in expression context and may be used freely as identifiers otherwise. `ASCII` is one such name. However, for these nonaffected function names, interpretation may vary in expression context: `func_name ()` is interpreted as a built-in function if there is one with the given name; if not, `func_name ()` is interpreted as a user-defined function or stored function if one exists with that name.

The `IGNORE_SPACE` SQL mode can be used to modify how the parser treats function names that are whitespace-sensitive:

- With `IGNORE_SPACE` disabled, the parser interprets the name as a function call when there is no whitespace between the name and the following parenthesis. This occurs even when the function name is used in nonexpression context:

```
mysql> CREATE TABLE count(i INT);
ERROR 1064 (42000): You have an error in your SQL syntax ...
near 'count(i INT)'
```

To eliminate the error and cause the name to be treated as an identifier, either use whitespace following the name or write it as a quoted identifier (or both):

```
CREATE TABLE count (i INT);
CREATE TABLE `count`(i INT);
CREATE TABLE `count` (i INT);
```

- With `IGNORE_SPACE` enabled, the parser loosens the requirement that there be no whitespace between the function name and the following parenthesis. This provides more flexibility in writing function calls. For example, either of the following function calls are legal:

```
SELECT COUNT(*) FROM mytable;
SELECT COUNT (*) FROM mytable;
```

However, enabling `IGNORE_SPACE` also has the side effect that the parser treats the affected function names as reserved words (see Section 9.3, "Keywords and Reserved Words"). This means that a space following the name no longer signifies its use as an identifier. The name can be used in function calls with or without following whitespace, but causes a syntax error in nonexpression context unless it is quoted. For example, with `IGNORE_SPACE` enabled, both of the following statements fail with a syntax error because the parser interprets `count` as a reserved word:

```
CREATE TABLE count(i INT);
CREATE TABLE count (i INT);
```

To use the function name in nonexpression context, write it as a quoted identifier:

```
CREATE TABLE `count`(i INT);
CREATE TABLE `count` (i INT);
```

To enable the `IGNORE_SPACE` SQL mode, use this statement:

```
SET sql_mode = 'IGNORE_SPACE';
```

`IGNORE_SPACE` is also enabled by certain other composite modes such as `ANSI` that include it in their value:

```
SET sql_mode = 'ANSI';
```

Check Section 5.1.7, "Server SQL Modes", to see which composite modes enable `IGNORE_SPACE`.

To minimize the dependency of SQL code on the `IGNORE_SPACE` setting, use these guidelines:

- Avoid creating UDFs or stored functions that have the same name as a built-in function.

- Avoid using function names in nonexpression context. For example, these statements use `count` (one of the affected function names affected by `IGNORE_SPACE`), so they fail with or without whitespace following the name if `IGNORE_SPACE` is enabled:

```
CREATE TABLE count(i INT);
CREATE TABLE count (i INT);
```

If you must use a function name in nonexpression context, write it as a quoted identifier:

```
CREATE TABLE `count`(i INT);
CREATE TABLE `count` (i INT);
```

Incompatibility warning: The change in MySQL 5.1.13 that reduces the number of function names affected by `IGNORE_SPACE` improves the consistency of parser operation. However, it also introduces the possibility of incompatibility for old SQL code that relies on the following conditions:

- `IGNORE_SPACE` is disabled.

- The presence or absence of whitespace following a function name is used to distinguish between a built-in function and stored function that have the same name, such as `PI()` versus `PI ()`.

For functions that are no longer affected by `IGNORE_SPACE` as of MySQL 5.1.13, that strategy no longer works. Either of the following approaches can be used if you have code that is subject to the preceding incompatibility:

- If a stored function has a name that conflicts with a built-in function, refer to the stored function with a schema name qualifier, regardless of whether whitespace is present. For example, write *schema_name*`.PI()` or *schema_name*`.PI ()`.

- Alternatively, rename the stored function to use a nonconflicting name and change invocations of the function to use the new name.

Function Name Resolution

The following rules describe how the server resolves references to function names for function creation and invocation:

- Built-in functions and user-defined functions

  As of MySQL 5.1.14, an error occurs if you try to create a UDF with the same name as a built-in function. Before 5.1.14, a UDF can be created with the same name as a built-in function but the UDF cannot be invoked because the parser resolves invocations of the function to refer to the built-in function. For example, if you create a UDF named `ABS`, references to `ABS()` invoke the built-in function.

- Built-in functions and stored functions

  It is possible to create a stored function with the same name as a built-in function, but to invoke the stored function it is necessary to qualify it with a schema name. For example, if you create a stored function named `PI` in the `test` schema, you invoke it as `test.PI()` because the server resolves `PI()` as a reference to the built-in function. As of 5.1.14, the server creates a warning if the stored function name collides with a built-in function name. The warning can be displayed with `SHOW WARNINGS`.

- User-defined functions and stored functions

  User-defined functions and stored functions share the same namespace, so you cannot create a UDF and a stored function with the same name.

The preceding function name resolution rules have implications for upgrading to versions of MySQL that implement new built-in functions:

- If you have already created a user-defined function with a given name and upgrade MySQL to a version that implements a new built-in function with the same name, the UDF becomes inaccessible. To correct this, use `DROP FUNCTION` to drop the UDF and `CREATE FUNCTION` to re-create the UDF with a different nonconflicting name. Then modify any affected code to use the new name.

- If a new version of MySQL implements a built-in function with the same name as an existing stored function, you have two choices: Rename the stored function to use a nonconflicting name, or change calls to the function so that they use a schema qualifier (that is, use `schema_name.func_name()` syntax). In either case, modify any affected code accordingly.

9.3 Keywords and Reserved Words

Keywords are words that have significance in SQL. Certain keywords, such as `SELECT`, `DELETE`, or `BIGINT`, are reserved and require special treatment for use as identifiers such as table and column names. This may also be true for the names of built-in functions.

Nonreserved keywords are permitted as identifiers without quoting. Reserved words are permitted as identifiers if you quote them as described in Section 9.2, "Schema Object Names":

```
mysql> CREATE TABLE interval (begin INT, end INT);
ERROR 1064 (42000): You have an error in your SQL syntax ...
near 'interval (begin INT, end INT)'
```

`BEGIN` and `END` are keywords but not reserved, so their use as identifiers does not require quoting. `INTERVAL` is a reserved keyword and must be quoted to be used as an identifier:

```
mysql> CREATE TABLE `interval` (begin INT, end INT);
Query OK, 0 rows affected (0.01 sec)
```

Exception: A word that follows a period in a qualified name must be an identifier, so it need not be quoted even if it is reserved:

```
mysql> CREATE TABLE mydb.interval (begin INT, end INT);
Query OK, 0 rows affected (0.01 sec)
```

Names of built-in functions are permitted as identifiers but may require care to be used as such. For example, COUNT is acceptable as a column name. However, by default, no whitespace is permitted in function invocations between the function name and the following "(" character. This requirement enables the parser to distinguish whether the name is used in a function call or in nonfunction context. For further details on recognition of function names, see Section 9.2.4, "Function Name Parsing and Resolution".

The following table shows the keywords and reserved words in MySQL 5.1, along with changes to individual words from version to version. Reserved keywords are marked with (R). In addition, _FILENAME is reserved.

At some point, you might upgrade to a higher version, so it is a good idea to have a look at future reserved words, too. You can find these in the manuals that cover higher versions of MySQL. Most of the reserved words in the table are forbidden by standard SQL as column or table names (for example, GROUP). A few are reserved because MySQL needs them and uses a yacc parser.

Table 9.2 Keywords and Reserved Words in MySQL 5.1

ACCESSIBLE[a] (R)	ACTION	ADD (R)
AFTER	AGAINST	AGGREGATE
ALGORITHM	ALL (R)	ALTER (R)
ANALYZE (R)	AND (R)	ANY
AS (R)	ASC (R)	ASCII
ASENSITIVE (R)	AT[b]	AUTHORS
AUTOEXTEND_SIZE[c]	AUTO_INCREMENT	AVG
AVG_ROW_LENGTH	BACKUP	BDB[d]
BEFORE (R)	BEGIN	BERKELEYDB[e]
BETWEEN (R)	BIGINT (R)	BINARY (R)
BINLOG	BIT	BLOB (R)
BLOCK[f]	BOOL	BOOLEAN
BOTH (R)	BTREE	BY (R)
BYTE	CACHE	CALL (R)
CASCADE (R)	CASCADED	CASE (R)
CHAIN	CHANGE (R)	CHANGED
CHAR (R)	CHARACTER (R)	CHARSET
CHECK (R)	CHECKSUM	CIPHER
CLIENT	CLOSE	COALESCE
CODE	COLLATE (R)	COLLATION
COLUMN (R)	COLUMNS	COMMENT
COMMIT	COMMITTED	COMPACT
COMPLETION[g]	COMPRESSED	CONCURRENT
CONDITION (R)	CONNECTION[h]	CONSISTENT
CONSTRAINT (R)	CONTAINS	CONTEXT[i]

CONTINUE (R)	CONTRIBUTORS[j]	CONVERT (R)
CPU[k]	CREATE (R)	CROSS (R)
CUBE	CURRENT_DATE (R)	CURRENT_TIME (R)
CURRENT_TIMESTAMP (R)	CURRENT_USER (R)	CURSOR (R)
DATA	DATABASE (R)	DATABASES (R)
DATAFILE[l]	DATE	DATETIME
DAY	DAY_HOUR (R)	DAY_MICROSECOND (R)
DAY_MINUTE (R)	DAY_SECOND (R)	DEALLOCATE
DEC (R)	DECIMAL (R)	DECLARE (R)
DEFAULT (R)	DEFINER	DELAYED (R)
DELAY_KEY_WRITE	DELETE (R)	DESC (R)
DESCRIBE (R)	DES_KEY_FILE	DETERMINISTIC (R)
DIRECTORY	DISABLE	DISCARD
DISK[m]	DISTINCT (R)	DISTINCTROW (R)
DIV (R)	DO	DOUBLE (R)
DROP (R)	DUAL (R)	DUMPFILE
DUPLICATE	DYNAMIC	EACH (R)
ELSE (R)	ELSEIF (R)	ENABLE
ENCLOSED (R)	END	ENDS[n]
ENGINE	ENGINES	ENUM
ERRORS	ESCAPE	ESCAPED (R)
EVENT[o]	EVENTS	EVERY[p]
EXECUTE	EXISTS (R)	EXIT (R)
EXPANSION	EXPLAIN (R)	EXTENDED
EXTENT_SIZE[q]	FALSE (R)	FAST
FAULTS[r]	FETCH (R)	FIELDS
FILE	FIRST	FIXED
FLOAT (R)	FLOAT4 (R)	FLOAT8 (R)
FLUSH	FOR (R)	FORCE (R)
FOREIGN (R)	FOUND	FRAC_SECOND
FROM (R)	FULL	FULLTEXT (R)
FUNCTION	GEOMETRY	GEOMETRYCOLLECTION
GET_FORMAT	GLOBAL	GOTO[s]
GRANT (R)	GRANTS	GROUP (R)
HANDLER	HASH	HAVING (R)
HELP	HIGH_PRIORITY (R)	HOST[t]
HOSTS	HOUR	HOUR_MICROSECOND (R)
HOUR_MINUTE (R)	HOUR_SECOND (R)	IDENTIFIED
IF (R)	IGNORE (R)	IMPORT

IN (R)	INDEX (R)	INDEXES
INFILE (R)	INITIAL_SIZE[u]	INNER (R)
INNOBASE	INNODB	INOUT (R)
INSENSITIVE (R)	INSERT (R)	INSERT_METHOD
INSTALL	INT (R)	INT1 (R)
INT2 (R)	INT3 (R)	INT4 (R)
INT8 (R)	INTEGER (R)	INTERVAL (R)
INTO (R)	INVOKER	IO[v]
IO_THREAD	IPC[w]	IS (R)
ISOLATION	ISSUER	ITERATE (R)
JOIN (R)	KEY (R)	KEYS (R)
KEY_BLOCK_SIZE[x]	KILL (R)	LABEL[y]
LANGUAGE	LAST	LEADING (R)
LEAVE (R)	LEAVES	LEFT (R)
LESS	LEVEL	LIKE (R)
LIMIT (R)	LINEAR (R)	LINES (R)
LINESTRING	LIST	LOAD (R)
LOCAL	LOCALTIME (R)	LOCALTIMESTAMP (R)
LOCK (R)	LOCKS	LOGFILE[z]
LOGS	LONG (R)	LONGBLOB (R)
LONGTEXT (R)	LOOP (R)	LOW_PRIORITY (R)
MASTER	MASTER_CONNECT_RETRY	MASTER_HOST
MASTER_LOG_FILE	MASTER_LOG_POS	MASTER_PASSWORD
MASTER_PORT	MASTER_SERVER_ID	MASTER_SSL
MASTER_SSL_CA	MASTER_SSL_CAPATH	MASTER_SSL_CERT
MASTER_SSL_CIPHER	MASTER_SSL_KEY	MASTER_SSL_VERIFY_SERVER_CERT[aa] (R)
MASTER_USER	MATCH (R)	MAXVALUE
MAX_CONNECTIONS_PER_HOUR	MAX_QUERIES_PER_HOUR	MAX_ROWS
MAX_SIZE[ab]	MAX_UPDATES_PER_HOUR	MAX_USER_CONNECTIONS
MEDIUM	MEDIUMBLOB (R)	MEDIUMINT (R)
MEDIUMTEXT (R)	MEMORY[ac]	MERGE
MICROSECOND	MIDDLEINT (R)	MIGRATE
MINUTE	MINUTE_MICROSECOND (R)	MINUTE_SECOND (R)
MIN_ROWS	MOD (R)	MODE
MODIFIES (R)	MODIFY	MONTH
MULTILINESTRING	MULTIPOINT	MULTIPOLYGON
MUTEX	NAME	NAMES
NATIONAL	NATURAL (R)	NCHAR

NDB	NDBCLUSTER	NEW
NEXT	NO	NODEGROUP
NONE	NOT (R)	NO_WAIT[ad]
NO_WRITE_TO_BINLOG (R)	NULL (R)	NUMERIC (R)
NVARCHAR	OFFSET	OLD_PASSWORD
ON (R)	ONE	ONE_SHOT
OPEN	OPTIMIZE (R)	OPTION (R)
OPTIONALLY (R)	OPTIONS[ae]	OR (R)
ORDER (R)	OUT (R)	OUTER (R)
OUTFILE (R)	OWNER[af]	PACK_KEYS
PAGE[ag]	PAGE_CHECKSUM[ah]	PARSER
PARTIAL	PARTITION	PARTITIONING[ai]
PARTITIONS	PASSWORD	PHASE
PLUGIN	PLUGINS[aj]	POINT
POLYGON	PORT[ak]	PRECISION (R)
PREPARE	PRESERVE[al]	PREV
PRIMARY (R)	PRIVILEGES	PROCEDURE (R)
PROCESSLIST	PROFILE[am]	PROFILES[an]
PURGE (R)	QUARTER	QUERY
QUICK	RAID0[ao]	RAID_CHUNKS[ap]
RAID_CHUNKSIZE[aq]	RAID_TYPE[ar]	RANGE (R)
READ (R)	READS (R)	READ_ONLY[as]
READ_WRITE[at] (R)	REAL (R)	REBUILD[au]
RECOVER	REDOFILE[av]	REDO_BUFFER_SIZE[aw]
REDUNDANT	REFERENCES (R)	REGEXP (R)
RELAY_LOG_FILE	RELAY_LOG_POS	RELAY_THREAD
RELEASE (R)	RELOAD	REMOVE[ax]
RENAME (R)	REORGANISE[ay]	REORGANIZE[az]
REPAIR	REPEAT (R)	REPEATABLE
REPLACE (R)	REPLICATION	REQUIRE (R)
RESET	RESTORE	RESTRICT (R)
RESUME	RETURN (R)	RETURNS
REVOKE (R)	RIGHT (R)	RLIKE (R)
ROLLBACK	ROLLUP	ROUTINE
ROW	ROWS	ROW_FORMAT
RTREE	SAVEPOINT	SCHEDULE[ba]
SCHEDULER[bb]	SCHEMA (R)	SCHEMAS (R)
SECOND	SECOND_MICROSECOND (R)	SECURITY
SELECT (R)	SENSITIVE (R)	SEPARATOR (R)

SERIAL	SERIALIZABLE	SERVER[bc]
SESSION	SET (R)	SHARE
SHOW (R)	SHUTDOWN	SIGNED
SIMPLE	SLAVE	SMALLINT (R)
SNAPSHOT	SOCKET[bd]	SOME
SONAME	SOUNDS	SOURCE[be]
SPATIAL (R)	SPECIFIC (R)	SQL (R)
SQLEXCEPTION (R)	SQLSTATE (R)	SQLWARNING (R)
SQL_BIG_RESULT (R)	SQL_BUFFER_RESULT	SQL_CACHE
SQL_CALC_FOUND_ROWS (R)	SQL_NO_CACHE	SQL_SMALL_RESULT (R)
SQL_THREAD	SQL_TSI_DAY	SQL_TSI_FRAC_SECOND
SQL_TSI_HOUR	SQL_TSI_MINUTE	SQL_TSI_MONTH
SQL_TSI_QUARTER	SQL_TSI_SECOND	SQL_TSI_WEEK
SQL_TSI_YEAR	SSL (R)	START
STARTING (R)	STARTS[bf]	STATUS
STOP	STORAGE	STRAIGHT_JOIN (R)
STRING	STRIPED[bg]	SUBJECT
SUBPARTITION	SUBPARTITIONS	SUPER
SUSPEND	SWAPS[bh]	SWITCHES[bi]
TABLE (R)	TABLES	TABLESPACE
TABLE_CHECKSUM[bj]	TEMPORARY	TEMPTABLE
TERMINATED (R)	TEXT	THAN
THEN (R)	TIME	TIMESTAMP
TIMESTAMPADD	TIMESTAMPDIFF	TINYBLOB (R)
TINYINT (R)	TINYTEXT (R)	TO (R)
TRAILING (R)	TRANSACTION	TRANSACTIONAL[bk]
TRIGGER (R)	TRIGGERS	TRUE (R)
TRUNCATE	TYPE	TYPES
UNCOMMITTED	UNDEFINED	UNDO (R)
UNDOFILE[bl]	UNDO_BUFFER_SIZE[bm]	UNICODE
UNINSTALL	UNION (R)	UNIQUE (R)
UNKNOWN	UNLOCK (R)	UNSIGNED (R)
UNTIL	UPDATE (R)	UPGRADE[bn]
USAGE (R)	USE (R)	USER
USER_RESOURCES	USE_FRM	USING (R)
UTC_DATE (R)	UTC_TIME (R)	UTC_TIMESTAMP (R)
VALUE	VALUES (R)	VARBINARY (R)
VARCHAR (R)	VARCHARACTER (R)	VARIABLES
VARYING (R)	VIEW	WAIT[bo]

`WARNINGS`	`WEEK`	`WHEN` (R)
`WHERE` (R)	`WHILE` (R)	`WITH` (R)
`WORK`	`WRAPPER`^{bp}	`WRITE` (R)
`X509`	`XA`	`XOR` (R)
`YEAR`	`YEAR_MONTH` (R)	`ZEROFILL` (R)

[a]`ACCESSIBLE`: added in 5.1.6 (reserved)

[b]`AT`: added in 5.1.6 (nonreserved)

[c]`AUTOEXTEND_SIZE`: added in 5.1.6 (nonreserved)

[d]`BDB`: removed in 5.1.12

[e]`BERKELEYDB`: removed in 5.1.12

[f]`BLOCK`: added in 5.1.24 (nonreserved)

[g]`COMPLETION`: added in 5.1.6 (nonreserved)

[h]`CONNECTION`: became nonreserved in 5.1.16

[i]`CONTEXT`: added in 5.1.24 (nonreserved)

[j]`CONTRIBUTORS`: added in 5.1.12 (nonreserved)

[k]`CPU`: added in 5.1.24 (nonreserved)

[l]`DATAFILE`: added in 5.1.6 (nonreserved)

[m]`DISK`: added in 5.1.6 (nonreserved)

[n]`ENDS`: added in 5.1.6 (nonreserved)

[o]`EVENT`: added in 5.1.6 (nonreserved)

[p]`EVERY`: added in 5.1.6 (nonreserved)

[q]`EXTENT_SIZE`: added in 5.1.6 (nonreserved)

[r]`FAULTS`: added in 5.1.24 (nonreserved)

[s]`GOTO`: removed in 5.1.11

[t]`HOST`: added in 5.1.15 (nonreserved)

[u]`INITIAL_SIZE`: added in 5.1.6 (nonreserved)

[v]`IO`: added in 5.1.24 (nonreserved)

[w]`IPC`: added in 5.1.24 (nonreserved)

[x]`KEY_BLOCK_SIZE`: added in 5.1.11 (nonreserved)

[y]`LABEL`: removed in 5.1.11

[z]`LOGFILE`: added in 5.1.6 (nonreserved)

[aa]`MASTER_SSL_VERIFY_SERVER_CERT`: added in 5.1.18 (reserved)

[ab]`MAX_SIZE`: added in 5.1.6 (nonreserved)

[ac]`MEMORY`: added in 5.1.6 (nonreserved)

[ad]`NO_WAIT`: added in 5.1.6 (nonreserved)

[ae]`OPTIONS`: added in 5.1.15 (nonreserved)

[af]`OWNER`: added in 5.1.15 (nonreserved)

[ag]`PAGE`: added in 5.1.24 (nonreserved)

[ah]`PAGE_CHECKSUM`: added in 5.1.24 (nonreserved); removed in 5.1.38

[ai]`PARTITIONING`: added in 5.1.9 (nonreserved)

[aj]`PLUGINS`: added in 5.1.9 (nonreserved)

[ak]`PORT`: added in 5.1.15 (nonreserved)

[al]`PRESERVE`: added in 5.1.6 (nonreserved)

[am]`PROFILE`: added in 5.1.24 (nonreserved)

[an]`PROFILES`: added in 5.1.24 (nonreserved)

[ao]`RAID0`: removed in 5.1.7

[ap]`RAID_CHUNKS`: removed in 5.1.7

[aq]`RAID_CHUNKSIZE`: removed in 5.1.7

[ar]`RAID_TYPE`: removed in 5.1.7

[as]`READ_ONLY`: added in 5.1.6 (reserved); became nonreserved in 5.1.24

[at]`READ_WRITE`: added in 5.1.6 (reserved)

[au]`REBUILD`: added in 5.1.6 (nonreserved)

[av]`REDOFILE`: added in 5.1.6 (nonreserved)

[aw]REDO_BUFFER_SIZE: added in 5.1.6 (nonreserved)

[ax]REMOVE: added in 5.1.9 (nonreserved)

[ay]REORGANISE: removed in 5.1.6

[az]REORGANIZE: added in 5.1.6 (nonreserved)

[ba]SCHEDULE: added in 5.1.6 (nonreserved)

[bb]SCHEDULER: added in 5.1.11 (nonreserved); removed in 5.1.12

[bc]SERVER: added in 5.1.15 (nonreserved)

[bd]SOCKET: added in 5.1.15 (nonreserved)

[be]SOURCE: added in 5.1.24 (nonreserved)

[bf]STARTS: added in 5.1.6 (nonreserved)

[bg]STRIPED: removed in 5.1.7

[bh]SWAPS: added in 5.1.24 (nonreserved)

[bi]SWITCHES: added in 5.1.24 (nonreserved)

[bj]TABLE_CHECKSUM: added in 5.1.24 (nonreserved)

[bk]TRANSACTIONAL: added in 5.1.24 (nonreserved); removed in 5.1.38

[bl]UNDOFILE: added in 5.1.6 (nonreserved)

[bm]UNDO_BUFFER_SIZE: added in 5.1.6 (nonreserved)

[bn]UPGRADE: added in 5.1.7 (reserved); became nonreserved in 5.1.12

[bo]WAIT: added in 5.1.6 (nonreserved)

[bp]WRAPPER: added in 5.1.15 (nonreserved)

The following table shows the keywords and reserved words that are added in MySQL 5.1. Reserved keywords are marked with (R).

Table 9.3 Keywords and Reserved Words Added in MySQL 5.1 Compared to MySQL 5.0

ACCESSIBLE (R)	AT	AUTHORS
AUTOEXTEND_SIZE	COALESCE	COMPLETION
CONTRIBUTORS	DATAFILE	DISK
ENDS	EVENT	EVERY
EXTENT_SIZE	HOST	INITIAL_SIZE
INSTALL	KEY_BLOCK_SIZE	LESS
LINEAR (R)	LIST	LOGFILE
MASTER_SSL_VERIFY_SERVER_CERT (R)	MAXVALUE	MAX_SIZE
NODEGROUP	NO_WAIT	OPTIONS
OWNER	PARSER	PARTITION
PARTITIONING	PARTITIONS	PLUGIN
PLUGINS	PORT	PRESERVE
RANGE (R)	READ_ONLY	READ_WRITE (R)
REBUILD	REDOFILE	REDO_BUFFER_SIZE
REMOVE	REORGANIZE	SCHEDULE
SERVER	SOCKET	STARTS
SUBPARTITION	SUBPARTITIONS	TABLE_CHECKSUM
THAN	UNDOFILE	UNDO_BUFFER_SIZE
UNINSTALL	WAIT	WRAPPER

The following table shows the keywords and reserved words that are removed in MySQL 5.1. Reserved keywords are marked with (R).

Table 9.4 Keywords and Reserved Words Removed in MySQL 5.1 Compared to MySQL 5.0

BDB	BERKELEYDB	RAID0
RAID_CHUNKS	RAID_CHUNKSIZE	RAID_TYPE
STRIPED		

9.4 User-Defined Variables

You can store a value in a user-defined variable in one statement and then refer to it later in another statement. This enables you to pass values from one statement to another.

User variables are written as @*var_name*, where the variable name *var_name* consists of alphanumeric characters, ".", "_", and "$". A user variable name can contain other characters if you quote it as a string or identifier (for example, @'my-var', @"my-var", or @`my-var`).

User-defined variables are session-specific. That is, a user variable defined by one client cannot be seen or used by other clients. All variables for a given client session are automatically freed when that client exits.

User variable names are not case sensitive in MySQL 5.0 and up.

One way to set a user-defined variable is by issuing a SET statement:

```
SET @var_name = expr [, @var_name = expr] ...
```

For SET, either = or := can be used as the assignment operator.

You can also assign a value to a user variable in statements other than SET. In this case, the assignment operator must be := and not = because the latter is treated as the comparison operator = in non-SET statements:

```
mysql> SET @t1=1, @t2=2, @t3:=4;
mysql> SELECT @t1, @t2, @t3, @t4 := @t1+@t2+@t3;
+------+------+------+--------------------+
| @t1  | @t2  | @t3  | @t4 := @t1+@t2+@t3 |
+------+------+------+--------------------+
|    1 |    2 |    4 |                  7 |
+------+------+------+--------------------+
```

User variables can be assigned a value from a limited set of data types: integer, decimal, floating-point, binary or nonbinary string, or NULL value. Assignment of decimal and real values does not preserve the precision or scale of the value. A value of a type other than one of the permissible types is converted to a permissible type. For example, a value having a temporal or spatial data type is converted to a binary string.

If a user variable is assigned a nonbinary (character) string value, it has the same character set and collation as the string. The coercibility of user variables is implicit. (This is the same coercibility as for table column values.)

Bit values assigned to user variables are treated as binary strings. To assign a bit value as a number to a user variable, use CAST() or +0:

```
mysql> SET @v1 = b'1000001';
mysql> SET @v2 = CAST(b'1000001' AS UNSIGNED), @v3 = b'1000001'+0;
```

```
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| A    |   65 |   65 |
+------+------+------+
```

If the value of a user variable is selected in a result set, it is returned to the client as a string.

If you refer to a variable that has not been initialized, it has a value of `NULL` and a type of string.

User variables may be used in most contexts where expressions are permitted. This does not currently include contexts that explicitly require a literal value, such as in the `LIMIT` clause of a `SELECT` statement, or the `IGNORE` `N` `LINES` clause of a `LOAD DATA` statement.

As a general rule, other than in `SET` statements, you should never assign a value to a user variable and read the value within the same statement. For example, to increment a variable, this is okay:

```
SET @a = @a + 1;
```

For other statements, such as `SELECT`, you might get the results you expect, but this is not guaranteed. In the following statement, you might think that MySQL will evaluate `@a` first and then do an assignment second:

```
SELECT @a, @a:=@a+1, ...;
```

However, the order of evaluation for expressions involving user variables is undefined.

Another issue with assigning a value to a variable and reading the value within the same non-`SET` statement is that the default result type of a variable is based on its type at the start of the statement. The following example illustrates this:

```
mysql> SET @a='test';
mysql> SELECT @a,(@a:=20) FROM tbl_name;
```

For this `SELECT` statement, MySQL reports to the client that column one is a string and converts all accesses of `@a` to strings, even though @a is set to a number for the second row. After the `SELECT` statement executes, `@a` is regarded as a number for the next statement.

To avoid problems with this behavior, either do not assign a value to and read the value of the same variable within a single statement, or else set the variable to `0`, `0.0`, or `''` to define its type before you use it.

In a `SELECT` statement, each select expression is evaluated only when sent to the client. This means that in a `HAVING`, `GROUP BY`, or `ORDER BY` clause, referring to a variable that is assigned a value in the select expression list does *not* work as expected:

```
mysql> SELECT (@aa:=id) AS a, (@aa+3) AS b FROM tbl_name HAVING b=5;
```

The reference to `b` in the `HAVING` clause refers to an alias for an expression in the select list that uses `@aa`. This does not work as expected: `@aa` contains the value of `id` from the previous selected row, not from the current row.

User variables are intended to provide data values. They cannot be used directly in an SQL statement as an identifier or as part of an identifier, such as in contexts where a table or database name is expected, or

as a reserved word such as `SELECT`. This is true even if the variable is quoted, as shown in the following example:

```
mysql> SELECT c1 FROM t;
+----+
| c1 |
+----+
|  0 |
+----+
|  1 |
+----+
2 rows in set (0.00 sec)

mysql> SET @col = "c1";
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @col FROM t;
+------+
| @col |
+------+
| c1   |
+------+
1 row in set (0.00 sec)

mysql> SELECT `@col` FROM t;
ERROR 1054 (42S22): Unknown column '@col' in 'field list'

mysql> SET @col = "`c1`";
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @col FROM t;
+------+
| @col |
+------+
| `c1` |
+------+
1 row in set (0.00 sec)
```

An exception to this principle that user variables cannot be used to provide identifiers, is when you are constructing a string for use as a prepared statement to execute later. In this case, user variables can be used to provide any part of the statement. The following example illustrates how this can be done:

```
mysql> SET @c = "c1";
Query OK, 0 rows affected (0.00 sec)

mysql> SET @s = CONCAT("SELECT ", @c, " FROM t");
Query OK, 0 rows affected (0.00 sec)

mysql> PREPARE stmt FROM @s;
Query OK, 0 rows affected (0.04 sec)
Statement prepared

mysql> EXECUTE stmt;
+----+
| c1 |
+----+
|  0 |
+----+
|  1 |
+----+
2 rows in set (0.00 sec)

mysql> DEALLOCATE PREPARE stmt;
Query OK, 0 rows affected (0.00 sec)
```

See Section 13.5, "SQL Syntax for Prepared Statements", for more information.

A similar technique can be used in application programs to construct SQL statements using program variables, as shown here using PHP 5:

```php
<?php
  $mysqli = new mysqli("localhost", "user", "pass", "test");

  if( mysqli_connect_errno() )
    die("Connection failed: %s\n", mysqli_connect_error());

  $col = "c1";

  $query = "SELECT $col FROM t";

  $result = $mysqli->query($query);

  while($row = $result->fetch_assoc())
  {
    echo "<p>" . $row["$col"] . "</p>\n";
  }

  $result->close();

  $mysqli->close();
?>
```

Assembling an SQL statement in this fashion is sometimes known as "Dynamic SQL".

9.5 Expression Syntax

The following rules define expression syntax in MySQL. The grammar shown here is based on that given in the `sql/sql_yacc.yy` file of MySQL source distributions. See the notes after the grammar for additional information about some of the terms.

```
expr:
    expr OR expr
  | expr || expr
  | expr XOR expr
  | expr AND expr
  | expr && expr
  | NOT expr
  | ! expr
  | boolean_primary IS [NOT] {TRUE | FALSE | UNKNOWN}
  | boolean_primary

boolean_primary:
    boolean_primary IS [NOT] NULL
  | boolean_primary <=> predicate
  | boolean_primary comparison_operator predicate
  | boolean_primary comparison_operator {ALL | ANY} (subquery)
  | predicate

comparison_operator: = | >= | > | <= | < | <> | !=

predicate:
    bit_expr [NOT] IN (subquery)
  | bit_expr [NOT] IN (expr [, expr] ...)
  | bit_expr [NOT] BETWEEN bit_expr AND predicate
  | bit_expr SOUNDS LIKE bit_expr
  | bit_expr [NOT] LIKE simple_expr [ESCAPE simple_expr]
  | bit_expr [NOT] REGEXP bit_expr
  | bit_expr
```

```
bit_expr:
    bit_expr | bit_expr
  | bit_expr & bit_expr
  | bit_expr << bit_expr
  | bit_expr >> bit_expr
  | bit_expr + bit_expr
  | bit_expr - bit_expr
  | bit_expr * bit_expr
  | bit_expr / bit_expr
  | bit_expr DIV bit_expr
  | bit_expr MOD bit_expr
  | bit_expr % bit_expr
  | bit_expr ^ bit_expr
  | bit_expr + interval_expr
  | bit_expr - interval_expr
  | simple_expr

simple_expr:
    literal
  | identifier
  | function_call
  | simple_expr COLLATE collation_name
  | param_marker
  | variable
  | simple_expr || simple_expr
  | + simple_expr
  | - simple_expr
  | ~ simple_expr
  | ! simple_expr
  | BINARY simple_expr
  | (expr [, expr] ...)
  | ROW (expr, expr [, expr] ...)
  | (subquery)
  | EXISTS (subquery)
  | {identifier expr}
  | match_expr
  | case_expr
  | interval_expr
```

Notes:

For operator precedence, see in Section 12.3.1, "Operator Precedence".

For literal value syntax, see Section 9.1, "Literal Values".

For identifier syntax, see Section 9.2, "Schema Object Names".

Variables can be user variables, system variables, or stored program local variables or parameters:

• User variables: Section 9.4, "User-Defined Variables"

• System variables: Section 5.1.5, "Using System Variables"

• Local variables: Section 13.6.4.1, "Local Variable DECLARE Syntax"

• Parameters: Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax"

param_marker is ? as used in prepared statements for placeholders. See Section 13.5.1, "PREPARE Syntax".

(subquery) indicates a subquery that returns a single value; that is, a scalar subquery. See Section 13.2.9.1, "The Subquery as Scalar Operand".

{identifier expr} is ODBC escape syntax and is accepted for ODBC compatibility. The value is *expr*. The curly braces in the syntax should be written literally; they are not metasyntax as used elsewhere in syntax descriptions.

match_expr indicates a `MATCH` expression. See Section 12.9, "Full-Text Search Functions".

case_expr indicates a `CASE` expression. See Section 12.4, "Control Flow Functions".

interval_expr represents a time interval. The syntax is `INTERVAL expr unit`, where *unit* is a specifier such as `HOUR`, `DAY`, or `WEEK`. For the full list of *unit* specifiers, see the description of the `DATE_ADD()` function in Section 12.7, "Date and Time Functions".

The meaning of some operators depends on the SQL mode:

- By default, `||` is a logical `OR` operator. With `PIPES_AS_CONCAT` enabled, `||` is string concatenation, with a precedence between `^` and the unary operators.

- By default, `!` has a higher precedence than `NOT`. With `HIGH_NOT_PRECEDENCE` enabled, `!` and `NOT` have the same precedence.

See Section 5.1.7, "Server SQL Modes".

9.6 Comment Syntax

MySQL Server supports three comment styles:

- From a "`#`" character to the end of the line.

- From a "`--`" sequence to the end of the line. In MySQL, the "`--`" (double-dash) comment style requires the second dash to be followed by at least one whitespace or control character (such as a space, tab, newline, and so on). This syntax differs slightly from standard SQL comment syntax, as discussed in Section 1.8.2.5, "'--' as the Start of a Comment".

- From a `/*` sequence to the following `*/` sequence, as in the C programming language. This syntax enables a comment to extend over multiple lines because the beginning and closing sequences need not be on the same line.

The following example demonstrates all three comment styles:

```
mysql> SELECT 1+1;     # This comment continues to the end of line
mysql> SELECT 1+1;     -- This comment continues to the end of line
mysql> SELECT 1 /* this is an in-line comment */ + 1;
mysql> SELECT 1+
/*
this is a
multiple-line comment
*/
1;
```

Nested comments are not supported. (Under some conditions, nested comments might be permitted, but usually are not, and users should avoid them.)

MySQL Server supports some variants of C-style comments. These enable you to write code that includes MySQL extensions, but is still portable, by using comments of the following form:

```
/*! MySQL-specific code */
```

In this case, MySQL Server parses and executes the code within the comment as it would any other SQL statement, but other SQL servers will ignore the extensions. For example, MySQL Server recognizes the STRAIGHT_JOIN keyword in the following statement, but other servers will not:

```
SELECT /*! STRAIGHT_JOIN */ col1 FROM table1,table2 WHERE ...
```

If you add a version number after the "!" character, the syntax within the comment is executed only if the MySQL version is greater than or equal to the specified version number. The TEMPORARY keyword in the following comment is executed only by servers from MySQL 3.23.02 or higher:

```
CREATE /*!32302 TEMPORARY */ TABLE t (a INT);
```

The comment syntax just described applies to how the mysqld server parses SQL statements. The mysql client program also performs some parsing of statements before sending them to the server. (It does this to determine statement boundaries within a multiple-statement input line.)

Comments in this format, /*!12345 ... */, are not stored on the server. If this format is used to comment stored routines, the comments will not be retained on the server.

The use of short-form mysql commands such as \C within multiple-line /* ... */ comments is not supported.

Chapter 10 Globalization

Table of Contents

This chapter covers issues of globalization, which includes internationalization (MySQL's capabilities for adapting to local use) and localization (selecting particular local conventions):

• MySQL support for character sets in SQL statements.

• How to configure the server to support different character sets.

• Selecting the language for error messages.

• How to set the server's time zone and enable per-connection time zone support.

• Selecting the locale for day and month names.

10.1 Character Set Support

MySQL includes character set support that enables you to store data using a variety of character sets and perform comparisons according to a variety of collations. You can specify character sets at the server,

database, table, and column level. MySQL supports the use of character sets for the `MyISAM`, `MEMORY`, `NDBCLUSTER`, and `InnoDB` storage engines.

This chapter discusses the following topics:

- What are character sets and collations?

- The multiple-level default system for character set assignment.

- Syntax for specifying character sets and collations.

- Affected functions and operations.

- Unicode support.

- The character sets and collations that are available, with notes.

Character set issues affect not only data storage, but also communication between client programs and the MySQL server. If you want the client program to communicate with the server using a character set different from the default, you'll need to indicate which one. For example, to use the `utf8` Unicode character set, issue this statement after connecting to the server:

```
SET NAMES 'utf8';
```

For more information about configuring character sets for application use and character set-related issues in client/server communication, see Section 10.1.5, "Configuring the Character Set and Collation for Applications", and Section 10.1.4, "Connection Character Sets and Collations".

10.1.1 Character Sets and Collations in General

A *character set* is a set of symbols and encodings. A *collation* is a set of rules for comparing characters in a character set. Let's make the distinction clear with an example of an imaginary character set.

Suppose that we have an alphabet with four letters: "`A`", "`B`", "`a`", "`b`". We give each letter a number: "`A`" = 0, "`B`" = 1, "`a`" = 2, "`b`" = 3. The letter "`A`" is a symbol, the number 0 is the **encoding** for "`A`", and the combination of all four letters and their encodings is a **character set**.

Suppose that we want to compare two string values, "`A`" and "`B`". The simplest way to do this is to look at the encodings: 0 for "`A`" and 1 for "`B`". Because 0 is less than 1, we say "`A`" is less than "`B`". What we've just done is apply a collation to our character set. The collation is a set of rules (only one rule in this case): "compare the encodings." We call this simplest of all possible collations a *binary* collation.

But what if we want to say that the lowercase and uppercase letters are equivalent? Then we would have at least two rules: (1) treat the lowercase letters "`a`" and "`b`" as equivalent to "`A`" and "`B`"; (2) then compare the encodings. We call this a *case-insensitive* collation. It is a little more complex than a binary collation.

In real life, most character sets have many characters: not just "`A`" and "`B`" but whole alphabets, sometimes multiple alphabets or eastern writing systems with thousands of characters, along with many special symbols and punctuation marks. Also in real life, most collations have many rules, not just for whether to distinguish lettercase, but also for whether to distinguish accents (an "accent" is a mark attached to a character as in German "Ö"), and for multiple-character mappings (such as the rule that "Ö" = "`OE`" in one of the two German collations).

MySQL can do these things for you:

- Store strings using a variety of character sets.

- Compare strings using a variety of collations.

- Mix strings with different character sets or collations in the same server, the same database, or even the same table.

- Enable specification of character set and collation at any level.

In these respects, MySQL is far ahead of most other database management systems. However, to use these features effectively, you need to know what character sets and collations are available, how to change the defaults, and how they affect the behavior of string operators and functions.

10.1.2 Character Sets and Collations in MySQL

The MySQL server supports multiple character sets. To list the available character sets, use the `SHOW CHARACTER SET` statement. A partial listing follows. For more complete information, see Section 10.1.13, "Character Sets and Collations That MySQL Supports".

```
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese    | big5_chinese_ci     |      2 |
| dec8     | DEC West European           | dec8_swedish_ci     |      1 |
| cp850    | DOS West European           | cp850_general_ci    |      1 |
| hp8      | HP West European            | hp8_english_ci      |      1 |
| koi8r    | KOI8-R Relcom Russian       | koi8r_general_ci    |      1 |
| latin1   | cp1252 West European        | latin1_swedish_ci   |      1 |
| latin2   | ISO 8859-2 Central European | latin2_general_ci   |      1 |
| swe7     | 7bit Swedish                | swe7_swedish_ci     |      1 |
| ascii    | US ASCII                    | ascii_general_ci    |      1 |
| ujis     | EUC-JP Japanese             | ujis_japanese_ci    |      3 |
| sjis     | Shift-JIS Japanese          | sjis_japanese_ci    |      2 |
| hebrew   | ISO 8859-8 Hebrew           | hebrew_general_ci   |      1 |
| tis620   | TIS620 Thai                 | tis620_thai_ci      |      1 |
| euckr    | EUC-KR Korean               | euckr_korean_ci     |      2 |
| koi8u    | KOI8-U Ukrainian            | koi8u_general_ci    |      1 |
| gb2312   | GB2312 Simplified Chinese    | gb2312_chinese_ci   |      2 |
| greek    | ISO 8859-7 Greek            | greek_general_ci    |      1 |
| cp1250   | Windows Central European    | cp1250_general_ci   |      1 |
| gbk      | GBK Simplified Chinese      | gbk_chinese_ci      |      2 |
| latin5   | ISO 8859-9 Turkish          | latin5_turkish_ci   |      1 |
...
```

Any given character set always has at least one collation. It may have several collations. To list the collations for a character set, use the `SHOW COLLATION` statement. For example, to see the collations for the `latin1` (cp1252 West European) character set, use this statement to find those collation names that begin with `latin1`:

```
mysql> SHOW COLLATION LIKE 'latin1%';
+---------------------+---------+----+---------+----------+---------+
| Collation           | Charset | Id | Default | Compiled | Sortlen |
+---------------------+---------+----+---------+----------+---------+
| latin1_german1_ci   | latin1  |  5 |         |          |       0 |
| latin1_swedish_ci   | latin1  |  8 | Yes     | Yes      |       1 |
| latin1_danish_ci    | latin1  | 15 |         |          |       0 |
| latin1_german2_ci   | latin1  | 31 |         | Yes      |       2 |
| latin1_bin          | latin1  | 47 |         | Yes      |       1 |
| latin1_general_ci   | latin1  | 48 |         |          |       0 |
| latin1_general_cs   | latin1  | 49 |         |          |       0 |
| latin1_spanish_ci   | latin1  | 94 |         |          |       0 |
+---------------------+---------+----+---------+----------+---------+
```

The `latin1` collations have the following meanings.

Collation	Meaning
`latin1_german1_ci`	German DIN-1
`latin1_swedish_ci`	Swedish/Finnish
`latin1_danish_ci`	Danish/Norwegian
`latin1_german2_ci`	German DIN-2
`latin1_bin`	Binary according to `latin1` encoding
`latin1_general_ci`	Multilingual (Western European)
`latin1_general_cs`	Multilingual (ISO Western European), case sensitive
`latin1_spanish_ci`	Modern Spanish

Collations have these general characteristics:

- Two different character sets cannot have the same collation.

- Each character set has one collation that is the *default collation*. For example, the default collation for `latin1` is `latin1_swedish_ci`. The output for `SHOW CHARACTER SET` indicates which collation is the default for each displayed character set.

- There is a convention for collation names: They start with the name of the character set with which they are associated, they usually include a language name, and they end with `_ci` (case insensitive), `_cs` (case sensitive), or `_bin` (binary).

In cases where a character set has multiple collations, it might not be clear which collation is most suitable for a given application. To avoid choosing the wrong collation, it can be helpful to perform some comparisons with representative data values to make sure that a given collation sorts values the way you expect.

Collation-Charts.Org is a useful site for information that shows how one collation compares to another.

10.1.3 Specifying Character Sets and Collations

There are default settings for character sets and collations at four levels: server, database, table, and column. The description in the following sections may appear complex, but it has been found in practice that multiple-level defaulting leads to natural and obvious results.

`CHARACTER SET` is used in clauses that specify a character set. `CHARSET` can be used as a synonym for `CHARACTER SET`.

Character set issues affect not only data storage, but also communication between client programs and the MySQL server. If you want the client program to communicate with the server using a character set different from the default, you'll need to indicate which one. For example, to use the `utf8` Unicode character set, issue this statement after connecting to the server:

```
SET NAMES 'utf8';
```

For more information about character set-related issues in client/server communication, see Section 10.1.4, "Connection Character Sets and Collations".

10.1.3.1 Server Character Set and Collation

MySQL Server has a server character set and a server collation. These can be set at server startup on the command line or in an option file and changed at runtime.

Initially, the server character set and collation depend on the options that you use when you start `mysqld`. You can use `--character-set-server` for the character set. Along with it, you can add `--collation-server` for the collation. If you don't specify a character set, that is the same as saying `--character-set-server=latin1`. If you specify only a character set (for example, `latin1`) but not a collation, that is the same as saying `--character-set-server=latin1 --collation-server=latin1_swedish_ci` because `latin1_swedish_ci` is the default collation for `latin1`. Therefore, the following three commands all have the same effect:

```
shell> mysqld
shell> mysqld --character-set-server=latin1
shell> mysqld --character-set-server=latin1 \
          --collation-server=latin1_swedish_ci
```

One way to change the settings is by recompiling. If you want to change the default server character set and collation when building from sources, use: `--with-charset` and `--with-collation` as arguments for `configure`. For example:

```
shell> ./configure --with-charset=latin1
```

Or:

```
shell> ./configure --with-charset=latin1 \
          --with-collation=latin1_german1_ci
```

Both `mysqld` and `configure` verify that the character set/collation combination is valid. If not, each program displays an error message and terminates.

The server character set and collation are used as default values if the database character set and collation are not specified in `CREATE DATABASE` statements. They have no other purpose.

The current server character set and collation can be determined from the values of the `character_set_server` and `collation_server` system variables. These variables can be changed at runtime.

10.1.3.2 Database Character Set and Collation

Every database has a database character set and a database collation. The `CREATE DATABASE` and `ALTER DATABASE` statements have optional clauses for specifying the database character set and collation:

```
CREATE DATABASE db_name
    [[DEFAULT] CHARACTER SET charset_name]
    [[DEFAULT] COLLATE collation_name]

ALTER DATABASE db_name
    [[DEFAULT] CHARACTER SET charset_name]
    [[DEFAULT] COLLATE collation_name]
```

The keyword `SCHEMA` can be used instead of `DATABASE`.

All database options are stored in a text file named `db.opt` that can be found in the database directory.

The `CHARACTER SET` and `COLLATE` clauses make it possible to create databases with different character sets and collations on the same MySQL server.

Example:

```
CREATE DATABASE db_name CHARACTER SET latin1 COLLATE latin1_swedish_ci;
```

MySQL chooses the database character set and database collation in the following manner:

- If both `CHARACTER SET X` and `COLLATE Y` are specified, character set `X` and collation `Y` are used.

- If `CHARACTER SET X` is specified without `COLLATE`, character set `X` and its default collation are used. To see the default collation for each character set, use the `SHOW COLLATION` statement.

- If `COLLATE Y` is specified without `CHARACTER SET`, the character set associated with `Y` and collation `Y` are used.

- Otherwise, the server character set and server collation are used.

The character set and collation for the default database can be determined from the values of the `character_set_database` and `collation_database` system variables. The server sets these variables whenever the default database changes. If there is no default database, the variables have the same value as the corresponding server-level system variables, `character_set_server` and `collation_server`.

To see the default character set and collation for a given database, use these statements:

```
USE db_name;
SELECT @@character_set_database, @@collation_database;
```

Alternatively, to display the values without changing the default database:

```
SELECT DEFAULT_CHARACTER_SET_NAME, DEFAULT_COLLATION_NAME
FROM INFORMATION_SCHEMA.SCHEMATA WHERE SCHEMA_NAME = 'db_name';
```

The database character set and collation affect these aspects of server operation:

- For `CREATE TABLE` statements, the database character set and collation are used as default values for table definitions if the table character set and collation are not specified. To override this, provide explicit `CHARACTER SET` and `COLLATE` table options.

- For `LOAD DATA` statements that include no `CHARACTER SET` clause, the server uses the character set indicated by the `character_set_database` system variable to interpret the information in the file. To override this, provide an explicit `CHARACTER SET` clause.

- For stored routines (procedures and functions), the database character set and collation in effect at routine creation time are used as the character set and collation of character data parameters for which the declaration includes no `CHARACTER SET` or `COLLATE` attribute. To override this, provide explicit `CHARACTER SET` and `COLLATE` attributes.

10.1.3.3 Table Character Set and Collation

Every table has a table character set and a table collation. The `CREATE TABLE` and `ALTER TABLE` statements have optional clauses for specifying the table character set and collation:

```
CREATE TABLE tbl_name (column_list)
    [[DEFAULT] CHARACTER SET charset_name]
    [COLLATE collation_name]]

ALTER TABLE tbl_name
```

```
    [[DEFAULT] CHARACTER SET charset_name]
    [COLLATE collation_name]
```

Example:

```
CREATE TABLE t1 ( ... )
CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

MySQL chooses the table character set and collation in the following manner:

- If both CHARACTER SET X and COLLATE Y are specified, character set X and collation Y are used.

- If CHARACTER SET X is specified without COLLATE, character set X and its default collation are used. To see the default collation for each character set, use the SHOW COLLATION statement.

- If COLLATE Y is specified without CHARACTER SET, the character set associated with Y and collation Y are used.

- Otherwise, the database character set and collation are used.

The table character set and collation are used as default values for column definitions if the column character set and collation are not specified in individual column definitions. The table character set and collation are MySQL extensions; there are no such things in standard SQL.

10.1.3.4 Column Character Set and Collation

Every "character" column (that is, a column of type CHAR, VARCHAR, or TEXT) has a column character set and a column collation. Column definition syntax for CREATE TABLE and ALTER TABLE has optional clauses for specifying the column character set and collation:

```
col_name {CHAR | VARCHAR | TEXT} (col_length)
    [CHARACTER SET charset_name]
    [COLLATE collation_name]
```

These clauses can also be used for ENUM and SET columns:

```
col_name {ENUM | SET} (val_list)
    [CHARACTER SET charset_name]
    [COLLATE collation_name]
```

Examples:

```
CREATE TABLE t1
(
    col1 VARCHAR(5)
      CHARACTER SET latin1
      COLLATE latin1_german1_ci
);

ALTER TABLE t1 MODIFY
    col1 VARCHAR(5)
      CHARACTER SET latin1
      COLLATE latin1_swedish_ci;
```

MySQL chooses the column character set and collation in the following manner:

- If both CHARACTER SET X and COLLATE Y are specified, character set X and collation Y are used.

```
CREATE TABLE t1
(
    col1 CHAR(10) CHARACTER SET utf8 COLLATE utf8_unicode_ci
) CHARACTER SET latin1 COLLATE latin1_bin;
```

The character set and collation are specified for the column, so they are used. The column has character set `utf8` and collation `utf8_unicode_ci`.

- If `CHARACTER SET X` is specified without `COLLATE`, character set `X` and its default collation are used.

```
CREATE TABLE t1
(
    col1 CHAR(10) CHARACTER SET utf8
) CHARACTER SET latin1 COLLATE latin1_bin;
```

The character set is specified for the column, but the collation is not. The column has character set `utf8` and the default collation for `utf8`, which is `utf8_general_ci`. To see the default collation for each character set, use the `SHOW COLLATION` statement.

- If `COLLATE Y` is specified without `CHARACTER SET`, the character set associated with `Y` and collation `Y` are used.

```
CREATE TABLE t1
(
    col1 CHAR(10) COLLATE utf8_polish_ci
) CHARACTER SET latin1 COLLATE latin1_bin;
```

The collation is specified for the column, but the character set is not. The column has collation `utf8_polish_ci` and the character set is the one associated with the collation, which is `utf8`.

- Otherwise, the table character set and collation are used.

```
CREATE TABLE t1
(
    col1 CHAR(10)
) CHARACTER SET latin1 COLLATE latin1_bin;
```

Neither the character set nor collation are specified for the column, so the table defaults are used. The column has character set `latin1` and collation `latin1_bin`.

The `CHARACTER SET` and `COLLATE` clauses are standard SQL.

If you use `ALTER TABLE` to convert a column from one character set to another, MySQL attempts to map the data values, but if the character sets are incompatible, there may be data loss.

10.1.3.5 Character String Literal Character Set and Collation

Every character string literal has a character set and a collation.

A character string literal may have an optional character set introducer and `COLLATE` clause:

```
[_charset_name]'string' [COLLATE collation_name]
```

Examples:

```
SELECT 'string';
SELECT _latin1'string';
SELECT _latin1'string' COLLATE latin1_danish_ci;
```

For the simple statement `SELECT 'string'`, the string has the character set and collation defined by the `character_set_connection` and `collation_connection` system variables.

The `_charset_name` expression is formally called an *introducer*. It tells the parser, "the string that is about to follow uses character set `X`." Because this has confused people in the past, we emphasize that an introducer does not change the string to the introducer character set like `CONVERT()` would do. It does not change the string's value, although padding may occur. The introducer is just a signal. An introducer is also legal before standard hex literal and numeric hex literal notation (`x'literal'` and `0xnnnn`), or before bit-field literal notation (`b'literal'` and `0bnnnn`).

Examples:

```
SELECT _latin1 x'AABBCC';
SELECT _latin1 0xAABBCC;
SELECT _latin1 b'1100011';
SELECT _latin1 0b1100011;
```

MySQL determines a literal's character set and collation in the following manner:

- If both `_X` and `COLLATE Y` are specified, character set `X` and collation `Y` are used.

- If `_X` is specified but `COLLATE` is not specified, character set `X` and its default collation are used. To see the default collation for each character set, use the `SHOW COLLATION` statement.

- Otherwise, the character set and collation given by the `character_set_connection` and `collation_connection` system variables are used.

Examples:

- A string with `latin1` character set and `latin1_german1_ci` collation:

  ```
  SELECT _latin1'Müller' COLLATE latin1_german1_ci;
  ```

- A string with `latin1` character set and its default collation (that is, `latin1_swedish_ci`):

  ```
  SELECT _latin1'Müller';
  ```

- A string with the connection default character set and collation:

  ```
  SELECT 'Müller';
  ```

Character set introducers and the `COLLATE` clause are implemented according to standard SQL specifications.

An introducer indicates the character set for the following string, but does not change now how the parser performs escape processing within the string. Escapes are always interpreted by the parser according to the character set given by `character_set_connection`.

The following examples show that escape processing occurs using `character_set_connection` even in the presence of an introducer. The examples use `SET NAMES` (which changes `character_set_connection`, as discussed in Section 10.1.4, "Connection Character Sets and

Collations"), and display the resulting strings using the `HEX()` function so that the exact string contents can be seen.

Example 1:

```
mysql> SET NAMES latin1;
Query OK, 0 rows affected (0.01 sec)

mysql> SELECT HEX('à\n'), HEX(_sjis'à\n');
+-----------+-----------------+
| HEX('à\n') | HEX(_sjis'à\n') |
+-----------+-----------------+
| E00A      | E00A            |
+-----------+-----------------+
1 row in set (0.00 sec)
```

Here, "à" (hex value `E0`) is followed by "`\n`", the escape sequence for newline. The escape sequence is interpreted using the `character_set_connection` value of `latin1` to produce a literal newline (hex value `0A`). This happens even for the second string. That is, the introducer of `_sjis` does not affect the parser's escape processing.

Example 2:

```
mysql> SET NAMES sjis;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT HEX('à\n'), HEX(_latin1'à\n');
+-----------+-------------------+
| HEX('à\n') | HEX(_latin1'à\n') |
+-----------+-------------------+
| E05C6E    | E05C6E            |
+-----------+-------------------+
1 row in set (0.04 sec)
```

Here, `character_set_connection` is `sjis`, a character set in which the sequence of "à" followed by "\" (hex values `05` and `5C`) is a valid multibyte character. Hence, the first two bytes of the string are interpreted as a single `sjis` character, and the "\" is not interpreted as an escape character. The following "n" (hex value `6E`) is not interpreted as part of an escape sequence. This is true even for the second string; the introducer of `_latin1` does not affect escape processing.

10.1.3.6 National Character Set

Standard SQL defines `NCHAR` or `NATIONAL CHAR` as a way to indicate that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. For example, these data type declarations are equivalent:

```
CHAR(10) CHARACTER SET utf8
NATIONAL CHARACTER(10)
NCHAR(10)
```

As are these:

```
VARCHAR(10) CHARACTER SET utf8
NATIONAL VARCHAR(10)
NVARCHAR(10)
NCHAR VARCHAR(10)
NATIONAL CHARACTER VARYING(10)
```

```
NATIONAL CHAR VARYING(10)
```

You can use `N'literal'` (or `n'literal'`) to create a string in the national character set. These statements are equivalent:

```
SELECT N'some text';
SELECT n'some text';
SELECT _utf8'some text';
```

For information on upgrading character sets to MySQL 5.1 from versions prior to 4.1, see the *MySQL 3.23, 4.0, 4.1 Reference Manual*.

10.1.3.7 Examples of Character Set and Collation Assignment

The following examples show how MySQL determines default character set and collation values.

Example 1: Table and Column Definition

```
CREATE TABLE t1
(
    c1 CHAR(10) CHARACTER SET latin1 COLLATE latin1_german1_ci
) DEFAULT CHARACTER SET latin2 COLLATE latin2_bin;
```

Here we have a column with a `latin1` character set and a `latin1_german1_ci` collation. The definition is explicit, so that is straightforward. Notice that there is no problem with storing a `latin1` column in a `latin2` table.

Example 2: Table and Column Definition

```
CREATE TABLE t1
(
    c1 CHAR(10) CHARACTER SET latin1
) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

This time we have a column with a `latin1` character set and a default collation. Although it might seem natural, the default collation is not taken from the table level. Instead, because the default collation for `latin1` is always `latin1_swedish_ci`, column `c1` has a collation of `latin1_swedish_ci` (not `latin1_danish_ci`).

Example 3: Table and Column Definition

```
CREATE TABLE t1
(
    c1 CHAR(10)
) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

We have a column with a default character set and a default collation. In this circumstance, MySQL checks the table level to determine the column character set and collation. Consequently, the character set for column `c1` is `latin1` and its collation is `latin1_danish_ci`.

Example 4: Database, Table, and Column Definition

```
CREATE DATABASE d1
    DEFAULT CHARACTER SET latin2 COLLATE latin2_czech_ci;
USE d1;
```

```
CREATE TABLE t1
(
    c1 CHAR(10)
);
```

We create a column without specifying its character set and collation. We're also not specifying a character set and a collation at the table level. In this circumstance, MySQL checks the database level to determine the table settings, which thereafter become the column settings.) Consequently, the character set for column `c1` is `latin2` and its collation is `latin2_czech_ci`.

10.1.3.8 Compatibility with Other DBMSs

For MaxDB compatibility these two statements are the same:

```
CREATE TABLE t1 (f1 CHAR(N) UNICODE);
CREATE TABLE t1 (f1 CHAR(N) CHARACTER SET ucs2);
```

10.1.4 Connection Character Sets and Collations

Several character set and collation system variables relate to a client's interaction with the server. Some of these have been mentioned in earlier sections:

- The server character set and collation are the values of the `character_set_server` and `collation_server` system variables.

- The character set and collation of the default database are the values of the `character_set_database` and `collation_database` system variables.

Additional character set and collation system variables are involved in handling traffic for the connection between a client and the server. Every client has connection-related character set and collation system variables.

A "connection" is what you make when you connect to the server. The client sends SQL statements, such as queries, over the connection to the server. The server sends responses, such as result sets or error messages, over the connection back to the client. This leads to several questions about character set and collation handling for client connections, each of which can be answered in terms of system variables:

- What character set is the statement in when it leaves the client?

  The server takes the `character_set_client` system variable to be the character set in which statements are sent by the client.

- What character set should the server translate a statement to after receiving it?

  For this, the server uses the `character_set_connection` and `collation_connection` system variables. It converts statements sent by the client from `character_set_client` to `character_set_connection` (except for string literals that have an introducer such as `_latin1` or `_utf8`). `collation_connection` is important for comparisons of literal strings. For comparisons of strings with column values, `collation_connection` does not matter because columns have their own collation, which has a higher collation precedence.

- What character set should the server translate to before shipping result sets back to the client?

  The `character_set_results` system variable indicates the character set in which the server returns query results to the client. This includes result data such as column values, and result metadata such as column names.

Clients can fine-tune the settings for these variables, or depend on the defaults (in which case, you can skip the rest of this section). If you do not use the defaults, you must change the character settings *for each connection to the server.*

Two statements affect the connection-related character set variables as a group:

- `SET NAMES 'charset_name' [COLLATE 'collation_name']`

  `SET NAMES` indicates what character set the client will use to send SQL statements to the server. Thus, `SET NAMES 'cp1251'` tells the server, "future incoming messages from this client are in character set `cp1251`." It also specifies the character set that the server should use for sending results back to the client. (For example, it indicates what character set to use for column values if you use a `SELECT` statement.)

  A `SET NAMES 'charset_name'` statement is equivalent to these three statements:

  ```
  SET character_set_client = charset_name;
  SET character_set_results = charset_name;
  SET character_set_connection = charset_name;
  ```

  Setting `character_set_connection` to `charset_name` also implicitly sets `collation_connection` to the default collation for `charset_name`. It is unnecessary to set that collation explicitly. To specify a particular collation, use the optional `COLLATE` clause:

  ```
  SET NAMES 'charset_name' COLLATE 'collation_name'
  ```

- `SET CHARACTER SET charset_name`

  `SET CHARACTER SET` is similar to `SET NAMES` but sets `character_set_connection` and `collation_connection` to `character_set_database` and `collation_database`. A `SET CHARACTER SET charset_name` statement is equivalent to these three statements:

  ```
  SET character_set_client = charset_name;
  SET character_set_results = charset_name;
  SET collation_connection = @@collation_database;
  ```

  Setting `collation_connection` also implicitly sets `character_set_connection` to the character set associated with the collation (equivalent to executing `SET character_set_connection = @@character_set_database`). It is unnecessary to set `character_set_connection` explicitly.

> **Note**
>
> `ucs2` cannot be used as a client character set, which means that it does not work for `SET NAMES` or `SET CHARACTER SET`.

The MySQL client programs `mysql`, `mysqladmin`, `mysqlcheck`, `mysqlimport`, and `mysqlshow` determine the default character set to use as follows:

- In the absence of other information, the programs use the compiled-in default character set, usually `latin1`.

- The programs support a `--default-character-set` option, which enables users to specify the character set explicitly to override whatever default the client otherwise determines.

When a client connects to the server, it sends the name of the character set that it wants to use. The server uses the name to set the `character_set_client`, `character_set_results`, and

`character_set_connection` system variables. In effect, the server performs a `SET NAMES` operation using the character set name.

With the `mysql` client, to use a character set different from the default, you could explicitly execute `SET NAMES` every time you start up. To accomplish the same result more easily, add the `--default-character-set` option setting to your `mysql` command line or in your option file. For example, the following option file setting changes the three connection-related character set variables set to `koi8r` each time you invoke `mysql`:

```
[mysql]
default-character-set=koi8r
```

If you are using the `mysql` client with auto-reconnect enabled (which is not recommended), it is preferable to use the `charset` command rather than `SET NAMES`. For example:

```
mysql> charset utf8
Charset changed
```

The `charset` command issues a `SET NAMES` statement, and also changes the default character set that `mysql` uses when it reconnects after the connection has dropped.

Example: Suppose that `column1` is defined as `CHAR(5) CHARACTER SET latin2`. If you do not say `SET NAMES` or `SET CHARACTER SET`, then for `SELECT column1 FROM t`, the server sends back all the values for `column1` using the character set that the client specified when it connected. On the other hand, if you say `SET NAMES 'latin1'` or `SET CHARACTER SET latin1` before issuing the `SELECT` statement, the server converts the `latin2` values to `latin1` just before sending results back. Conversion may be lossy if there are characters that are not in both character sets.

If you want the server to perform no conversion of result sets or error messages, set `character_set_results` to `NULL` or `binary`:

```
SET character_set_results = NULL;
```

To see the values of the character set and collation system variables that apply to your connection, use these statements:

```
SHOW VARIABLES LIKE 'character_set%';
SHOW VARIABLES LIKE 'collation%';
```

You must also consider the environment within which your MySQL applications execute. See Section 10.1.5, "Configuring the Character Set and Collation for Applications".

For more information about character sets and error messages, see Section 10.1.6, "Character Set for Error Messages".

10.1.5 Configuring the Character Set and Collation for Applications

For applications that store data using the default MySQL character set and collation (`latin1`, `latin1_swedish_ci`), no special configuration should be needed. If applications require data storage using a different character set or collation, you can configure character set information several ways:

- Specify character settings per database. For example, applications that use one database might require `utf8`, whereas applications that use another database might require `sjis`.

- Specify character settings at server startup. This causes the server to use the given settings for all applications that do not make other arrangements.

- Specify character settings at configuration time, if you build MySQL from source. This causes the server to use the given settings for all applications, without having to specify them at server startup.

When different applications require different character settings, the per-database technique provides a good deal of flexibility. If most or all applications use the same character set, specifying character settings at server startup or configuration time may be most convenient.

For the per-database or server-startup techniques, the settings control the character set for data storage. Applications must also tell the server which character set to use for client/server communications, as described in the following instructions.

The examples shown here assume use of the `utf8` character set and `utf8_general_ci` collation.

Specify character settings per database. To create a database such that its tables will use a given default character set and collation for data storage, use a `CREATE DATABASE` statement like this:

```
CREATE DATABASE mydb
  DEFAULT CHARACTER SET utf8
  DEFAULT COLLATE utf8_general_ci;
```

Tables created in the database will use `utf8` and `utf8_general_ci` by default for any character columns.

Applications that use the database should also configure their connection to the server each time they connect. This can be done by executing a `SET NAMES 'utf8'` statement after connecting. The statement can be used regardless of connection method: The `mysql` client, PHP scripts, and so forth.

In some cases, it may be possible to configure the connection to use the desired character set some other way. For example, for connections made using `mysql`, you can specify the `--default-character-set=utf8` command-line option to achieve the same effect as `SET NAMES 'utf8'`.

For more information about configuring client connections, see Section 10.1.4, "Connection Character Sets and Collations".

If you change the default character set or collation for a database, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults. (In a stored routine, variables with character data types use the database defaults if the character set or collation are not specified explicitly. See Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax".)

Specify character settings at server startup. To select a character set and collation at server startup, use the `--character-set-server` and `--collation-server` options. For example, to specify the options in an option file, include these lines:

```
[mysqld]
character-set-server=utf8
collation-server=utf8_general_ci
```

These settings apply server-wide and apply as the defaults for databases created by any application, and for tables created in those databases.

It is still necessary for applications to configure their connection using `SET NAMES` or equivalent after they connect, as described previously. You might be tempted to start the server with the `--`

`init_connect="SET NAMES 'utf8'"` option to cause `SET NAMES` to be executed automatically for each client that connects. However, this will yield inconsistent results because the `init_connect` value is not executed for users who have the `SUPER` privilege.

Specify character settings at MySQL configuration time. To select a character set and collation when you configure and build MySQL from source, use the `--with-charset` and `--with-collation` options:

```
shell> ./configure --with-charset=utf8 --with-collation=utf8_general_ci
```

The resulting server uses `utf8` and `utf8_general_ci` as the default for databases and tables and for client connections. It is unnecessary to use `--character-set-server` and `--collation-server` to specify those defaults at server startup. It is also unnecessary for applications to configure their connection using `SET NAMES` or equivalent after they connect to the server.

Regardless of how you configure the MySQL character set for application use, you must also consider the environment within which those applications execute. If you will send statements using UTF-8 text taken from a file that you create in an editor, you should edit the file with the locale of your environment set to UTF-8 so that the file encoding is correct and so that the operating system handles it correctly. If you use the `mysql` client from within a terminal window, the window must be configured to use UTF-8 or characters may not display properly. For a script that executes in a Web environment, the script must handle character encoding properly for its interaction with the MySQL server, and it must generate pages that correctly indicate the encoding so that browsers know how to display the content of the pages. For example, you can include this `<meta>` tag within your `<head>` element:

```
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
```

10.1.6 Character Set for Error Messages

This section describes how the server uses character sets for constructing error messages and returning them to clients. For information about the language of error messages (rather than the character set), see Section 10.2, "Setting the Error Message Language".

In MySQL, the server constructs error messages and returns them to clients as follows:

- The message template has the character set associated with the error message language. For example, English, Korean, and Russian messages use `latin1`, `euckr`, and `koi8r`, respectively.

- Parameters in the message template are replaced with values that apply to a specific error occurrence. These parameters use their own character set. Identifiers such as table or column names use UTF-8. Data values retain their character set. For example, in the following duplicate-key message, `'xxx'` has the character set of the table column associated with key 1:

```
Duplicate entry 'xxx' for key1
```

The preceding method of error-message construction can result in messages that contain a mix of character sets unless all items involved contain only ASCII characters. This issue is resolved in MySQL 5.5, in which error messages are constructed internally within the server using UTF-8 and returned to the client in the character set specified by the `character_set_results` system variable.

10.1.7 Collation Issues

The following sections discuss various aspects of character set collations.

10.1.7.1 Collation Naming Conventions

MySQL collation names follow these conventions:

- A name ending in `_ci` indicates a case-insensitive collation.

- A name ending in `_cs` indicates a case-sensitive collation.

- A name ending in `_bin` indicates a binary collation. Character comparisons are based on character binary code values.

10.1.7.2 Using COLLATE in SQL Statements

With the `COLLATE` clause, you can override whatever the default collation is for a comparison. `COLLATE` may be used in various parts of SQL statements. Here are some examples:

- With `ORDER BY`:

```
SELECT k
FROM t1
ORDER BY k COLLATE latin1_german2_ci;
```

- With `AS`:

```
SELECT k COLLATE latin1_german2_ci AS k1
FROM t1
ORDER BY k1;
```

- With `GROUP BY`:

```
SELECT k
FROM t1
GROUP BY k COLLATE latin1_german2_ci;
```

- With aggregate functions:

```
SELECT MAX(k COLLATE latin1_german2_ci)
FROM t1;
```

- With `DISTINCT`:

```
SELECT DISTINCT k COLLATE latin1_german2_ci
FROM t1;
```

- With `WHERE`:

```
    SELECT *
    FROM t1
    WHERE _latin1 'Müller' COLLATE latin1_german2_ci = k;
```

```
    SELECT *
    FROM t1
    WHERE k LIKE _latin1 'Müller' COLLATE latin1_german2_ci;
```

- With `HAVING`:

```
SELECT k
FROM t1
GROUP BY k
HAVING k = _latin1 'Müller' COLLATE latin1_german2_ci;
```

10.1.7.3 COLLATE Clause Precedence

The COLLATE clause has high precedence (higher than ||), so the following two expressions are equivalent:

```
x || y COLLATE z
x || (y COLLATE z)
```

10.1.7.4 Collations Must Be for the Right Character Set

Each character set has one or more collations, but each collation is associated with one and only one character set. Therefore, the following statement causes an error message because the latin2_bin collation is not legal with the latin1 character set:

```
mysql> SELECT _latin1 'x' COLLATE latin2_bin;
ERROR 1253 (42000): COLLATION 'latin2_bin' is not valid
for CHARACTER SET 'latin1'
```

10.1.7.5 Collation of Expressions

In the great majority of statements, it is obvious what collation MySQL uses to resolve a comparison operation. For example, in the following cases, it should be clear that the collation is the collation of column charset_name:

```
SELECT x FROM T ORDER BY x;
SELECT x FROM T WHERE x = x;
SELECT DISTINCT x FROM T;
```

However, with multiple operands, there can be ambiguity. For example:

```
SELECT x FROM T WHERE x = 'Y';
```

Should the comparison use the collation of the column x, or of the string literal 'Y'? Both x and 'Y' have collations, so which collation takes precedence?

Standard SQL resolves such questions using what used to be called "coercibility" rules. MySQL assigns coercibility values as follows:

- An explicit COLLATE clause has a coercibility of 0. (Not coercible at all.)

- The concatenation of two strings with different collations has a coercibility of 1.

- The collation of a column or a stored routine parameter or local variable has a coercibility of 2.

- A "system constant" (the string returned by functions such as USER() or VERSION()) has a coercibility of 3.

- The collation of a literal has a coercibility of 4.

- `NULL` or an expression that is derived from `NULL` has a coercibility of 5.

MySQL uses coercibility values with the following rules to resolve ambiguities:

- Use the collation with the lowest coercibility value.

- If both sides have the same coercibility, then:

  - If both sides are Unicode, or both sides are not Unicode, it is an error.

  - If one of the sides has a Unicode character set, and another side has a non-Unicode character set, the side with Unicode character set wins, and automatic character set conversion is applied to the non-Unicode side. For example, the following statement does not return an error:

    ```
    SELECT CONCAT(utf8_column, latin1_column) FROM t1;
    ```

    It returns a result that has a character set of `utf8` and the same collation as `utf8_column`. Values of `latin1_column` are automatically converted to `utf8` before concatenating.

  - For an operation with operands from the same character set but that mix a `_bin` collation and a `_ci` or `_cs` collation, the `_bin` collation is used. This is similar to how operations that mix nonbinary and binary strings evaluate the operands as binary strings, except that it is for collations rather than data types.

Although automatic conversion is not in the SQL standard, the SQL standard document does say that every character set is (in terms of supported characters) a "subset" of Unicode. Because it is a well-known principle that "what applies to a superset can apply to a subset," we believe that a collation for Unicode can apply for comparisons with non-Unicode strings.

Examples:

Comparison	Collation Used
`column1 = 'A'`	Use collation of `column1`
`column1 = 'A' COLLATE x`	Use collation of `'A' COLLATE x`
`column1 COLLATE x = 'A' COLLATE y`	Error

The `COERCIBILITY()` function can be used to determine the coercibility of a string expression:

```
mysql> SELECT COERCIBILITY('A' COLLATE latin1_swedish_ci);
        -> 0
mysql> SELECT COERCIBILITY(VERSION());
        -> 3
mysql> SELECT COERCIBILITY('A');
        -> 4
```

See Section 12.14, "Information Functions".

For implicit conversion of a numeric or temporal value to a string, such as occurs for the argument `1` in the expression `CONCAT(1, 'abc')`, the result is a binary string for which the character set and collation are `binary`. See Section 12.2, "Type Conversion in Expression Evaluation".

10.1.7.6 The _bin and binary Collations

This section describes how `_bin` collations for nonbinary strings differ from the `binary` "collation" for binary strings.

Nonbinary strings (as stored in the `CHAR`, `VARCHAR`, and `TEXT` data types) have a character set and collation. A given character set can have several collations, each of which defines a particular sorting and comparison order for the characters in the set. One of these is the binary collation for the character set, indicated by a `_bin` suffix in the collation name. For example, `latin1` and `utf8` have binary collations named `latin1_bin` and `utf8_bin`.

Binary strings (as stored in the `BINARY`, `VARBINARY`, and `BLOB` data types) have no character set or collation in the sense that nonbinary strings do. (Applied to a binary string, the `CHARSET()` and `COLLATION()` functions both return a value of `binary`.) Binary strings are sequences of bytes and the numeric values of those bytes determine sort order.

The `_bin` collations differ from the `binary` collation in several respects.

The unit for sorting and comparison. Binary strings are sequences of bytes. Sorting and comparison is always based on numeric byte values. Nonbinary strings are sequences of characters, which might be multibyte. Collations for nonbinary strings define an ordering of the character values for sorting and comparison. For the `_bin` collation, this ordering is based solely on binary code values of the characters (which is similar to ordering for binary strings except that a `_bin` collation must take into account that a character might contain multiple bytes). For other collations, character ordering might take additional factors such as lettercase into account.

Character set conversion. A nonbinary string has a character set and is converted to another character set in many cases, even when the string has a `_bin` collation:

- When assigning column values from another column that has a different character set:

```
UPDATE t1 SET utf8_bin_column=latin1_column;
INSERT INTO t1 (latin1_column) SELECT utf8_bin_column FROM t2;
```

- When assigning column values for `INSERT` or `UPDATE` using a string literal:

```
SET NAMES latin1;
INSERT INTO t1 (utf8_bin_column) VALUES ('string-in-latin1');
```

- When sending results from the server to a client:

```
SET NAMES latin1;
SELECT utf8_bin_column FROM t2;
```

For binary string columns, no conversion occurs. For the preceding cases, the string value is copied byte-wise.

Lettercase conversion. Collations provide information about lettercase of characters, so characters in a nonbinary string can be converted from one lettercase to another, even for `_bin` collations that ignore lettercase for ordering:

```
mysql> SET NAMES latin1 COLLATE latin1_bin;
Query OK, 0 rows affected (0.02 sec)

mysql> SELECT LOWER('aA'), UPPER('zZ');
+-------------+-------------+
| LOWER('aA') | UPPER('zZ') |
+-------------+-------------+
| aa          | ZZ          |
+-------------+-------------+
1 row in set (0.13 sec)
```

The concept of lettercase does not apply to bytes in a binary string. To perform lettercase conversion, the string must be converted to a nonbinary string:

```
mysql> SET NAMES binary;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT LOWER('aA'), LOWER(CONVERT('aA' USING latin1));
+------------+-----------------------------------+
| LOWER('aA') | LOWER(CONVERT('aA' USING latin1)) |
+------------+-----------------------------------+
| aA          | aa                                |
+------------+-----------------------------------+
1 row in set (0.00 sec)
```

Trailing space handling in comparisons. Nonbinary strings have `PADSPACE` behavior for all collations, including `_bin` collations. Trailing spaces are insignificant in comparisons:

```
mysql> SET NAMES utf8 COLLATE utf8_bin;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT 'a ' = 'a';
+------------+
| 'a ' = 'a' |
+------------+
|          1 |
+------------+
1 row in set (0.00 sec)
```

For binary strings, all characters are significant in comparisons, including trailing spaces:

```
mysql> SET NAMES binary;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT 'a ' = 'a';
+------------+
| 'a ' = 'a' |
+------------+
|          0 |
+------------+
1 row in set (0.00 sec)
```

Trailing space handling for inserts and retrievals. `CHAR(N)` columns store nonbinary strings. Values shorter than N characters are extended with spaces on insertion. For retrieval, trailing spaces are removed.

`BINARY(N)` columns store binary strings. Values shorter than N bytes are extended with `0x00` bytes on insertion. For retrieval, nothing is removed; a value of the declared length is always returned.

```
mysql> CREATE TABLE t1 (
    ->    a CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin,
    ->    b BINARY(10)
    -> );
Query OK, 0 rows affected (0.09 sec)

mysql> INSERT INTO t1 VALUES ('a','a');
Query OK, 1 row affected (0.01 sec)

mysql> SELECT HEX(a), HEX(b) FROM t1;
+--------+----------------------+
| HEX(a) | HEX(b)               |
+--------+----------------------+
| 61     | 61000000000000000000 |
```

```
+--------+----------------------+
1 row in set (0.04 sec)
```

10.1.7.7 The BINARY Operator

The `BINARY` operator casts the string following it to a binary string. This is an easy way to force a comparison to be done byte by byte rather than character by character. `BINARY` also causes trailing spaces to be significant.

```
mysql> SELECT 'a' = 'A';
        -> 1
mysql> SELECT BINARY 'a' = 'A';
        -> 0
mysql> SELECT 'a' = 'a ';
        -> 1
mysql> SELECT BINARY 'a' = 'a ';
        -> 0
```

`BINARY` *str* is shorthand for `CAST(`*str* `AS BINARY)`.

The `BINARY` attribute in character column definitions has a different effect. A character column defined with the `BINARY` attribute is assigned the binary collation of the column character set. Every character set has a binary collation. For example, the binary collation for the `latin1` character set is `latin1_bin`, so if the table default character set is `latin1`, these two column definitions are equivalent:

```
CHAR(10) BINARY
CHAR(10) CHARACTER SET latin1 COLLATE latin1_bin
```

The use of `CHARACTER SET binary` in the definition of a `CHAR`, `VARCHAR`, or `TEXT` column causes the column to be treated as a binary data type. For example, the following pairs of definitions are equivalent:

```
CHAR(10) CHARACTER SET binary
BINARY(10)

VARCHAR(10) CHARACTER SET binary
VARBINARY(10)

TEXT CHARACTER SET binary
BLOB
```

10.1.7.8 Examples of the Effect of Collation

Example 1: Sorting German Umlauts

Suppose that column `X` in table `T` has these `latin1` column values:

```
Muffler
Müller
MX Systems
MySQL
```

Suppose also that the column values are retrieved using the following statement:

```
SELECT X FROM T ORDER BY X COLLATE collation_name;
```

The following table shows the resulting order of the values if we use `ORDER BY` with different collations.

latin1_swedish_ci	latin1_german1_ci	latin1_german2_ci
Muffler	Muffler	Müller
MX Systems	Müller	Muffler
Müller	MX Systems	MX Systems
MySQL	MySQL	MySQL

The character that causes the different sort orders in this example is the U with two dots over it (ü), which the Germans call "U-umlaut."

- The first column shows the result of the SELECT using the Swedish/Finnish collating rule, which says that U-umlaut sorts with Y.

- The second column shows the result of the SELECT using the German DIN-1 rule, which says that U-umlaut sorts with U.

- The third column shows the result of the SELECT using the German DIN-2 rule, which says that U-umlaut sorts with UE.

Example 2: Searching for German Umlauts

Suppose that you have three tables that differ only by the character set and collation used:

```
mysql> SET NAMES utf8;
mysql> CREATE TABLE german1 (
    ->   c CHAR(10)
    -> ) CHARACTER SET latin1 COLLATE latin1_german1_ci;
mysql> CREATE TABLE german2 (
    ->   c CHAR(10)
    -> ) CHARACTER SET latin1 COLLATE latin1_german2_ci;
mysql> CREATE TABLE germanutf8 (
    ->   c CHAR(10)
    -> ) CHARACTER SET utf8 COLLATE utf8_unicode_ci;
```

Each table contains two records:

```
mysql> INSERT INTO german1 VALUES ('Bar'), ('Bär');
mysql> INSERT INTO german2 VALUES ('Bar'), ('Bär');
mysql> INSERT INTO germanutf8 VALUES ('Bar'), ('Bär');
```

Two of the above collations have an A = Ä equality, and one has no such equality (latin1_german2_ci). For that reason, you'll get these results in comparisons:

```
mysql> SELECT * FROM german1 WHERE c = 'Bär';
+------+
| c    |
+------+
| Bar  |
| Bär  |
+------+
mysql> SELECT * FROM german2 WHERE c = 'Bär';
+------+
| c    |
+------+
| Bär  |
+------+
mysql> SELECT * FROM germanutf8 WHERE c = 'Bär';
+------+
| c    |
```

```
+------+
| Bar  |
| Bär  |
+------+
```

This is not a bug but rather a consequence of the sorting properties of `latin1_german1_ci` and `utf8_unicode_ci` (the sorting shown is done according to the German DIN 5007 standard).

10.1.7.9 Collation and INFORMATION_SCHEMA Searches

String columns in `INFORMATION_SCHEMA` tables have a collation of `utf8_general_ci`, which is case insensitive. However, searches in `INFORMATION_SCHEMA` string columns are also affected by file system case sensitivity. For values that correspond to objects that are represented in the file system, such as names of databases and tables, searches may be case sensitive if the file system is case sensitive. This section describes how to work around this issue if necessary; see also Bug #34921.

Suppose that a query searches the `SCHEMATA.SCHEMA_NAME` column for the `test` database. On Linux, file systems are case sensitive, so comparisons of `SCHEMATA.SCHEMA_NAME` with `'test'` match, but comparisons with `'TEST'` do not:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
1 row in set (0.01 sec)

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME = 'TEST';
Empty set (0.00 sec)
```

On Windows or OS X where file systems are not case sensitive, comparisons match both `'test'` and `'TEST'`:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
1 row in set (0.00 sec)

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME = 'TEST';
+-------------+
| SCHEMA_NAME |
+-------------+
| TEST        |
+-------------+
1 row in set (0.00 sec)
```

The value of the `lower_case_table_names` system variable makes no difference in this context.

This behavior occurs because the `utf8_general_ci` collation is not used for `INFORMATION_SCHEMA` queries when searching the file system for database objects. It is a result of optimizations implemented for `INFORMATION_SCHEMA` searches in MySQL 5.1.21 and thus does not occur prior to 5.1.21. For information about these optimizations, see Section 8.2.4, "INFORMATION_SCHEMA Optimization".

Searches in `INFORMATION_SCHEMA` string columns for values that refer to `INFORMATION_SCHEMA` itself do use the `utf8_general_ci` collation because `INFORMATION_SCHEMA` is a "virtual" database and is not represented in the file system. For example, comparisons with `SCHEMATA.SCHEMA_NAME` match `'information_schema'` or `'INFORMATION_SCHEMA'` regardless of platform:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME = 'information_schema';
+--------------------+
| SCHEMA_NAME        |
+--------------------+
| information_schema |
+--------------------+
1 row in set (0.00 sec)

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME = 'INFORMATION_SCHEMA';
+--------------------+
| SCHEMA_NAME        |
+--------------------+
| information_schema |
+--------------------+
1 row in set (0.00 sec)
```

If the result of a string operation on an `INFORMATION_SCHEMA` column differs from expectations, a workaround is to use an explicit `COLLATE` clause to force a suitable collation (Section 10.1.7.2, "Using COLLATE in SQL Statements"). For example, to perform a case-insensitive search, use `COLLATE` with the `INFORMATION_SCHEMA` column name:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME COLLATE utf8_general_ci = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
1 row in set (0.00 sec)

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
    -> WHERE SCHEMA_NAME COLLATE utf8_general_ci = 'TEST';
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
1 row in set (0.00 sec)
```

You can also use the `UPPER()` or `LOWER()` function:

```
WHERE UPPER(SCHEMA_NAME) = 'TEST'
WHERE LOWER(SCHEMA_NAME) = 'test'
```

Although a case-insensitive comparison can be performed even on platforms with case-sensitive file systems, as just shown, it is not necessarily always the right thing to do. On such platforms, it is possible to have multiple objects with names that differ only in lettercase. For example, tables named `city`, `CITY`, and `City` can all exist simultaneously. Consider whether a search should match all such names or just one and write queries accordingly:

```
WHERE TABLE_NAME COLLATE utf8_bin = 'City'
WHERE TABLE_NAME COLLATE utf8_general_ci = 'city'
WHERE UPPER(TABLE_NAME) = 'CITY'
WHERE LOWER(TABLE_NAME) = 'city'
```

The first of those comparisons (with `utf8_bin`) is case sensitive; the others are not.

10.1.8 String Repertoire

The *repertoire* of a character set is the collection of characters in the set.

As of MySQL 5.1.21, string expressions have a repertoire attribute, which can have two values:

- `ASCII`: The expression can contain only characters in the Unicode range `U+0000` to `U+007F`.

- `UNICODE`: The expression can contain characters in the Unicode range `U+0000` to `U+FFFF`.

The `ASCII` range is a subset of `UNICODE` range, so a string with `ASCII` repertoire can be converted safely without loss of information to the character set of any string with `UNICODE` repertoire or to a character set that is a superset of `ASCII`. (All MySQL character sets are supersets of `ASCII` with the exception of `swe7`, which reuses some punctuation characters for Swedish accented characters.) The use of repertoire enables character set conversion in expressions for many cases where MySQL would otherwise return an "illegal mix of collations" error.

The following discussion provides examples of expressions and their repertoires, and describes how the use of repertoire changes string expression evaluation:

- The repertoire for string constants depends on string content:

```
SET NAMES utf8; SELECT 'abc';
SELECT _utf8'def';
SELECT N'MySQL';
```

Although the character set is `utf8` in each of the preceding cases, the strings do not actually contain any characters outside the ASCII range, so their repertoire is `ASCII` rather than `UNICODE`.

- Columns having the `ascii` character set have `ASCII` repertoire because of their character set. In the following table, `c1` has `ASCII` repertoire:

```
CREATE TABLE t1 (c1 CHAR(1) CHARACTER SET ascii);
```

The following example illustrates how repertoire enables a result to be determined in a case where an error occurs without repertoire:

```
CREATE TABLE t1 (
  c1 CHAR(1) CHARACTER SET latin1,
  c2 CHAR(1) CHARACTER SET ascii
);
INSERT INTO t1 VALUES ('a','b');
SELECT CONCAT(c1,c2) FROM t1;
```

Without repertoire, this error occurs:

```
ERROR 1267 (HY000): Illegal mix of collations (latin1_swedish_ci,IMPLICIT)
and (ascii_general_ci,IMPLICIT) for operation 'concat'
```

Using repertoire, subset to superset (`ascii` to `latin1`) conversion can occur and a result is returned:

```
+---------------+
| CONCAT(c1,c2) |
```

```
+---------------+
| ab            |
+---------------+
```

- Functions with one string argument inherit the repertoire of their argument. The result of `UPPER(_utf8'abc')` has `ASCII` repertoire, because its argument has `ASCII` repertoire.

- For functions that return a string but do not have string arguments and use `character_set_connection` as the result character set, the result repertoire is `ASCII` if `character_set_connection` is `ascii`, and `UNICODE` otherwise:

```
FORMAT(numeric_column, 4);
```

Use of repertoire changes how MySQL evaluates the following example:

```
SET NAMES ascii;
CREATE TABLE t1 (a INT, b VARCHAR(10) CHARACTER SET latin1);
INSERT INTO t1 VALUES (1,'b');
SELECT CONCAT(FORMAT(a, 4), b) FROM t1;
```

Without repertoire, this error occurs:

```
ERROR 1267 (HY000): Illegal mix of collations (ascii_general_ci,COERCIBLE)
and (latin1_swedish_ci,IMPLICIT) for operation 'concat'
```

With repertoire, a result is returned:

```
+-------------------------+
| CONCAT(FORMAT(a, 4), b) |
+-------------------------+
| 1.0000b                 |
+-------------------------+
```

- Functions with two or more string arguments use the "widest" argument repertoire for the result repertoire (`UNICODE` is wider than `ASCII`). Consider the following `CONCAT()` calls:

```
CONCAT(_ucs2 X'0041', _ucs2 X'0042')
CONCAT(_ucs2 X'0041', _ucs2 X'00C2')
```

For the first call, the repertoire is `ASCII` because both arguments are within the range of the `ascii` character set. For the second call, the repertoire is `UNICODE` because the second argument is outside the `ascii` character set range.

- The repertoire for function return values is determined based only on the repertoire of the arguments that affect the result's character set and collation.

```
IF(column1 < column2, 'smaller', 'greater')
```

The result repertoire is `ASCII` because the two string arguments (the second argument and the third argument) both have `ASCII` repertoire. The first argument does not matter for the result repertoire, even if the expression uses string values.

10.1.9 Operations Affected by Character Set Support

This section describes operations that take character set information into account.

10.1.9.1 Result Strings

MySQL has many operators and functions that return a string. This section answers the question: What is the character set and collation of such a string?

For simple functions that take string input and return a string result as output, the output's character set and collation are the same as those of the principal input value. For example, `UPPER(X)` returns a string whose character string and collation are the same as that of `X`. The same applies for `INSTR()`, `LCASE()`, `LOWER()`, `LTRIM()`, `MID()`, `REPEAT()`, `REPLACE()`, `REVERSE()`, `RIGHT()`, `RPAD()`, `RTRIM()`, `SOUNDEX()`, `SUBSTRING()`, `TRIM()`, `UCASE()`, and `UPPER()`.

Note: The `REPLACE()` function, unlike all other functions, always ignores the collation of the string input and performs a case-sensitive comparison.

If a string input or function result is a binary string, the string has no character set or collation. This can be checked by using the `CHARSET()` and `COLLATION()` functions, both of which return `binary` to indicate that their argument is a binary string:

```
mysql> SELECT CHARSET(BINARY 'a'), COLLATION(BINARY 'a');
+---------------------+-----------------------+
| CHARSET(BINARY 'a') | COLLATION(BINARY 'a') |
+---------------------+-----------------------+
| binary              | binary                |
+---------------------+-----------------------+
```

For operations that combine multiple string inputs and return a single string output, the "aggregation rules" of standard SQL apply for determining the collation of the result:

- If an explicit `COLLATE X` occurs, use `X`.

- If explicit `COLLATE X` and `COLLATE Y` occur, raise an error.

- Otherwise, if all collations are `X`, use `X`.

- Otherwise, the result has no collation.

For example, with `CASE ... WHEN a THEN b WHEN b THEN c COLLATE X END`, the resulting collation is `X`. The same applies for `UNION`, `||`, `CONCAT()`, `ELT()`, `GREATEST()`, `IF()`, and `LEAST()`.

For operations that convert to character data, the character set and collation of the strings that result from the operations are defined by the `character_set_connection` and `collation_connection` system variables. This applies only to `CAST()`, `CONV()`, `FORMAT()`, `HEX()`, and `SPACE()`.

If you are uncertain about the character set or collation of the result returned by a string function, you can use the `CHARSET()` or `COLLATION()` function to find out:

```
mysql> SELECT USER(), CHARSET(USER()), COLLATION(USER());
+----------------+-----------------+-------------------+
| USER()         | CHARSET(USER()) | COLLATION(USER()) |
+----------------+-----------------+-------------------+
| test@localhost | utf8            | utf8_general_ci   |
+----------------+-----------------+-------------------+
```

10.1.9.2 CONVERT() and CAST()

`CONVERT()` provides a way to convert data between different character sets. The syntax is:

```
CONVERT(expr USING transcoding_name)
```

In MySQL, transcoding names are the same as the corresponding character set names.

Examples:

```
SELECT CONVERT(_latin1'Müller' USING utf8);
INSERT INTO utf8table (utf8column)
    SELECT CONVERT(latin1field USING utf8) FROM latin1table;
```

CONVERT(... USING ...) is implemented according to the standard SQL specification.

You may also use CAST() to convert a string to a different character set. The syntax is:

```
CAST(character_string AS character_data_type CHARACTER SET charset_name)
```

Example:

```
SELECT CAST(_latin1'test' AS CHAR CHARACTER SET utf8);
```

If you use CAST() without specifying CHARACTER SET, the resulting character set and collation are defined by the character_set_connection and collation_connection system variables. If you use CAST() with CHARACTER SET X, the resulting character set and collation are X and the default collation of X.

You may not use a COLLATE clause inside a CONVERT() or CAST() call, but you may use it outside. For example, CAST(... COLLATE ...) is illegal, but CAST(...) COLLATE ... is legal:

```
SELECT CAST(_latin1'test' AS CHAR CHARACTER SET utf8) COLLATE utf8_bin;
```

10.1.9.3 SHOW Statements and INFORMATION_SCHEMA

Several SHOW statements provide additional character set information. These include SHOW CHARACTER SET, SHOW COLLATION, SHOW CREATE DATABASE, SHOW CREATE TABLE and SHOW COLUMNS. These statements are described here briefly. For more information, see Section 13.7.5, "SHOW Syntax".

INFORMATION_SCHEMA has several tables that contain information similar to that displayed by the SHOW statements. For example, the CHARACTER_SETS and COLLATIONS tables contain the information displayed by SHOW CHARACTER SET and SHOW COLLATION. See Chapter 20, *INFORMATION_SCHEMA Tables*.

The SHOW CHARACTER SET statement shows all available character sets. It takes an optional LIKE clause that indicates which character set names to match. For example:

```
mysql> SHOW CHARACTER SET LIKE 'latin%';
+---------+-----------------------------+-------------------+--------+
| Charset | Description                 | Default collation | Maxlen |
+---------+-----------------------------+-------------------+--------+
| latin1  | cp1252 West European        | latin1_swedish_ci |      1 |
| latin2  | ISO 8859-2 Central European | latin2_general_ci |      1 |
| latin5  | ISO 8859-9 Turkish          | latin5_turkish_ci |      1 |
| latin7  | ISO 8859-13 Baltic          | latin7_general_ci |      1 |
+---------+-----------------------------+-------------------+--------+
```

The output from SHOW COLLATION includes all available character sets. It takes an optional LIKE clause that indicates which collation names to match. For example:

```
mysql> SHOW COLLATION LIKE 'latin1%';
+-------------------+---------+----+---------+----------+---------+
| Collation         | Charset | Id | Default | Compiled | Sortlen |
+-------------------+---------+----+---------+----------+---------+
| latin1_german1_ci | latin1  |  5 |         |          |       0 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       0 |
| latin1_danish_ci  | latin1  | 15 |         |          |       0 |
| latin1_german2_ci | latin1  | 31 |         | Yes      |       2 |
| latin1_bin        | latin1  | 47 |         | Yes      |       0 |
| latin1_general_ci | latin1  | 48 |         |          |       0 |
| latin1_general_cs | latin1  | 49 |         |          |       0 |
| latin1_spanish_ci | latin1  | 94 |         |          |       0 |
+-------------------+---------+----+---------+----------+---------+
```

SHOW CREATE DATABASE displays the CREATE DATABASE statement that creates a given database:

```
mysql> SHOW CREATE DATABASE test;
+----------+----------------------------------------------------------------+
| Database | Create Database                                                |
+----------+----------------------------------------------------------------+
| test     | CREATE DATABASE `test` /*!40100 DEFAULT CHARACTER SET latin1 */ |
+----------+----------------------------------------------------------------+
```

If no COLLATE clause is shown, the default collation for the character set applies.

SHOW CREATE TABLE is similar, but displays the CREATE TABLE statement to create a given table. The column definitions indicate any character set specifications, and the table options include character set information.

The SHOW COLUMNS statement displays the collations of a table's columns when invoked as SHOW FULL COLUMNS. Columns with CHAR, VARCHAR, or TEXT data types have collations. Numeric and other noncharacter types have no collation (indicated by NULL as the Collation value). For example:

```
mysql> SHOW FULL COLUMNS FROM person\G
*************************** 1. row ***************************
     Field: id
      Type: smallint(5) unsigned
 Collation: NULL
      Null: NO
       Key: PRI
   Default: NULL
     Extra: auto_increment
Privileges: select,insert,update,references
   Comment:
*************************** 2. row ***************************
     Field: name
      Type: char(60)
 Collation: latin1_swedish_ci
      Null: NO
       Key:
   Default:
     Extra:
Privileges: select,insert,update,references
   Comment:
```

The character set is not part of the display but is implied by the collation name.

10.1.10 Unicode Support

MySQL supports two character sets for storing Unicode data:

- `ucs2`, the UCS-2 encoding of the Unicode character set using 16 bits per character.

- `utf8`, a UTF-8 encoding of the Unicode character set using one to three bytes per character.

These two character sets support the characters from the Basic Multilingual Plane (BMP) of Unicode Version 3.0. BMP characters have these characteristics:

- Their code values are between 0 and 65535 (or `U+0000` .. `U+FFFF`).

- They can be encoded with a fixed 16-bit word, as in `ucs2`.

- They can be encoded with 8, 16, or 24 bits, as in `utf8`.

- They are sufficient for almost all characters in major languages.

The `ucs2` and `utf8` character sets do not support supplementary characters that lie outside the BMP. Characters outside the BMP compare as REPLACEMENT CHARACTER and convert to `'?'` when converted to a Unicode character set.

A similar set of collations is available for each Unicode character set. For example, each has a Danish collation, the names of which are `ucs2_danish_ci` and `utf8_danish_ci`. All Unicode collations are listed at Section 10.1.13.1, "Unicode Character Sets".

The MySQL implementation of UCS-2 stores characters in big-endian byte order and does not use a byte order mark (BOM) at the beginning of values. Other database systems might use little-endian byte order or a BOM. In such cases, conversion of values will need to be performed when transferring data between those systems and MySQL.

MySQL uses no BOM for UTF-8 values.

Client applications that need to communicate with the server using Unicode should set the client character set accordingly; for example, by issuing a `SET NAMES 'utf8'` statement. `ucs2` cannot be used as a client character set, which means that it does not work for `SET NAMES` or `SET CHARACTER SET`. (See Section 10.1.4, "Connection Character Sets and Collations".)

The following sections provide additional detail on the Unicode character sets in MySQL.

10.1.10.1 The ucs2 Character Set (UCS-2 Unicode Encoding)

In UCS-2, every character is represented by a 2-byte Unicode code with the most significant byte first. For example: `LATIN CAPITAL LETTER A` has the code `0x0041` and it is stored as a 2-byte sequence: `0x00 0x41`. `CYRILLIC SMALL LETTER YERU` (Unicode `0x044B`) is stored as a 2-byte sequence: `0x04 0x4B`. For Unicode characters and their codes, please refer to the Unicode Home Page.

In MySQL, the `ucs2` character set is a fixed-length 16-bit encoding for Unicode BMP characters.

10.1.10.2 The utf8 Character Set (3-Byte UTF-8 Unicode Encoding)

UTF-8 (Unicode Transformation Format with 8-bit units) is an alternative way to store Unicode data. It is implemented according to RFC 3629, which describes encoding sequences that take from one to four bytes. MySQL support for UTF-8 does not include 4-byte sequences. (An older standard for UTF-8 encoding, RFC 2279, describes UTF-8 sequences that take from one to six bytes. RFC 3629 renders RFC 2279 obsolete; for this reason, sequences with five and six bytes are no longer used.)

The idea of UTF-8 is that various Unicode characters are encoded using byte sequences of different lengths:

- Basic Latin letters, digits, and punctuation signs use one byte.

- Most European and Middle East script letters fit into a 2-byte sequence: extended Latin letters (with tilde, macron, acute, grave and other accents), Cyrillic, Greek, Armenian, Hebrew, Arabic, Syriac, and others.

- Korean, Chinese, and Japanese ideographs use 3-byte sequences.

Tip: To save space with UTF-8, use `VARCHAR` instead of `CHAR`. Otherwise, MySQL must reserve three bytes for each character in a `CHAR CHARACTER SET utf8` column because that is the maximum possible length. For example, MySQL must reserve 30 bytes for a `CHAR(10) CHARACTER SET utf8` column.

For additional information about data type storage, see Section 11.7, "Data Type Storage Requirements". For information about `InnoDB` physical row storage, including how `InnoDB` tables that use `COMPACT` row format handle UTF-8 `CHAR(N)` columns internally, see Physical Row Structure.

10.1.11 UTF-8 for Metadata

Metadata is "the data about the data." Anything that *describes* the database—as opposed to being the *contents* of the database—is metadata. Thus column names, database names, user names, version names, and most of the string results from `SHOW` are metadata. This is also true of the contents of tables in `INFORMATION_SCHEMA` because those tables by definition contain information about database objects.

Representation of metadata must satisfy these requirements:

- All metadata must be in the same character set. Otherwise, neither the `SHOW` statements nor `SELECT` statements for tables in `INFORMATION_SCHEMA` would work properly because different rows in the same column of the results of these operations would be in different character sets.

- Metadata must include all characters in all languages. Otherwise, users would not be able to name columns and tables using their own languages.

To satisfy both requirements, MySQL stores metadata in a Unicode character set, namely UTF-8. This does not cause any disruption if you never use accented or non-Latin characters. But if you do, you should be aware that metadata is in UTF-8.

The metadata requirements mean that the return values of the `USER()`, `CURRENT_USER()`, `SESSION_USER()`, `SYSTEM_USER()`, `DATABASE()`, and `VERSION()` functions have the UTF-8 character set by default.

The server sets the `character_set_system` system variable to the name of the metadata character set:

```
mysql> SHOW VARIABLES LIKE 'character_set_system';
+----------------------+-------+
| Variable_name        | Value |
+----------------------+-------+
| character_set_system | utf8  |
+----------------------+-------+
```

Storage of metadata using Unicode does *not* mean that the server returns headers of columns and the results of `DESCRIBE` functions in the `character_set_system` character set by default. When you use `SELECT column1 FROM t`, the name `column1` itself is returned from the server to the client in the character set determined by the value of the `character_set_results` system variable, which has a default value of `latin1`. If you want the server to pass metadata results back in a different character set, use the `SET NAMES` statement to force the server to perform character set conversion. `SET NAMES` sets the `character_set_results` and other related system variables. (See Section 10.1.4, "Connection

Character Sets and Collations".) Alternatively, a client program can perform the conversion after receiving the result from the server. It is more efficient for the client to perform the conversion, but this option is not always available for all clients.

If `character_set_results` is set to `NULL`, no conversion is performed and the server returns metadata using its original character set (the set indicated by `character_set_system`).

Error messages returned from the server to the client are converted to the client character set automatically, as with metadata.

If you are using (for example) the `USER()` function for comparison or assignment within a single statement, don't worry. MySQL performs some automatic conversion for you.

```
SELECT * FROM t1 WHERE USER() = latin1_column;
```

This works because the contents of `latin1_column` are automatically converted to UTF-8 before the comparison.

```
INSERT INTO t1 (latin1_column) SELECT USER();
```

This works because the contents of `USER()` are automatically converted to `latin1` before the assignment.

Although automatic conversion is not in the SQL standard, the SQL standard document does say that every character set is (in terms of supported characters) a "subset" of Unicode. Because it is a well-known principle that "what applies to a superset can apply to a subset," we believe that a collation for Unicode can apply for comparisons with non-Unicode strings. For more information about coercion of strings, see Section 10.1.7.5, "Collation of Expressions".

10.1.12 Column Character Set Conversion

To convert a binary or nonbinary string column to use a particular character set, use `ALTER TABLE`. For successful conversion to occur, one of the following conditions must apply:

- If the column has a binary data type (`BINARY`, `VARBINARY`, `BLOB`), all the values that it contains must be encoded using a single character set (the character set you're converting the column to). If you use a binary column to store information in multiple character sets, MySQL has no way to know which values use which character set and cannot convert the data properly.

- If the column has a nonbinary data type (`CHAR`, `VARCHAR`, `TEXT`), its contents should be encoded in the column character set, not some other character set. If the contents are encoded in a different character set, you can convert the column to use a binary data type first, and then to a nonbinary column with the desired character set.

Suppose that a table `t` has a binary column named `col1` defined as `VARBINARY(50)`. Assuming that the information in the column is encoded using a single character set, you can convert it to a nonbinary column that has that character set. For example, if `col1` contains binary data representing characters in the `greek` character set, you can convert it as follows:

```
ALTER TABLE t MODIFY col1 VARCHAR(50) CHARACTER SET greek;
```

If your original column has a type of `BINARY(50)`, you could convert it to `CHAR(50)`, but the resulting values will be padded with `0x00` bytes at the end, which may be undesirable. To remove these bytes, use the `TRIM()` function:

```
UPDATE t SET col1 = TRIM(TRAILING 0x00 FROM col1);
```

Suppose that table `t` has a nonbinary column named `col1` defined as `CHAR(50) CHARACTER SET latin1` but you want to convert it to use `utf8` so that you can store values from many languages. The following statement accomplishes this:

```
ALTER TABLE t MODIFY col1 CHAR(50) CHARACTER SET utf8;
```

Conversion may be lossy if the column contains characters that are not in both character sets.

A special case occurs if you have old tables from before MySQL 4.1 where a nonbinary column contains values that actually are encoded in a character set different from the server's default character set. For example, an application might have stored `sjis` values in a column, even though MySQL's default character set was `latin1`. It is possible to convert the column to use the proper character set but an additional step is required. Suppose that the server's default character set was `latin1` and `col1` is defined as `CHAR(50)` but its contents are `sjis` values. The first step is to convert the column to a binary data type, which removes the existing character set information without performing any character conversion:

```
ALTER TABLE t MODIFY col1 BLOB;
```

The next step is to convert the column to a nonbinary data type with the proper character set:

```
ALTER TABLE t MODIFY col1 CHAR(50) CHARACTER SET sjis;
```

This procedure requires that the table not have been modified already with statements such as `INSERT` or `UPDATE` after an upgrade to MySQL 4.1 or later. In that case, MySQL would store new values in the column using `latin1`, and the column will contain a mix of `sjis` and `latin1` values and cannot be converted properly.

If you specified attributes when creating a column initially, you should also specify them when altering the table with `ALTER TABLE`. For example, if you specified `NOT NULL` and an explicit `DEFAULT` value, you should also provide them in the `ALTER TABLE` statement. Otherwise, the resulting column definition will not include those attributes.

To convert all character columns in a table, the `ALTER TABLE ... CONVERT TO CHARACTER SET charset` statement may be useful. See Section 13.1.7, "ALTER TABLE Syntax".

10.1.13 Character Sets and Collations That MySQL Supports

This section indicates which character sets MySQL supports. There is one subsection for each group of related character sets. For each character set, the permissible collations are listed.

To list the available character sets and their default collations, use the `SHOW CHARACTER SET` statement or query the `INFORMATION_SCHEMA CHARACTER_SETS` table. For example:

```
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+
| Charset  | Description                 | Default collation   |
+----------+-----------------------------+---------------------+
| big5     | Big5 Traditional Chinese    | big5_chinese_ci     |
| dec8     | DEC West European           | dec8_swedish_ci     |
```

```
| cp850    | DOS West European          | cp850_general_ci    |
| hp8      | HP West European           | hp8_english_ci      |
| koi8r    | KOI8-R Relcom Russian      | koi8r_general_ci    |
| latin1   | cp1252 West European       | latin1_swedish_ci   |
| latin2   | ISO 8859-2 Central European| latin2_general_ci   |
| swe7     | 7bit Swedish               | swe7_swedish_ci     |
| ascii    | US ASCII                   | ascii_general_ci    |
| ujis     | EUC-JP Japanese            | ujis_japanese_ci    |
| sjis     | Shift-JIS Japanese         | sjis_japanese_ci    |
| hebrew   | ISO 8859-8 Hebrew          | hebrew_general_ci   |
| tis620   | TIS620 Thai                | tis620_thai_ci      |
| euckr    | EUC-KR Korean              | euckr_korean_ci     |
| koi8u    | KOI8-U Ukrainian           | koi8u_general_ci    |
| gb2312   | GB2312 Simplified Chinese  | gb2312_chinese_ci   |
| greek    | ISO 8859-7 Greek           | greek_general_ci    |
| cp1250   | Windows Central European   | cp1250_general_ci   |
| gbk      | GBK Simplified Chinese     | gbk_chinese_ci      |
| latin5   | ISO 8859-9 Turkish         | latin5_turkish_ci   |
| armscii8 | ARMSCII-8 Armenian         | armscii8_general_ci |
| utf8     | UTF-8 Unicode              | utf8_general_ci     |
| ucs2     | UCS-2 Unicode              | ucs2_general_ci     |
| cp866    | DOS Russian                | cp866_general_ci    |
| keybcs2  | DOS Kamenicky Czech-Slovak | keybcs2_general_ci  |
| macce    | Mac Central European       | macce_general_ci    |
| macroman | Mac West European          | macroman_general_ci |
| cp852    | DOS Central European       | cp852_general_ci    |
| latin7   | ISO 8859-13 Baltic         | latin7_general_ci   |
| cp1251   | Windows Cyrillic           | cp1251_general_ci   |
| cp1256   | Windows Arabic             | cp1256_general_ci   |
| cp1257   | Windows Baltic             | cp1257_general_ci   |
| binary   | Binary pseudo charset      | binary              |
| geostd8  | GEOSTD8 Georgian           | geostd8_general_ci  |
| cp932    | SJIS for Windows Japanese  | cp932_japanese_ci   |
| eucjpms  | UJIS for Windows Japanese  | eucjpms_japanese_ci |
+----------+----------------------------+---------------------+
```

In cases where a character set has multiple collations, it might not be clear which collation is most suitable for a given application. To avoid choosing the wrong collation, it can be helpful to perform some comparisons with representative data values to make sure that a given collation sorts values the way you expect.

Collation-Charts.Org is a useful site for information that shows how one collation compares to another.

10.1.13.1 Unicode Character Sets

MySQL has two Unicode character sets:

- `ucs2`, the UCS-2 encoding of the Unicode character set using 16 bits per character.

- `utf8`, a UTF-8 encoding of the Unicode character set using one to three bytes per character.

You can store text in about 650 languages using these character sets. This section lists the collations available for each Unicode character set and describes their differentiating properties. For general information about the character sets, see Section 10.1.10, "Unicode Support".

A similar set of collations is available for each Unicode character set. These are shown in the following list, where *xxx* represents the character set name. For example, *xxx_danish_ci* represents the Danish collations, the specific names of which are `ucs2_danish_ci` and `utf8_danish_ci`.

- *xxx_bin*

- *xxx_czech_ci*

- *xxx_danish_ci*

- *xxx_esperanto_ci*

- *xxx_estonian_ci*

- *xxx_general_ci* (default)

- *xxx_general_mysql500_ci*

- *xxx_hungarian_ci*

- *xxx_icelandic_ci*

- *xxx_latvian_ci*

- *xxx_lithuanian_ci*

- *xxx_persian_ci*

- *xxx_polish_ci*

- *xxx_roman_ci*

- *xxx_romanian_ci*

- *xxx_slovak_ci*

- *xxx_slovenian_ci*

- *xxx_spanish_ci*

- *xxx_spanish2_ci*

- *xxx_swedish_ci*

- *xxx_turkish_ci*

- *xxx_unicode_ci*

The *xxx_hungarian_ci* collations were added in MySQL 5.1.5.

MySQL implements the *xxx_unicode_ci* collations according to the Unicode Collation Algorithm (UCA) described at http://www.unicode.org/reports/tr10/. The collation uses the version-4.0.0 UCA weight keys: http://www.unicode.org/Public/UCA/4.0.0/allkeys-4.0.0.txt. The *xxx_unicode_ci* collations have only partial support for the Unicode Collation Algorithm. Some characters are not supported yet. Also, combining marks are not fully supported. This affects primarily Vietnamese, Yoruba, and some smaller languages such as Navajo. A combined character will be considered different from the same character written with a single unicode character in string comparisons, and the two characters are considered to have a different length (for example, as returned by the CHAR_LENGTH() function or in result set metadata).

MySQL implements language-specific Unicode collations only if the ordering with *xxx_unicode_ci* does not work well for a language. Language-specific collations are UCA-based. They are derived from *xxx_unicode_ci* with additional language tailoring rules.

For any Unicode character set, operations performed using the *xxx_general_ci* collation are faster than those for the *xxx_unicode_ci* collation. For example, comparisons for the utf8_general_ci collation

are faster, but slightly less correct, than comparisons for `utf8_unicode_ci`. The reason for this is that `utf8_unicode_ci` supports mappings such as expansions; that is, when one character compares as equal to combinations of other characters. For example, in German and some other languages "ß" is equal to "ss". `utf8_unicode_ci` also supports contractions and ignorable characters. `utf8_general_ci` is a legacy collation that does not support expansions, contractions, or ignorable characters. It can make only one-to-one comparisons between characters.

To further illustrate, the following equalities hold in both `utf8_general_ci` and `utf8_unicode_ci` (for the effect this has in comparisons or when doing searches, see Section 10.1.7.8, "Examples of the Effect of Collation"):

```
Ä = A
Ö = O
Ü = U
```

A difference between the collations is that this is true for `utf8_general_ci`:

```
ß = s
```

Whereas this is true for `utf8_unicode_ci`, which supports the German DIN-1 ordering (also known as dictionary order):

```
ß = ss
```

MySQL implements language-specific collations for the `utf8` character set only if the ordering with `utf8_unicode_ci` does not work well for a language. For example, `utf8_unicode_ci` works fine for German dictionary order and French, so there is no need to create special `utf8` collations.

`utf8_general_ci` also is satisfactory for both German and French, except that "ß" is equal to "s", and not to "ss". If this is acceptable for your application, you should use `utf8_general_ci` because it is faster. Otherwise, use `utf8_unicode_ci` because it is more accurate.

`xxx_swedish_ci` includes Swedish rules. For example, in Swedish, the following relationship holds, which is not something expected by a German or French speaker:

```
Ü = Y < Ö
```

The `xxx_spanish_ci` and `xxx_spanish2_ci` collations correspond to modern Spanish and traditional Spanish, respectively. In both collations, "ñ" (n-tilde) is a separate letter between "n" and "o". In addition, for traditional Spanish, "ch" is a separate letter between "c" and "d", and "ll" is a separate letter between "l" and "m"

The `xxx_spanish2_ci` collations may also be used for Asturian and Galician.

The `xxx_danich_ci` collations may also be used for Norwegian.

In the `xxx_roman_ci` collations, `I` and `J` compare as equal, and `U` and `V` compare as equal.

The `xxx_general_mysql500_ci` collations were added in MySQL 5.1.62. They preserve the pre-5.1.24 ordering of the original `xxx_general_ci` collations and permit upgrades for tables created before MySQL 5.1.24. For more information, see Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt", and Section 2.13.4, "Rebuilding or Repairing Tables or Indexes".

For additional information about Unicode collations in MySQL, see Collation-Charts.Org (utf8).

10.1.13.2 West European Character Sets

Western European character sets cover most West European languages, such as French, Spanish, Catalan, Basque, Portuguese, Italian, Albanian, Dutch, German, Danish, Swedish, Norwegian, Finnish, Faroese, Icelandic, Irish, Scottish, and English.

- `ascii` (US ASCII) collations:

  - `ascii_bin`

  - `ascii_general_ci` (default)

- `cp850` (DOS West European) collations:

  - `cp850_bin`

  - `cp850_general_ci` (default)

- `dec8` (DEC Western European) collations:

  - `dec8_bin`

  - `dec8_swedish_ci` (default)

- `hp8` (HP Western European) collations:

  - `hp8_bin`

  - `hp8_english_ci` (default)

- `latin1` (cp1252 West European) collations:

  - `latin1_bin`

  - `latin1_danish_ci`

  - `latin1_general_ci`

  - `latin1_general_cs`

  - `latin1_german1_ci`

  - `latin1_german2_ci`

  - `latin1_spanish_ci`

  - `latin1_swedish_ci` (default)

`latin1` is the default character set. MySQL's `latin1` is the same as the Windows `cp1252` character set. This means it is the same as the official `ISO 8859-1` or IANA (Internet Assigned Numbers Authority) `latin1`, except that IANA `latin1` treats the code points between `0x80` and `0x9f` as "undefined," whereas `cp1252`, and therefore MySQL's `latin1`, assign characters for those positions. For example, `0x80` is the Euro sign. For the "undefined" entries in `cp1252`, MySQL translates `0x81` to Unicode `0x0081`, `0x8d` to `0x008d`, `0x8f` to `0x008f`, `0x90` to `0x0090`, and `0x9d` to `0x009d`.

The `latin1_swedish_ci` collation is the default that probably is used by the majority of MySQL customers. Although it is frequently said that it is based on the Swedish/Finnish collation rules, there are Swedes and Finns who disagree with this statement.

The `latin1_german1_ci` and `latin1_german2_ci` collations are based on the DIN-1 and DIN-2 standards, where DIN stands for *Deutsches Institut für Normung* (the German equivalent of ANSI). DIN-1 is called the "dictionary collation" and DIN-2 is called the "phone book collation." For an example of the effect this has in comparisons or when doing searches, see Section 10.1.7.8, "Examples of the Effect of Collation".

- `latin1_german1_ci` (dictionary) rules:

```
Ä = A
Ö = O
Ü = U
ß = s
```

- `latin1_german2_ci` (phone-book) rules:

```
Ä = AE
Ö = OE
Ü = UE
ß = ss
```

In the `latin1_spanish_ci` collation, "ñ" (n-tilde) is a separate letter between "n" and "o".

- `macroman` (Mac West European) collations:

  - `macroman_bin`

  - `macroman_general_ci` (default)

- `swe7` (7bit Swedish) collations:

  - `swe7_bin`

  - `swe7_swedish_ci` (default)

For additional information about Western European collations in MySQL, see Collation-Charts.Org (ascii, cp850, dec8, hp8, latin1, macroman, swe7).

10.1.13.3 Central European Character Sets

MySQL provides some support for character sets used in the Czech Republic, Slovakia, Hungary, Romania, Slovenia, Croatia, Poland, and Serbia (Latin).

- `cp1250` (Windows Central European) collations:

  - `cp1250_bin`

  - `cp1250_croatian_ci`

  - `cp1250_czech_cs`

  - `cp1250_general_ci` (default)

  - `cp1250_polish_ci`

- `cp852` (DOS Central European) collations:

  - `cp852_bin`

- cp852_general_ci (default)

- keybcs2 (DOS Kamenicky Czech-Slovak) collations:

  - keybcs2_bin

  - keybcs2_general_ci (default)

- latin2 (ISO 8859-2 Central European) collations:

  - latin2_bin

  - latin2_croatian_ci

  - latin2_czech_cs

  - latin2_general_ci (default)

  - latin2_hungarian_ci

- macce (Mac Central European) collations:

  - macce_bin

  - macce_general_ci (default)

For additional information about Central European collations in MySQL, see Collation-Charts.Org (cp1250, cp852, keybcs2, latin2, macce).

10.1.13.4 South European and Middle East Character Sets

South European and Middle Eastern character sets supported by MySQL include Armenian, Arabic, Georgian, Greek, Hebrew, and Turkish.

- armscii8 (ARMSCII-8 Armenian) collations:

  - armscii8_bin

  - armscii8_general_ci (default)

- cp1256 (Windows Arabic) collations:

  - cp1256_bin

  - cp1256_general_ci (default)

- geostd8 (GEOSTD8 Georgian) collations:

  - geostd8_bin

  - geostd8_general_ci (default)

- greek (ISO 8859-7 Greek) collations:

  - greek_bin

  - greek_general_ci (default)

- hebrew (ISO 8859-8 Hebrew) collations:

- `hebrew_bin`

- `hebrew_general_ci` (default)

- `latin5` (ISO 8859-9 Turkish) collations:

  - `latin5_bin`

  - `latin5_turkish_ci` (default)

For additional information about South European and Middle Eastern collations in MySQL, see Collation-Charts.Org (armscii8, cp1256, geostd8, greek, hebrew, latin5).

10.1.13.5 Baltic Character Sets

The Baltic character sets cover Estonian, Latvian, and Lithuanian languages.

- `cp1257` (Windows Baltic) collations:

  - `cp1257_bin`

  - `cp1257_general_ci` (default)

  - `cp1257_lithuanian_ci`

- `latin7` (ISO 8859-13 Baltic) collations:

  - `latin7_bin`

  - `latin7_estonian_cs`

  - `latin7_general_ci` (default)

  - `latin7_general_cs`

For additional information about Baltic collations in MySQL, see Collation-Charts.Org (cp1257, latin7).

10.1.13.6 Cyrillic Character Sets

The Cyrillic character sets and collations are for use with Belarusian, Bulgarian, Russian, Ukrainian, and Serbian (Cyrillic) languages.

- `cp1251` (Windows Cyrillic) collations:

  - `cp1251_bin`

  - `cp1251_bulgarian_ci`

  - `cp1251_general_ci` (default)

  - `cp1251_general_cs`

  - `cp1251_ukrainian_ci`

- `cp866` (DOS Russian) collations:

  - `cp866_bin`

- `cp866_general_ci` (default)

- `koi8r` (KOI8-R Relcom Russian) collations:

  - `koi8r_bin`

  - `koi8r_general_ci` (default)

- `koi8u` (KOI8-U Ukrainian) collations:

  - `koi8u_bin`

  - `koi8u_general_ci` (default)

For additional information about Cyrillic collations in MySQL, see Collation-Charts.Org (cp1251, cp866, koi8r, koi8u).).

10.1.13.7 Asian Character Sets

The Asian character sets that we support include Chinese, Japanese, Korean, and Thai. These can be complicated. For example, the Chinese sets must allow for thousands of different characters. See The cp932 Character Set, for additional information about the `cp932` and `sjis` character sets.

For answers to some common questions and problems relating support for Asian character sets in MySQL, see Section A.11, "MySQL 5.1 FAQ: MySQL Chinese, Japanese, and Korean Character Sets".

- `big5` (Big5 Traditional Chinese) collations:

  - `big5_bin`

  - `big5_chinese_ci` (default)

- `cp932` (SJIS for Windows Japanese) collations:

  - `cp932_bin`

  - `cp932_japanese_ci` (default)

- `eucjpms` (UJIS for Windows Japanese) collations:

  - `eucjpms_bin`

  - `eucjpms_japanese_ci` (default)

- `euckr` (EUC-KR Korean) collations:

  - `euckr_bin`

  - `euckr_korean_ci` (default)

- `gb2312` (GB2312 Simplified Chinese) collations:

  - `gb2312_bin`

  - `gb2312_chinese_ci` (default)

- `gbk` (GBK Simplified Chinese) collations:

- `gbk_bin`

- `gbk_chinese_ci` (default)

- `sjis` (Shift-JIS Japanese) collations:

  - `sjis_bin`

  - `sjis_japanese_ci` (default)

- `tis620` (TIS620 Thai) collations:

  - `tis620_bin`

  - `tis620_thai_ci` (default)

- `ujis` (EUC-JP Japanese) collations:

  - `ujis_bin`

  - `ujis_japanese_ci` (default)

The `big5_chinese_ci` collation sorts on number of strokes.

For additional information about Asian collations in MySQL, see Collation-Charts.Org (big5, cp932, eucjpms, euckr, gb2312, gbk, sjis, tis620, ujis).

The cp932 Character Set

Why is `cp932` needed?

In MySQL, the `sjis` character set corresponds to the `Shift_JIS` character set defined by IANA, which supports JIS X0201 and JIS X0208 characters. (See http://www.iana.org/assignments/character-sets.)

However, the meaning of "SHIFT JIS" as a descriptive term has become very vague and it often includes the extensions to `Shift_JIS` that are defined by various vendors.

For example, "SHIFT JIS" used in Japanese Windows environments is a Microsoft extension of `Shift_JIS` and its exact name is `Microsoft Windows Codepage : 932` or `cp932`. In addition to the characters supported by `Shift_JIS`, `cp932` supports extension characters such as NEC special characters, NEC selected—IBM extended characters, and IBM selected characters.

Many Japanese users have experienced problems using these extension characters. These problems stem from the following factors:

- MySQL automatically converts character sets.

- Character sets are converted using Unicode (`ucs2`).

- The `sjis` character set does not support the conversion of these extension characters.

- There are several conversion rules from so-called "SHIFT JIS" to Unicode, and some characters are converted to Unicode differently depending on the conversion rule. MySQL supports only one of these rules (described later).

The MySQL `cp932` character set is designed to solve these problems.

Because MySQL supports character set conversion, it is important to separate IANA `Shift_JIS` and `cp932` into two different character sets because they provide different conversion rules.

How does `cp932` differ from `sjis`?

The `cp932` character set differs from `sjis` in the following ways:

- `cp932` supports NEC special characters, NEC selected—IBM extended characters, and IBM selected characters.

- Some `cp932` characters have two different code points, both of which convert to the same Unicode code point. When converting from Unicode back to `cp932`, one of the code points must be selected. For this "round trip conversion," the rule recommended by Microsoft is used. (See http://support.microsoft.com/kb/170559/EN-US/.)

  The conversion rule works like this:

  - If the character is in both JIS X 0208 and NEC special characters, use the code point of JIS X 0208.

  - If the character is in both NEC special characters and IBM selected characters, use the code point of NEC special characters.

  - If the character is in both IBM selected characters and NEC selected—IBM extended characters, use the code point of IBM extended characters.

  The table shown at https://msdn.microsoft.com/en-us/goglobal/cc305152.aspx provides information about the Unicode values of `cp932` characters. For `cp932` table entries with characters under which a four-digit number appears, the number represents the corresponding Unicode (`ucs2`) encoding. For table entries with an underlined two-digit value appears, there is a range of `cp932` character values that begin with those two digits. Clicking such a table entry takes you to a page that displays the Unicode value for each of the `cp932` characters that begin with those digits.

  The following links are of special interest. They correspond to the encodings for the following sets of characters:

  - NEC special characters (lead byte `0x87`):

    ```
    https://msdn.microsoft.com/en-us/goglobal/gg674964
    ```

  - NEC selected—IBM extended characters (lead byte `0xED` and `0xEE`):

    ```
    https://msdn.microsoft.com/en-us/goglobal/gg671837
    https://msdn.microsoft.com/en-us/goglobal/gg671838
    ```

  - IBM selected characters (lead byte `0xFA`, `0xFB`, `0xFC`):

    ```
    https://msdn.microsoft.com/en-us/goglobal/gg671839
    https://msdn.microsoft.com/en-us/goglobal/gg671840
    https://msdn.microsoft.com/en-us/goglobal/gg671841
    ```

- `cp932` supports conversion of user-defined characters in combination with `eucjpms`, and solves the problems with `sjis`/`ujis` conversion. For details, please refer to http://www.sljfaq.org/afaq/encodings.html.

For some characters, conversion to and from `ucs2` is different for `sjis` and `cp932`. The following tables illustrate these differences.

Conversion to `ucs2`:

`sjis`/`cp932` Value	`sjis` -> `ucs2` Conversion	`cp932` -> `ucs2` Conversion
5C	005C	005C
7E	007E	007E
815C	2015	2015
815F	005C	FF3C
8160	301C	FF5E
8161	2016	2225
817C	2212	FF0D
8191	00A2	FFE0
8192	00A3	FFE1
81CA	00AC	FFE2

Conversion from `ucs2`:

`ucs2` value	`ucs2` -> `sjis` Conversion	`ucs2` -> `cp932` Conversion
005C	815F	5C
007E	7E	7E
00A2	8191	3F
00A3	8192	3F
00AC	81CA	3F
2015	815C	815C
2016	8161	3F
2212	817C	3F
2225	3F	8161
301C	8160	3F
FF0D	3F	817C
FF3C	3F	815F
FF5E	3F	8160
FFE0	3F	8191
FFE1	3F	8192
FFE2	3F	81CA

Users of any Japanese character sets should be aware that using `--character-set-client-handshake` (or `--skip-character-set-client-handshake`) has an important effect. See Section 5.1.3, "Server Command Options".

10.2 Setting the Error Message Language

By default, `mysqld` produces error messages in English, but they can also be displayed in any of several other languages: Czech, Danish, Dutch, Estonian, French, German, Greek, Hungarian, Italian, Japanese, Korean, Norwegian, Norwegian-ny, Polish, Portuguese, Romanian, Russian, Slovak, Spanish, or Swedish.

You can select which language the server uses for error messages using the instructions in this section.

To start `mysqld` with a particular language for error messages, use the `--language` or `-L` option. The option value can be a language name or the full path to the error message file. For example:

```
shell> mysqld --language=swedish
```

Or:

```
shell> mysqld --language=/usr/local/share/swedish
```

The language name should be specified in lowercase.

By default, the language files are located in the `share/mysql/LANGUAGE` directory under the MySQL base directory.

For information about changing the character set for error messages (rather than the language), see Section 10.1.6, "Character Set for Error Messages".

You can change the content of the error messages produced by the server using the instructions in the MySQL Internals manual, available at MySQL Internals: Error Messages. If you do change the content of error messages, remember to repeat your changes after each upgrade to a newer version of MySQL.

10.3 Adding a Character Set

This section discusses the procedure for adding a character set to MySQL. The proper procedure depends on whether the character set is simple or complex:

- If the character set does not need special string collating routines for sorting and does not need multibyte character support, it is simple.

- If the character set needs either of those features, it is complex.

For example, `greek` and `swe7` are simple character sets, whereas `big5` and `czech` are complex character sets.

To use the following instructions, you must have a MySQL source distribution. In the instructions, `MYSET` represents the name of the character set that you want to add.

1. Add a `<charset>` element for `MYSET` to the `sql/share/charsets/Index.xml` file. Use the existing contents in the file as a guide to adding new contents. A partial listing for the `latin1` `<charset>` element follows:

```
<charset name="latin1">
  <family>Western</family>
  <description>cp1252 West European</description>
  ...
  <collation name="latin1_swedish_ci" id="8" order="Finnish, Swedish">
    <flag>primary</flag>
    <flag>compiled</flag>
  </collation>
  <collation name="latin1_danish_ci" id="15" order="Danish"/>
  ...
  <collation name="latin1_bin" id="47" order="Binary">
    <flag>binary</flag>
    <flag>compiled</flag>
```

```
      </collation>
 ...
</charset>
```

The `<charset>` element must list all the collations for the character set. These must include at least a binary collation and a default (primary) collation. The default collation is often named using a suffix of `general_ci` (general, case insensitive). It is possible for the binary collation to be the default collation, but usually they are different. The default collation should have a `primary` flag. The binary collation should have a `binary` flag.

You must assign a unique ID number to each collation, chosen from the range 1 to 254. To find the maximum of the currently used collation IDs, use this query:

```
SELECT MAX(ID) FROM INFORMATION_SCHEMA.COLLATIONS;
```

2. This step depends on whether you are adding a simple or complex character set. A simple character set requires only a configuration file, whereas a complex character set requires C source file that defines collation functions, multibyte functions, or both.

   For a simple character set, create a configuration file, `MYSET.xml`, that describes the character set properties. Create this file in the `sql/share/charsets` directory. You can use a copy of `latin1.xml` as the basis for this file. The syntax for the file is very simple:

   - Comments are written as ordinary XML comments (`<!-- text -->`).

   - Words within `<map>` array elements are separated by arbitrary amounts of whitespace.

   - Each word within `<map>` array elements must be a number in hexadecimal format.

   - The `<map>` array element for the `<ctype>` element has 257 words. The other `<map>` array elements after that have 256 words. See Section 10.3.1, "Character Definition Arrays".

   - For each collation listed in the `<charset>` element for the character set in `Index.xml`, `MYSET.xml` must contain a `<collation>` element that defines the character ordering.

   For a complex character set, create a C source file that describes the character set properties and defines the support routines necessary to properly perform operations on the character set:

   - Create the file `ctype-MYSET.c` in the `strings` directory. Look at one of the existing `ctype-*.c` files (such as `ctype-big5.c`) to see what needs to be defined. The arrays in your file must have names like `ctype_MYSET`, `to_lower_MYSET`, and so on. These correspond to the arrays for a simple character set. See Section 10.3.1, "Character Definition Arrays".

   - For each `<collation>` element listed in the `<charset>` element for the character set in `Index.xml`, the `ctype-MYSET.c` file must provide an implementation of the collation.

   - If the character set requires string collating functions, see Section 10.3.2, "String Collating Support for Complex Character Sets".

   - If the character set requires multibyte character support, see Section 10.3.3, "Multi-Byte Character Support for Complex Character Sets".

3. Modify the configuration information. Use the existing configuration information as a guide to adding information for `MYSYS`. The example here assumes that the character set has default and binary collations, but more lines are needed if `MYSET` has additional collations.

   a. Edit `mysys/charset-def.c`, and "register" the collations for the new character set.

Add these lines to the "declaration" section:

```
#ifdef HAVE_CHARSET_MYSET
extern CHARSET_INFO my_charset_MYSET_general_ci;
extern CHARSET_INFO my_charset_MYSET_bin;
#endif
```

Add these lines to the "registration" section:

```
#ifdef HAVE_CHARSET_MYSET
  add_compiled_collation(&my_charset_MYSET_general_ci);
  add_compiled_collation(&my_charset_MYSET_bin);
#endif
```

b. If the character set uses `ctype-MYSET.c`, edit `strings/Makefile.am` and add `ctype-MYSET.c` to each definition of the `CSRCS` variable, and to the `EXTRA_DIST` variable.

c. If the character set uses `ctype-MYSET.c`, edit `libmysql/Makefile.shared` and add `ctype-MYSET.lo` to the `mystringsobjects` definition.

d. Edit `config/ac-macros/character_sets.m4`:

    i.   Add `MYSET` to one of the `define(CHARSETS_AVAILABLE...)` lines in alphabetic order.

    ii. Add `MYSET` to `CHARSETS_COMPLEX`. This is needed even for simple character sets, or `configure` will not recognize `--with-charset=MYSET`.

    iii. Add `MYSET` to the first `case` control structure. Omit the `USE_MB` and `USE_MB_IDENT` lines for 8-bit character sets.

    ```
    MYSET)
      AC_DEFINE(HAVE_CHARSET_MYSET, 1, [Define to enable charset MYSET])
      AC_DEFINE([USE_MB], 1, [Use multi-byte character routines])
      AC_DEFINE(USE_MB_IDENT, 1)
      ;;
    ```

    iv. Add `MYSET` to the second `case` control structure:

    ```
    MYSET)
      default_charset_default_collation="MYSET_general_ci"
      default_charset_collations="MYSET_general_ci MYSET_bin"
      ;;
    ```

4. Reconfigure, recompile, and test.

10.3.1 Character Definition Arrays

Each simple character set has a configuration file located in the `sql/share/charsets` directory. For a character set named `MYSYS`, the file is named `MYSET.xml`. It uses `<map>` array elements to list character set properties. `<map>` elements appear within these elements:

- `<ctype>` defines attributes for each character.

- `<lower>` and `<upper>` list the lowercase and uppercase characters.

- `<unicode>` maps 8-bit character values to Unicode values.

- `<collation>` elements indicate character ordering for comparisons and sorts, one element per collation. Binary collations need no `<map>` element because the character codes themselves provide the ordering.

For a complex character set as implemented in a `ctype-MYSET.c` file in the `strings` directory, there are corresponding arrays: `ctype_MYSET[]`, `to_lower_MYSET[]`, and so forth. Not every complex character set has all of the arrays. See also the existing `ctype-*.c` files for examples. See the `CHARSET_INFO.txt` file in the `strings` directory for additional information.

Most of the arrays are indexed by character value and have 256 elements. The `<ctype>` array is indexed by character value + 1 and has 257 elements. This is a legacy convention for handling `EOF`.

`<ctype>` array elements are bit values. Each element describes the attributes of a single character in the character set. Each attribute is associated with a bitmask, as defined in `include/m_ctype.h`:

```
#define _MY_U    01       /* Upper case */
#define _MY_L    02       /* Lower case */
#define _MY_NMR  04       /* Numeral (digit) */
#define _MY_SPC  010      /* Spacing character */
#define _MY_PNT  020      /* Punctuation */
#define _MY_CTR  040      /* Control character */
#define _MY_B    0100     /* Blank */
#define _MY_X    0200     /* heXadecimal digit */
```

The `<ctype>` value for a given character should be the union of the applicable bitmask values that describe the character. For example, `'A'` is an uppercase character (`_MY_U`) as well as a hexadecimal digit (`_MY_X`), so its `ctype` value should be defined like this:

```
ctype['A'+1] = _MY_U | _MY_X = 01 | 0200 = 0201
```

The bitmask values in `m_ctype.h` are octal values, but the elements of the `<ctype>` array in `MYSET.xml` should be written as hexadecimal values.

The `<lower>` and `<upper>` arrays hold the lowercase and uppercase characters corresponding to each member of the character set. For example:

```
lower['A'] should contain 'a'
upper['a'] should contain 'A'
```

Each `<collation>` array indicates how characters should be ordered for comparison and sorting purposes. MySQL sorts characters based on the values of this information. In some cases, this is the same as the `<upper>` array, which means that sorting is case-insensitive. For more complicated sorting rules (for complex character sets), see the discussion of string collating in Section 10.3.2, "String Collating Support for Complex Character Sets".

10.3.2 String Collating Support for Complex Character Sets

For a simple character set named *MYSET*, sorting rules are specified in the `MYSET.xml` configuration file using `<map>` array elements within `<collation>` elements. If the sorting rules for your language are too complex to be handled with simple arrays, you must define string collating functions in the `ctype-MYSET.c` source file in the `strings` directory.

The existing character sets provide the best documentation and examples to show how these functions are implemented. Look at the `ctype-*.c` files in the `strings` directory, such as the files for the `big5`, `czech`, `gbk`, `sjis`, and `tis160` character sets. Take a look at the `MY_COLLATION_HANDLER` structures

to see how they are used. See also the `CHARSET_INFO.txt` file in the `strings` directory for additional information.

10.3.3 Multi-Byte Character Support for Complex Character Sets

If you want to add support for a new character set named *MYSET* that includes multibyte characters, you must use multibyte character functions in the `ctype-MYSET.c` source file in the `strings` directory.

The existing character sets provide the best documentation and examples to show how these functions are implemented. Look at the `ctype-*.c` files in the `strings` directory, such as the files for the `euc_kr`, `gb2312`, `gbk`, `sjis`, and `ujis` character sets. Take a look at the `MY_CHARSET_HANDLER` structures to see how they are used. See also the `CHARSET_INFO.txt` file in the `strings` directory for additional information.

10.4 Adding a Collation to a Character Set

A collation is a set of rules that defines how to compare and sort character strings. Each collation in MySQL belongs to a single character set. Every character set has at least one collation, and most have two or more collations.

A collation orders characters based on weights. Each character in a character set maps to a weight. Characters with equal weights compare as equal, and characters with unequal weights compare according to the relative magnitude of their weights.

MySQL supports several collation implementations, as discussed in Section 10.4.1, "Collation Implementation Types". Some of these can be added to MySQL without recompiling:

• Simple collations for 8-bit character sets.

• UCA-based collations for Unicode character sets.

• Binary (*xxx_bin*) collations.

The following sections describe how to add collations of the first two types to existing character sets. All existing character sets already have a binary collation, so there is no need here to describe how to add one.

Summary of the procedure for adding a new collation:

1. Choose a collation ID.

2. Add configuration information that names the collation and describes the character-ordering rules.

3. Restart the server.

4. Verify that the collation is present.

The instructions here cover only collations that can be added without recompiling MySQL. To add a collation that does require recompiling (as implemented by means of functions in a C source file), use the instructions in Section 10.3, "Adding a Character Set". However, instead of adding all the information required for a complete character set, just modify the appropriate files for an existing character set. That is, based on what is already present for the character set's current collations, add data structures, functions, and configuration information for the new collation.

> **Note**
>
> If you modify an existing collation, that may affect the ordering of rows for indexes on columns that use the collation. In this case, rebuild any such indexes to

> avoid problems such as incorrect query results. For further information, see Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt".

Additional Resources

- The Unicode Collation Algorithm (UCA) specification: http://www.unicode.org/reports/tr10/

- The Locale Data Markup Language (LDML) specification: http://www.unicode.org/reports/tr35/

10.4.1 Collation Implementation Types

MySQL implements several types of collations:

Simple collations for 8-bit character sets

This kind of collation is implemented using an array of 256 weights that defines a one-to-one mapping from character codes to weights. `latin1_swedish_ci` is an example. It is a case-insensitive collation, so the uppercase and lowercase versions of a character have the same weights and they compare as equal.

```
mysql> SET NAMES 'latin1' COLLATE 'latin1_swedish_ci';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT 'a' = 'A';
+-----------+
| 'a' = 'A' |
+-----------+
|         1 |
+-----------+
1 row in set (0.00 sec)
```

For implementation instructions, see Section 10.4.3, "Adding a Simple Collation to an 8-Bit Character Set".

Complex collations for 8-bit character sets

This kind of collation is implemented using functions in a C source file that define how to order characters, as described in Section 10.3, "Adding a Character Set".

Collations for non-Unicode multibyte character sets

For this type of collation, 8-bit (single-byte) and multibyte characters are handled differently. For 8-bit characters, character codes map to weights in case-insensitive fashion. (For example, the single-byte characters `'a'` and `'A'` both have a weight of `0x41`.) For multibyte characters, there are two types of relationship between character codes and weights:

- Weights equal character codes. `sjis_japanese_ci` is an example of this kind of collation. The multibyte character `'ぢ'` has a character code of `0x82C0`, and the weight is also `0x82C0`.

- Character codes map one-to-one to weights, but a code is not necessarily equal to the weight. `gbk_chinese_ci` is an example of this kind of collation. The multibyte character `'膰'` has a character code of `0x81B0` but a weight of `0xC286`.

For implementation instructions, see Section 10.3, "Adding a Character Set".

Collations for Unicode multibyte character sets

Some of these collations are based on the Unicode Collation Algorithm (UCA), others are not.

Non-UCA collations have a one-to-one mapping from character code to weight. In MySQL, such collations are case insensitive and accent insensitive. `utf8_general_ci` is an example: `'a'`, `'A'`, `'À'`, and `'á'` each have different character codes but all have a weight of `0x0041` and compare as equal.

```
mysql> SET NAMES 'utf8' COLLATE 'utf8_general_ci';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT 'a' = 'A', 'a' = 'À', 'a' = 'á';
+-----------+-----------+-----------+
| 'a' = 'A' | 'a' = 'À' | 'a' = 'á' |
+-----------+-----------+-----------+
|         1 |         1 |         1 |
+-----------+-----------+-----------+
1 row in set (0.06 sec)
```

UCA-based collations in MySQL have these properties:

- If a character has weights, each weight uses 2 bytes (16 bits).

- A character may have zero weights (or an empty weight). In this case, the character is ignorable. Example: "U+0000 NULL" does not have a weight and is ignorable.

- A character may have one weight. Example: `'a'` has a weight of `0x0E33`.

- A character may have many weights. This is an expansion. Example: The German letter `'ß'` (SZ ligature, or SHARP S) has a weight of `0x0FEA0FEA`.

- Many characters may have one weight. This is a contraction. Example: `'ch'` is a single letter in Czech and has a weight of `0x0EE2`.

A many-characters-to-many-weights mapping is also possible (this is contraction with expansion), but is not supported by MySQL.

For implementation instructions, for a non-UCA collation, see Section 10.3, "Adding a Character Set". For a UCA collation, see Section 10.4.4, "Adding a UCA Collation to a Unicode Character Set".

Miscellaneous collations

There are also a few collations that do not fall into any of the previous categories.

10.4.2 Choosing a Collation ID

Each collation must have a unique ID. To add a collation, you must choose an ID value that is not currently used. The value must be in the range from 1 to 254. The collation ID that you choose will appear in these contexts:

- The `ID` column of the `INFORMATION_SCHEMA.COLLATIONS` table.

- The `Id` column of `SHOW COLLATION` output.

- The `charsetnr` member of the `MYSQL_FIELD` C API data structure.

- The `number` member of the `MY_CHARSET_INFO` data structure returned by the `mysql_get_character_set_info()` C API function.

To determine the largest currently used ID, issue the following statement:

```
mysql> SELECT MAX(ID) FROM INFORMATION_SCHEMA.COLLATIONS;
+---------+
| MAX(ID) |
+---------+
|     210 |
+---------+
```

For the output just shown, you could choose an ID higher than 210 for the new collation.

To display a list of all currently used IDs, issue this statement:

```
mysql> SELECT ID FROM INFORMATION_SCHEMA.COLLATIONS ORDER BY ID;
+-----+
| ID  |
+-----+
|   1 |
|   2 |
| ... |
|  52 |
|  53 |
|  57 |
|  58 |
| ... |
|  98 |
|  99 |
| 128 |
| 129 |
| ... |
| 210 |
+-----+
```

In this case, you can either choose an unused ID from within the current range of IDs, or choose an ID that is higher than the current maximum ID. For example, in the output just shown, there are unused IDs between 53 and 57, and between 99 and 128. Or you could choose an ID higher than 210.

> **Warning**
>
> If you upgrade MySQL, you may find that the collation ID you choose has been assigned to a collation included in the new MySQL distribution. In this case, you will need to choose a new value for your own collation.
>
> In addition, before upgrading, you should save the configuration files that you change. If you upgrade in place, the process will replace the your modified files.

10.4.3 Adding a Simple Collation to an 8-Bit Character Set

This section describes how to add a simple collation for an 8-bit character set by writing the `<collation>` elements associated with a `<charset>` character set description in the MySQL `Index.xml` file. The procedure described here does not require recompiling MySQL. The example adds a collation named `latin1_test_ci` to the `latin1` character set.

1. Choose a collation ID, as shown in Section 10.4.2, "Choosing a Collation ID". The following steps use an ID of 56.

2. Modify the `Index.xml` and `latin1.xml` configuration files. These files will be located in the directory named by the `character_sets_dir` system variable. You can check the variable value as follows, although the path name might be different on your system:

```
mysql> SHOW VARIABLES LIKE 'character_sets_dir';
```

```
+-------------------+-------------------------------------+
| Variable_name     | Value                               |
+-------------------+-------------------------------------+
| character_sets_dir | /user/local/mysql/share/mysql/charsets/ |
+-------------------+-------------------------------------+
```

3. Choose a name for the collation and list it in the `Index.xml` file. Find the `<charset>` element for the character set to which the collation is being added, and add a `<collation>` element that indicates the collation name and ID, to associate the name with the ID. For example:

```
<charset name="latin1">
  ...
  <collation name="latin1_test_ci" id="56"/>
  ...
</charset>
```

4. In the `latin1.xml` configuration file, add a `<collation>` element that names the collation and that contains a `<map>` element that defines a character code-to-weight mapping table for character codes 0 to 255. Each value within the `<map>` element must be a number in hexadecimal format.

```
<collation name="latin1_test_ci">
<map>
 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
 10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
 20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
 30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F
 40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
 50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F
 60 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
 50 51 52 53 54 55 56 57 58 59 5A 7B 7C 7D 7E 7F
 80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
 90 91 92 93 94 95 96 97 98 99 9A 9B 9C 9D 9E 9F
 A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AA AB AC AD AE AF
 B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 BA BB BC BD BE BF
 41 41 41 41 5B 5D 5B 43 45 45 45 45 49 49 49 49
 44 4E 4F 4F 4F 4F 5C D7 5C 55 55 55 59 59 DE DF
 41 41 41 41 5B 5D 5B 43 45 45 45 45 49 49 49 49
 44 4E 4F 4F 4F 4F 5C F7 5C 55 55 55 59 59 DE FF
</map>
</collation>
```

5. Restart the server and use this statement to verify that the collation is present:

```
mysql> SHOW COLLATION LIKE 'latin1_test_ci';
+----------------+---------+----+---------+----------+---------+
| Collation      | Charset | Id | Default | Compiled | Sortlen |
+----------------+---------+----+---------+----------+---------+
| latin1_test_ci | latin1  | 56 |         |          |       1 |
+----------------+---------+----+---------+----------+---------+
```

10.4.4 Adding a UCA Collation to a Unicode Character Set

This section describes how to add a UCA collation for a Unicode character set by writing the `<collation>` element within a `<charset>` character set description in the MySQL `Index.xml` file. The procedure described here does not require recompiling MySQL. It uses a subset of the Locale Data Markup Language (LDML) specification, which is available at http://www.unicode.org/reports/tr35/. In 5.1, this method of adding collations is supported as of MySQL 5.1.20. With this method, you need not define the entire collation. Instead, you begin with an existing "base" collation and describe the new collation in terms of how it differs from the base collation. The following table lists the base collations of the Unicode character sets for which UCA collations can be defined.

Table 10.1 MySQL Character Sets Available for User-Defined UCA Collations

Character Set	Base Collation
utf8	utf8_unicode_ci
ucs2	ucs2_unicode_ci

The following sections show how to add a collation that is defined using LDML syntax, and provide a summary of LDML rules supported in MySQL.

10.4.4.1 Defining a UCA Collation Using LDML Syntax

To add a UCA collation for a Unicode character set without recompiling MySQL, use the following procedure. If you are unfamiliar with the LDML rules used to describe the collation's sort characteristics, see Section 10.4.4.2, "LDML Syntax Supported in MySQL".

The example adds a collation named `utf8_phone_ci` to the `utf8` character set. The collation is designed for a scenario involving a Web application for which users post their names and phone numbers. Phone numbers can be given in very different formats:

```
+7-12345-67
+7-12-345-67
+7 12 345 67
+7 (12) 345 67
+71234567
```

The problem raised by dealing with these kinds of values is that the varying permissible formats make searching for a specific phone number very difficult. The solution is to define a new collation that reorders punctuation characters, making them ignorable.

1. Choose a collation ID, as shown in Section 10.4.2, "Choosing a Collation ID". The following steps use an ID of 252.

2. To modify the `Index.xml` configuration file. This file will be located in the directory named by the `character_sets_dir` system variable. You can check the variable value as follows, although the path name might be different on your system:

```
mysql> SHOW VARIABLES LIKE 'character_sets_dir';
+--------------------+----------------------------------------+
| Variable_name      | Value                                  |
+--------------------+----------------------------------------+
| character_sets_dir | /user/local/mysql/share/mysql/charsets/ |
+--------------------+----------------------------------------+
```

3. Choose a name for the collation and list it in the `Index.xml` file. In addition, you'll need to provide the collation ordering rules. Find the `<charset>` element for the character set to which the collation is being added, and add a `<collation>` element that indicates the collation name and ID, to associate the name with the ID. Within the `<collation>` element, provide a `<rules>` element containing the ordering rules:

```
<charset name="utf8">
  ...
  <collation name="utf8_phone_ci" id="252">
    <rules>
      <reset>\u0000</reset>
      <s>\u0020</s> <!-- space -->
      <s>\u0028</s> <!-- left parenthesis -->
```

```
        <s>\u0029</s> <!-- right parenthesis -->
        <s>\u002B</s> <!-- plus -->
        <s>\u002D</s> <!-- hyphen -->
      </rules>
    </collation>
    ...
</charset>
```

4. If you want a similar collation for other Unicode character sets, add other `<collation>` elements. For example, to define `ucs2_phone_ci`, add a `<collation>` element to the `<charset name="ucs2">` element. Remember that each collation must have its own unique ID.

5. Restart the server and use this statement to verify that the collation is present:

```
mysql> SHOW COLLATION LIKE 'utf8_phone_ci';
+---------------+---------+-----+---------+----------+---------+
| Collation     | Charset | Id  | Default | Compiled | Sortlen |
+---------------+---------+-----+---------+----------+---------+
| utf8_phone_ci | utf8    | 252 |         |          |       8 |
+---------------+---------+-----+---------+----------+---------+
```

Now test the collation to make sure that it has the desired properties.

Create a table containing some sample phone numbers using the new collation:

```
mysql> CREATE TABLE phonebook (
    ->    name VARCHAR(64),
    ->    phone VARCHAR(64) CHARACTER SET utf8 COLLATE utf8_phone_ci
    -> );
Query OK, 0 rows affected (0.09 sec)

mysql> INSERT INTO phonebook VALUES ('Svoj','+7 912 800 80 02');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Hf','+7 (912) 800 80 04');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Bar','+7-912-800-80-01');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Ramil','(7912) 800 80 03');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Sanja','+380 (912) 8008005');
Query OK, 1 row affected (0.00 sec)
```

Run some queries to see whether the ignored punctuation characters are in fact ignored for sorting and comparisons:

```
mysql> SELECT * FROM phonebook ORDER BY phone;
+-------+--------------------+
| name  | phone              |
+-------+--------------------+
| Sanja | +380 (912) 8008005 |
| Bar   | +7-912-800-80-01   |
| Svoj  | +7 912 800 80 02   |
| Ramil | (7912) 800 80 03   |
| Hf    | +7 (912) 800 80 04 |
+-------+--------------------+
5 rows in set (0.00 sec)

mysql> SELECT * FROM phonebook WHERE phone='+7(912)800-80-01';
```

```
+------+------------------+
| name | phone            |
+------+------------------+
| Bar  | +7-912-800-80-01 |
+------+------------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM phonebook WHERE phone='79128008001';
+------+------------------+
| name | phone            |
+------+------------------+
| Bar  | +7-912-800-80-01 |
+------+------------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM phonebook WHERE phone='7 9 1 2 8 0 0 8 0 0 1';
+------+------------------+
| name | phone            |
+------+------------------+
| Bar  | +7-912-800-80-01 |
+------+------------------+
1 row in set (0.00 sec)
```

10.4.4.2 LDML Syntax Supported in MySQL

This section describes the LDML syntax that MySQL recognizes. This is a subset of the syntax described in the LDML specification available at http://www.unicode.org/reports/tr35/, which should be consulted for further information. The rules described here are all supported except that character sorting occurs only at the primary level. Rules that specify differences at secondary or higher sort levels are recognized (and thus can be included in collation definitions) but are treated as equality at the primary level.

Character Representation

Characters named in LDML rules can be written in `\u`*nnnn* format, where *nnnn* is the hexadecimal Unicode code point value. Within hexadecimal values, the digits `A` through `F` are not case sensitive; `\u00E1` and `\u00e1` are equivalent. Basic Latin letters `A-Z` and `a-z` can also be written literally (this is a MySQL limitation; the LDML specification permits literal non-Latin1 characters in the rules). Only characters in the Basic Multilingual Plane can be specified. This notation does not apply to characters outside the BMP range of `0000` to `FFFF`.

The `Index.xml` file itself should be written using ASCII encoding.

Syntax Rules

LDML has reset rules and shift rules to specify character ordering. Orderings are given as a set of rules that begin with a reset rule that establishes an anchor point, followed by shift rules that indicate how characters sort relative to the anchor point.

- A `<reset>` rule does not specify any ordering in and of itself. Instead, it "resets" the ordering for subsequent shift rules to cause them to be taken in relation to a given character. Either of the following rules resets subsequent shift rules to be taken in relation to the letter `'A'`:

```
<reset>A</reset>

<reset>\u0041</reset>
```

- The `<p>`, `<s>`, and `<t>` shift rules define primary, secondary, and tertiary differences of a character from another character:

  - Use primary differences to distinguish separate letters.

- Use secondary differences to distinguish accent variations.

- Use tertiary differences to distinguish lettercase variations.

Either of these rules specifies a primary shift rule for the `'G'` character:

```
<p>G</p>

<p>\u0047</p>
```

10.5 Character Set Configuration

You can change the default server character set and collation with the `--character-set-server` and `--collation-server` options when you start the server. The collation must be a legal collation for the default character set. (Use the `SHOW COLLATION` statement to determine which collations are available for each character set.) See Section 5.1.3, "Server Command Options".

If you try to use a character set that is not compiled into your binary, you might run into the following problems:

- Your program uses an incorrect path to determine where the character sets are stored (which is typically the `share/mysql/charsets` or `share/charsets` directory under the MySQL installation directory). This can be fixed by using the `--character-sets-dir` option when you run the program in question. For example, to specify a directory to be used by MySQL client programs, list it in the `[client]` group of your option file. The examples given here show what the setting might look like for Unix or Windows, respectively:

```
[client]
character-sets-dir=/usr/local/mysql/share/mysql/charsets

[client]
character-sets-dir="C:/Program Files/MySQL/MySQL Server 5.1/share/charsets"
```

- The character set is a complex character set that cannot be loaded dynamically. In this case, you must recompile the program with support for the character set.

  For Unicode character sets, you can define collations without recompiling by using LDML notation. See Section 10.4.4, "Adding a UCA Collation to a Unicode Character Set".

- The character set is a dynamic character set, but you do not have a configuration file for it. In this case, you should install the configuration file for the character set from a new MySQL distribution.

- If your character set index file does not contain the name for the character set, your program displays an error message. The file is named `Index.xml` and the message is:

```
Character set 'charset_name' is not a compiled character set and is not
specified in the '/usr/share/mysql/charsets/Index.xml' file
```

  To solve this problem, you should either get a new index file or manually add the name of any missing character sets to the current file.

You can force client programs to use specific character set as follows:

```
[client]
default-character-set=charset_name
```

This is normally unnecessary. However, when `character_set_system` differs from `character_set_server` or `character_set_client`, and you input characters manually (as database object identifiers, column values, or both), these may be displayed incorrectly in output from the client or the output itself may be formatted incorrectly. In such cases, starting the mysql client with `--default-character-set=`*`system_character_set`*—that is, setting the client character set to match the system character set—should fix the problem.

For `MyISAM` tables, you can check the character set name and number for a table with `myisamchk -dvv` *`tbl_name`*.

10.6 MySQL Server Time Zone Support

The MySQL server maintains several time zone settings:

- The system time zone. When the server starts, it attempts to determine the time zone of the host machine and uses it to set the `system_time_zone` system variable. The value does not change thereafter.

  You can set the system time zone for MySQL Server at startup with the `--timezone=`*`timezone_name`* option to `mysqld_safe`. You can also set it by setting the `TZ` environment variable before you start `mysqld`. The permissible values for `--timezone` or `TZ` are system dependent. Consult your operating system documentation to see what values are acceptable.

- The server's current time zone. The global `time_zone` system variable indicates the time zone the server currently is operating in. The initial value for `time_zone` is `'SYSTEM'`, which indicates that the server time zone is the same as the system time zone.

  The initial global server time zone value can be specified explicitly at startup with the `--default-time-zone=`*`timezone`* option on the command line, or you can use the following line in an option file:

  ```
  default-time-zone='timezone'
  ```

  If you have the `SUPER` privilege, you can set the global server time zone value at runtime with this statement:

  ```
  mysql> SET GLOBAL time_zone = timezone;
  ```

- Per-connection time zones. Each client that connects has its own time zone setting, given by the session `time_zone` variable. Initially, the session variable takes its value from the global `time_zone` variable, but the client can change its own time zone with this statement:

  ```
  mysql> SET time_zone = timezone;
  ```

The current session time zone setting affects display and storage of time values that are zone-sensitive. This includes the values displayed by functions such as `NOW()` or `CURTIME()`, and values stored in and retrieved from `TIMESTAMP` columns. Values for `TIMESTAMP` columns are converted from the current time zone to UTC for storage, and from UTC to the current time zone for retrieval.

The current time zone setting does not affect values displayed by functions such as `UTC_TIMESTAMP()` or values in `DATE`, `TIME`, or `DATETIME` columns. Nor are values in those data types stored in UTC; the time zone applies for them only when converting from `TIMESTAMP` values. If you want locale-specific arithmetic for `DATE`, `TIME`, or `DATETIME` values, convert them to UTC, perform the arithmetic, and then convert back.

The current values of the global and client-specific time zones can be retrieved like this:

```
mysql> SELECT @@global.time_zone, @@session.time_zone;
```

timezone values can be given in several formats, none of which are case sensitive:

- The value `'SYSTEM'` indicates that the time zone should be the same as the system time zone.

- The value can be given as a string indicating an offset from UTC, such as `'+10:00'` or `'-6:00'`.

- The value can be given as a named time zone, such as `'Europe/Helsinki'`, `'US/Eastern'`, or `'MET'`. Named time zones can be used only if the time zone information tables in the `mysql` database have been created and populated.

Populating the Time Zone Tables

Several tables in the `mysql` system database exist to maintain time zone information (see Section 5.3, "The mysql System Database"). The MySQL installation procedure creates the time zone tables, but does not load them. You must do so manually using the following instructions.

> **Note**
>
> Loading the time zone information is not necessarily a one-time operation because the information changes occasionally. When such changes occur, applications that use the old rules become out of date and you may find it necessary to reload the time zone tables to keep the information used by your MySQL server current. See the notes at the end of this section.

If your system has its own *zoneinfo* database (the set of files describing time zones), you should use the `mysql_tzinfo_to_sql` program for filling the time zone tables. Examples of such systems are Linux, FreeBSD, Solaris, and OS X. One likely location for these files is the `/usr/share/zoneinfo` directory. If your system does not have a zoneinfo database, you can use the downloadable package described later in this section.

The `mysql_tzinfo_to_sql` program is used to load the time zone tables. On the command line, pass the zoneinfo directory path name to `mysql_tzinfo_to_sql` and send the output into the `mysql` program. For example:

```
shell> mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql -u root mysql
```

`mysql_tzinfo_to_sql` reads your system's time zone files and generates SQL statements from them. `mysql` processes those statements to load the time zone tables.

`mysql_tzinfo_to_sql` also can be used to load a single time zone file or to generate leap second information:

- To load a single time zone file *tz_file* that corresponds to a time zone name *tz_name*, invoke `mysql_tzinfo_to_sql` like this:

  ```
  shell> mysql_tzinfo_to_sql tz_file tz_name | mysql -u root mysql
  ```

  With this approach, you must execute a separate command to load the time zone file for each named zone that the server needs to know about.

- If your time zone needs to account for leap seconds, initialize the leap second information like this, where *tz_file* is the name of your time zone file:

```
shell> mysql_tzinfo_to_sql --leap tz_file | mysql -u root mysql
```

- After running `mysql_tzinfo_to_sql`, it is best to restart the server so that it does not continue to use any previously cached time zone data.

If your system is one that has no zoneinfo database (for example, Windows or HP-UX), you can use a package that is available for download at the MySQL Developer Zone:

```
http://dev.mysql.com/downloads/timezones.html
```

You can use either a package that contains SQL statements to populate your existing time zone tables, or a package that contains pre-built `MyISAM` time zone tables to replace your existing tables:

- To use a time zone package that contains SQL statements, download and unpack it, then load the package file contents into your existing time zone tables:

```
shell> mysql -u root mysql < file_name
```

Then restart the server.

- To use a time zone package that contains `.frm`, `.MYD`, and `.MYI` files for the `MyISAM` time zone tables, download and unpack it. These table files are part of the `mysql` database, so you should place the files in the `mysql` subdirectory of your MySQL server's data directory. Stop the server before doing this and restart it afterward.

>
> **Warning**
>
> Do not use a downloadable package if your system has a zoneinfo database. Use the `mysql_tzinfo_to_sql` utility instead. Otherwise, you may cause a difference in datetime handling between MySQL and other applications on your system.

For information about time zone settings in replication setup, please see Section 16.4.1, "Replication Features and Issues".

10.6.1 Staying Current with Time Zone Changes

When time zone rules change, applications that use the old rules become out of date. To stay current, it is necessary to make sure that your system uses current time zone information is used. For MySQL, there are two factors to consider in staying current:

- The operating system time affects the value that the MySQL server uses for times if its time zone is set to `SYSTEM`. Make sure that your operating system is using the latest time zone information. For most operating systems, the latest update or service pack prepares your system for the time changes. Check the Web site for your operating system vendor for an update that addresses the time changes.

- If you replace the system's `/etc/localtime` timezone file with a version that uses rules differing from those in effect at `mysqld` startup, you should restart `mysqld` so that it uses the updated rules. Otherwise, `mysqld` might not notice when the system changes its time.

- If you use named time zones with MySQL, make sure that the time zone tables in the `mysql` database are up to date. If your system has its own zoneinfo database, you should reload the MySQL time zone tables whenever the zoneinfo database is updated. For systems that do not have their own zoneinfo database, check the MySQL Developer Zone for updates. When a new update is available, download it and use it to replace the content of your current time zone tables. For instructions for both methods,

see Populating the Time Zone Tables. `mysqld` caches time zone information that it looks up, so after updating the time zone tables, you should restart `mysqld` to make sure that it does not continue to serve outdated time zone data.

If you are uncertain whether named time zones are available, for use either as the server's time zone setting or by clients that set their own time zone, check whether your time zone tables are empty. The following query determines whether the table that contains time zone names has any rows:

```
mysql> SELECT COUNT(*) FROM mysql.time_zone_name;
+----------+
| COUNT(*) |
+----------+
|        0 |
+----------+
```

A count of zero indicates that the table is empty. In this case, no one can be using named time zones, and you don't need to update the tables. A count greater than zero indicates that the table is not empty and that its contents are available to be used for named time zone support. In this case, you should be sure to reload your time zone tables so that anyone who uses named time zones will get correct query results.

To check whether your MySQL installation is updated properly for a change in Daylight Saving Time rules, use a test like the one following. The example uses values that are appropriate for the 2007 DST 1-hour change that occurs in the United States on March 11 at 2 a.m.

The test uses these two queries:

```
SELECT CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central');
SELECT CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central');
```

The two time values indicate the times at which the DST change occurs, and the use of named time zones requires that the time zone tables be used. The desired result is that both queries return the same result (the input time, converted to the equivalent value in the 'US/Central' time zone).

Before updating the time zone tables, you would see an incorrect result like this:

```
mysql> SELECT CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 01:00:00                                       |
+-----------------------------------------------------------+

mysql> SELECT CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 02:00:00                                       |
+-----------------------------------------------------------+
```

After updating the tables, you should see the correct result:

```
mysql> SELECT CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 01:00:00                                       |
+-----------------------------------------------------------+

mysql> SELECT CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central');
```

```
+--------------------------------------------------------------+
| CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central') |
+--------------------------------------------------------------+
| 2007-03-11 01:00:00                                          |
+--------------------------------------------------------------+
```

10.6.2 Time Zone Leap Second Support

Before MySQL 5.1.31, if the operating system is configured to return leap seconds from OS time calls or if the MySQL server uses a time zone definition that has leap seconds, functions such as `NOW()` could return a value having a time part that ends with `:59:60` or `:59:61`. If such values are inserted into a table, they would be dumped as is by `mysqldump` but considered invalid when reloaded, leading to backup/restore problems.

As of MySQL 5.1.31, leap second values are returned with a time part that ends with `:59:59`. This means that a function such as `NOW()` can return the same value for two or three consecutive seconds during the leap second. It remains true that literal temporal values having a time part that ends with `:59:60` or `:59:61` are considered invalid.

If it is necessary to search for `TIMESTAMP` values one second before the leap second, anomalous results may be obtained if you use a comparison with `'YYYY-MM-DD hh:mm:ss'` values. The following example demonstrates this. It changes the local time zone to UTC so there is no difference between internal values (which are in UTC) and displayed values (which have time zone correction applied).

```
mysql> CREATE TABLE t1 (
    ->    a INT,
    ->    ts TIMESTAMP DEFAULT NOW(),
    ->    PRIMARY KEY (ts)
    -> );
Query OK, 0 rows affected (0.01 sec)

mysql> -- change to UTC
mysql> SET time_zone = '+00:00';
Query OK, 0 rows affected (0.00 sec)

mysql> -- Simulate NOW() = '2008-12-31 23:59:59'
mysql> SET timestamp = 1230767999;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t1 (a) VALUES (1);
Query OK, 1 row affected (0.00 sec)

mysql> -- Simulate NOW() = '2008-12-31 23:59:60'
mysql> SET timestamp = 1230768000;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t1 (a) VALUES (2);
Query OK, 1 row affected (0.00 sec)

mysql> -- values differ internally but display the same
mysql> SELECT a, ts, UNIX_TIMESTAMP(ts) FROM t1;
+------+---------------------+--------------------+
| a    | ts                  | UNIX_TIMESTAMP(ts) |
+------+---------------------+--------------------+
|    1 | 2008-12-31 23:59:59 |         1230767999 |
|    2 | 2008-12-31 23:59:59 |         1230768000 |
+------+---------------------+--------------------+
2 rows in set (0.00 sec)

mysql> -- only the non-leap value matches
mysql> SELECT * FROM t1 WHERE ts = '2008-12-31 23:59:59';
+------+---------------------+
```

```
| a    | ts                  |
+------+---------------------+
|    1 | 2008-12-31 23:59:59 |
+------+---------------------+
1 row in set (0.00 sec)

mysql> -- the leap value with seconds=60 is invalid
mysql> SELECT * FROM t1 WHERE ts = '2008-12-31 23:59:60';
Empty set, 2 warnings (0.00 sec)
```

To work around this, you can use a comparison based on the UTC value actually stored in column, which has the leap second correction applied:

```
mysql> -- selecting using UNIX_TIMESTAMP value return leap value
mysql> SELECT * FROM t1 WHERE UNIX_TIMESTAMP(ts) = 1230768000;
+------+---------------------+
| a    | ts                  |
+------+---------------------+
|    2 | 2008-12-31 23:59:59 |
+------+---------------------+
1 row in set (0.00 sec)
```

10.7 MySQL Server Locale Support

Beginning with MySQL 5.1.12, the locale indicated by the `lc_time_names` system variable controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()`, and `MONTHNAME()` functions.

`lc_time_names` does not affect the `STR_TO_DATE()` or `GET_FORMAT()` function.

Locale names have language and region subtags listed by IANA (http://www.iana.org/assignments/language-subtag-registry) such as `'ja_JP'` or `'pt_BR'`. The default value is `'en_US'` regardless of your system's locale setting, but you can set the value at server startup or set the `GLOBAL` value if you have the `SUPER` privilege. Any client can examine the value of `lc_time_names` or set its `SESSION` value to affect the locale for its own connection.

```
mysql> SET NAMES 'utf8';
Query OK, 0 rows affected (0.09 sec)

mysql> SELECT @@lc_time_names;
+-----------------+
| @@lc_time_names |
+-----------------+
| en_US           |
+-----------------+
1 row in set (0.00 sec)

mysql> SELECT DAYNAME('2010-01-01'), MONTHNAME('2010-01-01');
+-----------------------+-------------------------+
| DAYNAME('2010-01-01') | MONTHNAME('2010-01-01') |
+-----------------------+-------------------------+
| Friday                | January                 |
+-----------------------+-------------------------+
1 row in set (0.00 sec)

mysql> SELECT DATE_FORMAT('2010-01-01','%W %a %M %b');
+----------------------------------------+
| DATE_FORMAT('2010-01-01','%W %a %M %b') |
+----------------------------------------+
| Friday Fri January Jan                 |
+----------------------------------------+
```

```
1 row in set (0.00 sec)

mysql> SET lc_time_names = 'es_MX';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@lc_time_names;
+-----------------+
| @@lc_time_names |
+-----------------+
| es_MX           |
+-----------------+
1 row in set (0.00 sec)

mysql> SELECT DAYNAME('2010-01-01'), MONTHNAME('2010-01-01');
+----------------------+-------------------------+
| DAYNAME('2010-01-01') | MONTHNAME('2010-01-01') |
+----------------------+-------------------------+
| viernes              | enero                   |
+----------------------+-------------------------+
1 row in set (0.00 sec)

mysql> SELECT DATE_FORMAT('2010-01-01','%W %a %M %b');
+----------------------------------------+
| DATE_FORMAT('2010-01-01','%W %a %M %b') |
+----------------------------------------+
| viernes vie enero ene                  |
+----------------------------------------+
1 row in set (0.00 sec)
```

The day or month name for each of the affected functions is converted from `utf8` to the character set indicated by the `character_set_connection` system variable.

`lc_time_names` may be set to any of the following locale values.

`ar_AE`: Arabic - United Arab Emirates	`ar_BH`: Arabic - Bahrain
`ar_DZ`: Arabic - Algeria	`ar_EG`: Arabic - Egypt
`ar_IN`: Arabic - India	`ar_IQ`: Arabic - Iraq
`ar_JO`: Arabic - Jordan	`ar_KW`: Arabic - Kuwait
`ar_LB`: Arabic - Lebanon	`ar_LY`: Arabic - Libya
`ar_MA`: Arabic - Morocco	`ar_OM`: Arabic - Oman
`ar_QA`: Arabic - Qatar	`ar_SA`: Arabic - Saudi Arabia
`ar_SD`: Arabic - Sudan	`ar_SY`: Arabic - Syria
`ar_TN`: Arabic - Tunisia	`ar_YE`: Arabic - Yemen
`be_BY`: Belarusian - Belarus	`bg_BG`: Bulgarian - Bulgaria
`ca_ES`: Catalan - Spain	`cs_CZ`: Czech - Czech Republic
`da_DK`: Danish - Denmark	`de_AT`: German - Austria
`de_BE`: German - Belgium	`de_CH`: German - Switzerland
`de_DE`: German - Germany	`de_LU`: German - Luxembourg
`en_AU`: English - Australia	`en_CA`: English - Canada
`en_GB`: English - United Kingdom	`en_IN`: English - India
`en_NZ`: English - New Zealand	`en_PH`: English - Philippines
`en_US`: English - United States	`en_ZA`: English - South Africa
`en_ZW`: English - Zimbabwe	`es_AR`: Spanish - Argentina

`es_BO`: Spanish - Bolivia	`es_CL`: Spanish - Chile
`es_CO`: Spanish - Columbia	`es_CR`: Spanish - Costa Rica
`es_DO`: Spanish - Dominican Republic	`es_EC`: Spanish - Ecuador
`es_ES`: Spanish - Spain	`es_GT`: Spanish - Guatemala
`es_HN`: Spanish - Honduras	`es_MX`: Spanish - Mexico
`es_NI`: Spanish - Nicaragua	`es_PA`: Spanish - Panama
`es_PE`: Spanish - Peru	`es_PR`: Spanish - Puerto Rico
`es_PY`: Spanish - Paraguay	`es_SV`: Spanish - El Salvador
`es_US`: Spanish - United States	`es_UY`: Spanish - Uruguay
`es_VE`: Spanish - Venezuela	`et_EE`: Estonian - Estonia
`eu_ES`: Basque - Basque	`fi_FI`: Finnish - Finland
`fo_FO`: Faroese - Faroe Islands	`fr_BE`: French - Belgium
`fr_CA`: French - Canada	`fr_CH`: French - Switzerland
`fr_FR`: French - France	`fr_LU`: French - Luxembourg
`gl_ES`: Galician - Spain	`gu_IN`: Gujarati - India
`he_IL`: Hebrew - Israel	`hi_IN`: Hindi - India
`hr_HR`: Croatian - Croatia	`hu_HU`: Hungarian - Hungary
`id_ID`: Indonesian - Indonesia	`is_IS`: Icelandic - Iceland
`it_CH`: Italian - Switzerland	`it_IT`: Italian - Italy
`ja_JP`: Japanese - Japan	`ko_KR`: Korean - Republic of Korea
`lt_LT`: Lithuanian - Lithuania	`lv_LV`: Latvian - Latvia
`mk_MK`: Macedonian - FYROM	`mn_MN`: Mongolia - Mongolian
`ms_MY`: Malay - Malaysia	`nb_NO`: Norwegian(Bokmål) - Norway
`nl_BE`: Dutch - Belgium	`nl_NL`: Dutch - The Netherlands
`no_NO`: Norwegian - Norway	`pl_PL`: Polish - Poland
`pt_BR`: Portugese - Brazil	`pt_PT`: Portugese - Portugal
`ro_RO`: Romanian - Romania	`ru_RU`: Russian - Russia
`ru_UA`: Russian - Ukraine	`sk_SK`: Slovak - Slovakia
`sl_SI`: Slovenian - Slovenia	`sq_AL`: Albanian - Albania
`sr_YU`: Serbian - Yugoslavia	`sv_FI`: Swedish - Finland
`sv_SE`: Swedish - Sweden	`ta_IN`: Tamil - India
`te_IN`: Telugu - India	`th_TH`: Thai - Thailand
`tr_TR`: Turkish - Turkey	`uk_UA`: Ukrainian - Ukraine
`ur_PK`: Urdu - Pakistan	`vi_VN`: Vietnamese - Viet Nam
`zh_CN`: Chinese - China	`zh_HK`: Chinese - Hong Kong
`zh_TW`: Chinese - Taiwan Province of China	

Chapter 11 Data Types

Table of Contents

MySQL supports a number of SQL data types in several categories: numeric types, date and time types, string (character and byte) types, and spatial types. This chapter provides an overview of these data types, a more detailed description of the properties of the types in each category, and a summary of the data type storage requirements. The initial overview is intentionally brief. The more detailed descriptions later in the chapter should be consulted for additional information about particular data types, such as the permissible formats in which you can specify values.

Data type descriptions use these conventions:

- M indicates the maximum display width for integer types. For floating-point and fixed-point types, M is the total number of digits that can be stored (the precision). For string types, M is the maximum length. The maximum permissible value of M depends on the data type.

- *D* applies to floating-point and fixed-point types and indicates the number of digits following the decimal point (the scale). The maximum possible value is 30, but should be no greater than *M*−2.

- Square brackets ("`[`" and "`]`") indicate optional parts of type definitions.

11.1 Data Type Overview

11.1.1 Numeric Type Overview

A summary of the numeric data types follows. For additional information about properties and storage requirements of the numeric types, see Section 11.2, "Numeric Types", and Section 11.7, "Data Type Storage Requirements".

M indicates the maximum display width for integer types. The maximum display width is 255. Display width is unrelated to the range of values a type can contain, as described in Section 11.2, "Numeric Types". For floating-point and fixed-point types, *M* is the total number of digits that can be stored.

If you specify `ZEROFILL` for a numeric column, MySQL automatically adds the `UNSIGNED` attribute to the column.

Numeric data types that permit the `UNSIGNED` attribute also permit `SIGNED`. However, these data types are signed by default, so the `SIGNED` attribute has no effect.

`SERIAL` is an alias for `BIGINT UNSIGNED NOT NULL AUTO_INCREMENT UNIQUE`.

`SERIAL DEFAULT VALUE` in the definition of an integer column is an alias for `NOT NULL AUTO_INCREMENT UNIQUE`.

> **Warning**
>
> When you use subtraction between integer values where one is of type `UNSIGNED`, the result is unsigned unless the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled. See Section 12.10, "Cast Functions and Operators".

- `BIT[(M)]`

  A bit-field type. *M* indicates the number of bits per value, from 1 to 64. The default is 1 if *M* is omitted.

- `TINYINT[(M)] [UNSIGNED] [ZEROFILL]`

  A very small integer. The signed range is `-128` to `127`. The unsigned range is `0` to `255`.

- `BOOL`, `BOOLEAN`

  These types are synonyms for `TINYINT(1)`. A value of zero is considered false. Nonzero values are considered true:

```
mysql> SELECT IF(0, 'true', 'false');
+-----------------------+
| IF(0, 'true', 'false') |
+-----------------------+
| false                 |
+-----------------------+

mysql> SELECT IF(1, 'true', 'false');
+-----------------------+
| IF(1, 'true', 'false') |
+-----------------------+
| true                  |
```

```
+-----------------------+

mysql> SELECT IF(2, 'true', 'false');
+-----------------------+
| IF(2, 'true', 'false') |
+-----------------------+
| true                  |
+-----------------------+
```

However, the values TRUE and FALSE are merely aliases for 1 and 0, respectively, as shown here:

```
mysql> SELECT IF(0 = FALSE, 'true', 'false');
+------------------------------+
| IF(0 = FALSE, 'true', 'false') |
+------------------------------+
| true                         |
+------------------------------+

mysql> SELECT IF(1 = TRUE, 'true', 'false');
+------------------------------+
| IF(1 = TRUE, 'true', 'false') |
+------------------------------+
| true                         |
+------------------------------+

mysql> SELECT IF(2 = TRUE, 'true', 'false');
+------------------------------+
| IF(2 = TRUE, 'true', 'false') |
+------------------------------+
| false                        |
+------------------------------+

mysql> SELECT IF(2 = FALSE, 'true', 'false');
+------------------------------+
| IF(2 = FALSE, 'true', 'false') |
+------------------------------+
| false                        |
+------------------------------+
```

The last two statements display the results shown because 2 is equal to neither 1 nor 0.

- SMALLINT[(*M*)] [UNSIGNED] [ZEROFILL]

  A small integer. The signed range is −32768 to 32767. The unsigned range is 0 to 65535.

- MEDIUMINT[(*M*)] [UNSIGNED] [ZEROFILL]

  A medium-sized integer. The signed range is −8388608 to 8388607. The unsigned range is 0 to 16777215.

- INT[(*M*)] [UNSIGNED] [ZEROFILL]

  A normal-size integer. The signed range is −2147483648 to 2147483647. The unsigned range is 0 to 4294967295.

- INTEGER[(*M*)] [UNSIGNED] [ZEROFILL]

  This type is a synonym for INT.

- BIGINT[(*M*)] [UNSIGNED] [ZEROFILL]

  A large integer. The signed range is −9223372036854775808 to 9223372036854775807. The unsigned range is 0 to 18446744073709551615.

`SERIAL` is an alias for `BIGINT UNSIGNED NOT NULL AUTO_INCREMENT UNIQUE`.

Some things you should be aware of with respect to `BIGINT` columns:

- All arithmetic is done using signed `BIGINT` or `DOUBLE` values, so you should not use unsigned big integers larger than `9223372036854775807` (63 bits) except with bit functions! If you do that, some of the last digits in the result may be wrong because of rounding errors when converting a `BIGINT` value to a `DOUBLE`.

  MySQL can handle `BIGINT` in the following cases:

  - When using integers to store large unsigned values in a `BIGINT` column.

  - In `MIN(col_name)` or `MAX(col_name)`, where `col_name` refers to a `BIGINT` column.

  - When using operators (`+`, `-`, `*`, and so on) where both operands are integers.

- You can always store an exact integer value in a `BIGINT` column by storing it using a string. In this case, MySQL performs a string-to-number conversion that involves no intermediate double-precision representation.

- The `-`, `+`, and `*` operators use `BIGINT` arithmetic when both operands are integer values. This means that if you multiply two big integers (or results from functions that return integers), you may get unexpected results when the result is larger than `9223372036854775807`.

- `DECIMAL[(M[,D])] [UNSIGNED] [ZEROFILL]`

  A packed "exact" fixed-point number. M is the total number of digits (the precision) and D is the number of digits after the decimal point (the scale). The decimal point and (for negative numbers) the "–" sign are not counted in M. If D is 0, values have no decimal point or fractional part. The maximum number of digits (M) for `DECIMAL` is 65. The maximum number of supported decimals (D) is 30. If D is omitted, the default is 0. If M is omitted, the default is 10.

  `UNSIGNED`, if specified, disallows negative values.

  All basic calculations (`+`, `-`, `*`, `/`) with `DECIMAL` columns are done with a precision of 65 digits.

- `DEC[(M[,D])] [UNSIGNED] [ZEROFILL]`, `NUMERIC[(M[,D])] [UNSIGNED] [ZEROFILL]`, `FIXED[(M[,D])] [UNSIGNED] [ZEROFILL]`

  These types are synonyms for `DECIMAL`. The `FIXED` synonym is available for compatibility with other database systems.

- `FLOAT[(M,D)] [UNSIGNED] [ZEROFILL]`

  A small (single-precision) floating-point number. Permissible values are `-3.402823466E+38` to `-1.175494351E-38`, `0`, and `1.175494351E-38` to `3.402823466E+38`. These are the theoretical limits, based on the IEEE standard. The actual range might be slightly smaller depending on your hardware or operating system.

  M is the total number of digits and D is the number of digits following the decimal point. If M and D are omitted, values are stored to the limits permitted by the hardware. A single-precision floating-point number is accurate to approximately 7 decimal places.

  `UNSIGNED`, if specified, disallows negative values.

Using `FLOAT` might give you some unexpected problems because all calculations in MySQL are done with double precision. See Section B.5.4.7, "Solving Problems with No Matching Rows".

- `DOUBLE[(M,D)] [UNSIGNED] [ZEROFILL]`

A normal-size (double-precision) floating-point number. Permissible values are `-1.7976931348623157E+308` to `-2.2250738585072014E-308`, `0`, and `2.2250738585072014E-308` to `1.7976931348623157E+308`. These are the theoretical limits, based on the IEEE standard. The actual range might be slightly smaller depending on your hardware or operating system.

M is the total number of digits and D is the number of digits following the decimal point. If M and D are omitted, values are stored to the limits permitted by the hardware. A double-precision floating-point number is accurate to approximately 15 decimal places.

`UNSIGNED`, if specified, disallows negative values.

- `DOUBLE PRECISION[(M,D)] [UNSIGNED] [ZEROFILL]`, `REAL[(M,D)] [UNSIGNED] [ZEROFILL]`

These types are synonyms for `DOUBLE`. Exception: If the `REAL_AS_FLOAT` SQL mode is enabled, `REAL` is a synonym for `FLOAT` rather than `DOUBLE`.

- `FLOAT(p) [UNSIGNED] [ZEROFILL]`

A floating-point number. p represents the precision in bits, but MySQL uses this value only to determine whether to use `FLOAT` or `DOUBLE` for the resulting data type. If p is from 0 to 24, the data type becomes `FLOAT` with no M or D values. If p is from 25 to 53, the data type becomes `DOUBLE` with no M or D values. The range of the resulting column is the same as for the single-precision `FLOAT` or double-precision `DOUBLE` data types described earlier in this section.

`FLOAT(p)` syntax is provided for ODBC compatibility.

11.1.2 Date and Time Type Overview

A summary of the temporal data types follows. For additional information about properties and storage requirements of the temporal types, see Section 11.3, "Date and Time Types", and Section 11.7, "Data Type Storage Requirements". For descriptions of functions that operate on temporal values, see Section 12.7, "Date and Time Functions".

For the `DATE` and `DATETIME` range descriptions, "supported" means that although earlier values might work, there is no guarantee.

- `DATE`

A date. The supported range is `'1000-01-01'` to `'9999-12-31'`. MySQL displays `DATE` values in `'YYYY-MM-DD'` format, but permits assignment of values to `DATE` columns using either strings or numbers.

- `DATETIME`

A date and time combination. The supported range is `'1000-01-01 00:00:00'` to `'9999-12-31 23:59:59'`. MySQL displays `DATETIME` values in `'YYYY-MM-DD HH:MM:SS'` format, but permits assignment of values to `DATETIME` columns using either strings or numbers.

- `TIMESTAMP`

A timestamp. The range is `'1970-01-01 00:00:01'` UTC to `'2038-01-19 03:14:07'` UTC. `TIMESTAMP` values are stored as the number of seconds since the epoch (`'1970-01-01 00:00:00'` UTC). A `TIMESTAMP` cannot represent the value `'1970-01-01 00:00:00'` because that is equivalent to 0 seconds from the epoch and the value 0 is reserved for representing `'0000-00-00 00:00:00'`, the "zero" `TIMESTAMP` value.

Unless specified otherwise, the first `TIMESTAMP` column in a table is defined to be automatically set to the date and time of the most recent modification if not explicitly assigned a value. This makes `TIMESTAMP` useful for recording the timestamp of an `INSERT` or `UPDATE` operation. You can also set any `TIMESTAMP` column to the current date and time by assigning it a `NULL` value, unless it has been defined with the `NULL` attribute to permit `NULL` values. The automatic initialization and updating to the current date and time can be specified using `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP` clauses, as described in Section 11.3.5, "Automatic Initialization and Updating for TIMESTAMP".

> **Note**
>
> The `TIMESTAMP` format that was used prior to MySQL 4.1 is not supported in MySQL 5.1; see *MySQL 3.23, 4.0, 4.1 Reference Manual* for information regarding the old format.

- `TIME`

  A time. The range is `'-838:59:59'` to `'838:59:59'`. MySQL displays `TIME` values in `'HH:MM:SS'` format, but permits assignment of values to `TIME` columns using either strings or numbers.

- `YEAR[(2|4)]`

  A year in two-digit or four-digit format. The default is four-digit format. `YEAR(2)` or `YEAR(4)` differ in display format, but have the same range of values. In four-digit format, values display as `1901` to `2155`, and `0000`. In two-digit format, values display as `70` to `69`, representing years from 1970 to 2069. MySQL displays `YEAR` values in `YYYY` or `YY` format, but permits assignment of values to `YEAR` columns using either strings or numbers.

  > **Note**
  >
  > The `YEAR(2)` data type has certain issues that you should consider before choosing to use it. As of MySQL 5.1.65, `YEAR(2)` is deprecated. For more information, see Section 11.3.4, "YEAR(2) Limitations and Migrating to YEAR(4)".

  For additional information about `YEAR` display format and interpretation of input values, see Section 11.3.3, "The YEAR Type".

The `SUM()` and `AVG()` aggregate functions do not work with temporal values. (They convert the values to numbers, losing everything after the first nonnumeric character.) To work around this problem, convert to numeric units, perform the aggregate operation, and convert back to a temporal value. Examples:

```
SELECT SEC_TO_TIME(SUM(TIME_TO_SEC(time_col))) FROM tbl_name;
SELECT FROM_DAYS(SUM(TO_DAYS(date_col))) FROM tbl_name;
```

> **Note**
>
> The MySQL server can be run with the `MAXDB` SQL mode enabled. In this case, `TIMESTAMP` is identical with `DATETIME`. If this mode is enabled at the time that a table is created, `TIMESTAMP` columns are created as `DATETIME` columns. As a

> result, such columns use `DATETIME` display format, have the same range of values, and there is no automatic initialization or updating to the current date and time. See Section 5.1.7, "Server SQL Modes".

11.1.3 String Type Overview

A summary of the string data types follows. For additional information about properties and storage requirements of the string types, see Section 11.4, "String Types", and Section 11.7, "Data Type Storage Requirements".

In some cases, MySQL may change a string column to a type different from that given in a `CREATE TABLE` or `ALTER TABLE` statement. See Section 13.1.17.4, "Silent Column Specification Changes".

MySQL interprets length specifications in character column definitions in character units. This applies to `CHAR`, `VARCHAR`, and the `TEXT` types.

Column definitions for many string data types can include attributes that specify the character set or collation of the column. These attributes apply to the `CHAR`, `VARCHAR`, the `TEXT` types, `ENUM`, and `SET` data types:

- The `CHARACTER SET` attribute specifies the character set, and the `COLLATE` attribute specifies a collation for the character set. For example:

```
CREATE TABLE t
(
    c1 VARCHAR(20) CHARACTER SET utf8,
    c2 TEXT CHARACTER SET latin1 COLLATE latin1_general_cs
);
```

  This table definition creates a column named `c1` that has a character set of `utf8` with the default collation for that character set, and a column named `c2` that has a character set of `latin1` and a case-sensitive collation.

  The rules for assigning the character set and collation when either or both of the `CHARACTER SET` and `COLLATE` attributes are missing are described in Section 10.1.3.4, "Column Character Set and Collation".

  `CHARSET` is a synonym for `CHARACTER SET`.

- Specifying the `CHARACTER SET binary` attribute for a character data type causes the column to be created as the corresponding binary data type: `CHAR` becomes `BINARY`, `VARCHAR` becomes `VARBINARY`, and `TEXT` becomes `BLOB`. For the `ENUM` and `SET` data types, this does not occur; they are created as declared. Suppose that you specify a table using this definition:

```
CREATE TABLE t
(
  c1 VARCHAR(10) CHARACTER SET binary,
  c2 TEXT CHARACTER SET binary,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

  The resulting table has this definition:

```
CREATE TABLE t
(
  c1 VARBINARY(10),
  c2 BLOB,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

- The `ASCII` attribute is shorthand for `CHARACTER SET latin1`.

- The `UNICODE` attribute is shorthand for `CHARACTER SET ucs2`.

- The `BINARY` attribute is shorthand for specifying the binary collation of the column character set. In this case, sorting and comparison are based on numeric character values.

Character column sorting and comparison are based on the character set assigned to the column. For the `CHAR`, `VARCHAR`, `TEXT`, `ENUM`, and `SET` data types, you can declare a column with a binary collation or the `BINARY` attribute to cause sorting and comparison to use the underlying character code values rather than a lexical ordering.

Section 10.1, "Character Set Support", provides additional information about use of character sets in MySQL.

-     `[NATIONAL] CHAR[(M)] [CHARACTER SET charset_name] [COLLATE collation_name]`

  A fixed-length string that is always right-padded with spaces to the specified length when stored. `M` represents the column length in characters. The range of `M` is 0 to 255. If `M` is omitted, the length is 1.

  > **Note**
  >
  > Trailing spaces are removed when `CHAR` values are retrieved unless the `PAD_CHAR_TO_FULL_LENGTH` SQL mode is enabled.

  `CHAR` is shorthand for `CHARACTER`. `NATIONAL CHAR` (or its equivalent short form, `NCHAR`) is the standard SQL way to define that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. Section 10.1.3.6, "National Character Set".

  The `CHAR BYTE` data type is an alias for the `BINARY` data type. This is a compatibility feature.

  MySQL permits you to create a column of type `CHAR(0)`. This is useful primarily when you have to be compliant with old applications that depend on the existence of a column but that do not actually use its value. `CHAR(0)` is also quite nice when you need a column that can take only two values: A column that is defined as `CHAR(0) NULL` occupies only one bit and can take only the values `NULL` and `''` (the empty string).

-     `[NATIONAL] VARCHAR(M) [CHARACTER SET charset_name] [COLLATE collation_name]`

  A variable-length string. `M` represents the maximum column length in characters. The range of `M` is 0 to 65,535. The effective maximum length of a `VARCHAR` is subject to the maximum row size (65,535 bytes, which is shared among all columns) and the character set used. For example, `utf8` characters can require up to three bytes per character, so a `VARCHAR` column that uses the `utf8` character set can be declared to be a maximum of 21,844 characters. See Section C.7.4, "Limits on Table Column Count and Row Size".

  MySQL stores `VARCHAR` values as a 1-byte or 2-byte length prefix plus data. The length prefix indicates the number of bytes in the value. A `VARCHAR` column uses one length byte if values require no more than 255 bytes, two length bytes if values may require more than 255 bytes.

  > **Note**
  >
  > MySQL follows the standard SQL specification, and does *not* remove trailing spaces from `VARCHAR` values.

VARCHAR is shorthand for CHARACTER VARYING. NATIONAL VARCHAR is the standard SQL way to define that a VARCHAR column should use some predefined character set. MySQL uses utf8 as this predefined character set. Section 10.1.3.6, "National Character Set". NVARCHAR is shorthand for NATIONAL VARCHAR.

- BINARY(*M*)

  The BINARY type is similar to the CHAR type, but stores binary byte strings rather than nonbinary character strings. *M* represents the column length in bytes.

- VARBINARY(*M*)

  The VARBINARY type is similar to the VARCHAR type, but stores binary byte strings rather than nonbinary character strings. *M* represents the maximum column length in bytes.

- TINYBLOB

  A BLOB column with a maximum length of 255 (2^8 − 1) bytes. Each TINYBLOB value is stored using a 1-byte length prefix that indicates the number of bytes in the value.

- TINYTEXT [CHARACTER SET *charset_name*] [COLLATE *collation_name*]

  A TEXT column with a maximum length of 255 (2^8 − 1) characters. The effective maximum length is less if the value contains multibyte characters. Each TINYTEXT value is stored using a 1-byte length prefix that indicates the number of bytes in the value.

- BLOB[(*M*)]

  A BLOB column with a maximum length of 65,535 (2^{16} − 1) bytes. Each BLOB value is stored using a 2-byte length prefix that indicates the number of bytes in the value.

  An optional length *M* can be given for this type. If this is done, MySQL creates the column as the smallest BLOB type large enough to hold values *M* bytes long.

- TEXT[(*M*)] [CHARACTER SET *charset_name*] [COLLATE *collation_name*]

  A TEXT column with a maximum length of 65,535 (2^{16} − 1) characters. The effective maximum length is less if the value contains multibyte characters. Each TEXT value is stored using a 2-byte length prefix that indicates the number of bytes in the value.

  An optional length *M* can be given for this type. If this is done, MySQL creates the column as the smallest TEXT type large enough to hold values *M* characters long.

- MEDIUMBLOB

  A BLOB column with a maximum length of 16,777,215 (2^{24} − 1) bytes. Each MEDIUMBLOB value is stored using a 3-byte length prefix that indicates the number of bytes in the value.

- MEDIUMTEXT [CHARACTER SET *charset_name*] [COLLATE *collation_name*]

  A TEXT column with a maximum length of 16,777,215 (2^{24} − 1) characters. The effective maximum length is less if the value contains multibyte characters. Each MEDIUMTEXT value is stored using a 3-byte length prefix that indicates the number of bytes in the value.

- LONGBLOB

A `BLOB` column with a maximum length of 4,294,967,295 or 4GB ($2^{32} - 1$) bytes. The effective maximum length of `LONGBLOB` columns depends on the configured maximum packet size in the client/server protocol and available memory. Each `LONGBLOB` value is stored using a 4-byte length prefix that indicates the number of bytes in the value.

- `LONGTEXT [CHARACTER SET charset_name] [COLLATE collation_name]`

A `TEXT` column with a maximum length of 4,294,967,295 or 4GB ($2^{32} - 1$) characters. The effective maximum length is less if the value contains multibyte characters. The effective maximum length of `LONGTEXT` columns also depends on the configured maximum packet size in the client/server protocol and available memory. Each `LONGTEXT` value is stored using a 4-byte length prefix that indicates the number of bytes in the value.

- `ENUM('value1','value2',...) [CHARACTER SET charset_name] [COLLATE collation_name]`

An enumeration. A string object that can have only one value, chosen from the list of values `'value1'`, `'value2'`,`...`, `NULL` or the special `''` error value. `ENUM` values are represented internally as integers.

An `ENUM` column can have a maximum of 65,535 distinct elements. (The practical limit is less than 3000.) A table can have no more than 255 unique element list definitions among its `ENUM` and `SET` columns considered as a group. For more information on these limits, see Section C.7.5, "Limits Imposed by .frm File Structure".

- `SET('value1','value2',...) [CHARACTER SET charset_name] [COLLATE collation_name]`

A set. A string object that can have zero or more values, each of which must be chosen from the list of values `'value1'`, `'value2'`, `...` `SET` values are represented internally as integers.

A `SET` column can have a maximum of 64 distinct members. A table can have no more than 255 unique element list definitions among its `ENUM` and `SET` columns considered as a group. For more information on this limit, see Section C.7.5, "Limits Imposed by .frm File Structure".

11.2 Numeric Types

MySQL supports all standard SQL numeric data types. These types include the exact numeric data types (`INTEGER`, `SMALLINT`, `DECIMAL`, and `NUMERIC`), as well as the approximate numeric data types (`FLOAT`, `REAL`, and `DOUBLE PRECISION`). The keyword `INT` is a synonym for `INTEGER`, and the keywords `DEC` and `FIXED` are synonyms for `DECIMAL`. MySQL treats `DOUBLE` as a synonym for `DOUBLE PRECISION` (a nonstandard extension). MySQL also treats `REAL` as a synonym for `DOUBLE PRECISION` (a nonstandard variation), unless the `REAL_AS_FLOAT` SQL mode is enabled.

The `BIT` data type stores bit-field values and is supported for `MyISAM`, `MEMORY`, `InnoDB`, and `NDBCLUSTER` tables.

For information about how MySQL handles assignment of out-of-range values to columns and overflow during expression evaluation, see Section 11.2.6, "Out-of-Range and Overflow Handling".

For information about numeric type storage requirements, see Section 11.7, "Data Type Storage Requirements".

The data type used for the result of a calculation on numeric operands depends on the types of the operands and the operations performed on them. For more information, see Section 12.6.1, "Arithmetic Operators".

11.2.1 Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT

MySQL supports the SQL standard integer types `INTEGER` (or `INT`) and `SMALLINT`. As an extension to the standard, MySQL also supports the integer types `TINYINT`, `MEDIUMINT`, and `BIGINT`. The following table shows the required storage and range for each integer type.

Type	Storage	Minimum Value	Maximum Value
	(Bytes)	(Signed/Unsigned)	(Signed/Unsigned)
TINYINT	1	-128	127
		0	255
SMALLINT	2	-32768	32767
		0	65535
MEDIUMINT	3	-8388608	8388607
		0	16777215
INT	4	-2147483648	2147483647
		0	4294967295
BIGINT	8	-9223372036854775808	9223372036854775807
		0	18446744073709551615

11.2.2 Fixed-Point Types (Exact Value) - DECIMAL, NUMERIC

The `DECIMAL` and `NUMERIC` types store exact numeric data values. These types are used when it is important to preserve exact precision, for example with monetary data. In MySQL, `NUMERIC` is implemented as `DECIMAL`, so the following remarks about `DECIMAL` apply equally to `NUMERIC`.

MySQL stores `DECIMAL` values in binary format. See Section 12.18, "Precision Math".

In a `DECIMAL` column declaration, the precision and scale can be (and usually is) specified; for example:

```
salary DECIMAL(5,2)
```

In this example, `5` is the precision and `2` is the scale. The precision represents the number of significant digits that are stored for values, and the scale represents the number of digits that can be stored following the decimal point.

Standard SQL requires that `DECIMAL(5,2)` be able to store any value with five digits and two decimals, so values that can be stored in the `salary` column range from `-999.99` to `999.99`.

In standard SQL, the syntax `DECIMAL($M$)` is equivalent to `DECIMAL($M$,0)`. Similarly, the syntax `DECIMAL` is equivalent to `DECIMAL($M$,0)`, where the implementation is permitted to decide the value of M. MySQL supports both of these variant forms of `DECIMAL` syntax. The default value of M is 10.

If the scale is 0, `DECIMAL` values contain no decimal point or fractional part.

The maximum number of digits for `DECIMAL` is 65, but the actual range for a given `DECIMAL` column can be constrained by the precision or scale for a given column. When such a column is assigned a value with more digits following the decimal point than are permitted by the specified scale, the value is converted to that scale. (The precise behavior is operating system-specific, but generally the effect is truncation to the permissible number of digits.)

11.2.3 Floating-Point Types (Approximate Value) - FLOAT, DOUBLE

The `FLOAT` and `DOUBLE` types represent approximate numeric data values. MySQL uses four bytes for single-precision values and eight bytes for double-precision values.

For `FLOAT`, the SQL standard permits an optional specification of the precision (but not the range of the exponent) in bits following the keyword `FLOAT` in parentheses. MySQL also supports this optional precision specification, but the precision value is used only to determine storage size. A precision from 0 to 23 results in a 4-byte single-precision `FLOAT` column. A precision from 24 to 53 results in an 8-byte double-precision `DOUBLE` column.

MySQL permits a nonstandard syntax: `FLOAT(M,D)` or `REAL(M,D)` or `DOUBLE PRECISION(M,D)`. Here, "`(M,D)`" means than values can be stored with up to M digits in total, of which D digits may be after the decimal point. For example, a column defined as `FLOAT(7,4)` will look like `-999.9999` when displayed. MySQL performs rounding when storing values, so if you insert `999.00009` into a `FLOAT(7,4)` column, the approximate result is `999.0001`.

Because floating-point values are approximate and not stored as exact values, attempts to treat them as exact in comparisons may lead to problems. They are also subject to platform or implementation dependencies. For more information, see Section B.5.4.8, "Problems with Floating-Point Values"

For maximum portability, code requiring storage of approximate numeric data values should use `FLOAT` or `DOUBLE PRECISION` with no specification of precision or number of digits.

11.2.4 Bit-Value Type - BIT

The `BIT` data type is used to store bit-field values. A type of `BIT(M)` enables storage of M-bit values. M can range from 1 to 64.

To specify bit values, `b'value'` notation can be used. `value` is a binary value written using zeros and ones. For example, `b'111'` and `b'10000000'` represent 7 and 128, respectively. See Section 9.1.6, "Bit-Field Literals".

If you assign a value to a `BIT(M)` column that is less than M bits long, the value is padded on the left with zeros. For example, assigning a value of `b'101'` to a `BIT(6)` column is, in effect, the same as assigning `b'000101'`.

MySQL Cluster.   The maximum combined size of all `BIT` columns used in a given `NDB` table must not exceed 4096 bits.

11.2.5 Numeric Type Attributes

MySQL supports an extension for optionally specifying the display width of integer data types in parentheses following the base keyword for the type. For example, `INT(4)` specifies an `INT` with a display width of four digits. This optional display width may be used by applications to display integer values having a width less than the width specified for the column by left-padding them with spaces. (That is, this width is present in the metadata returned with result sets. Whether it is used or not is up to the application.)

The display width does *not* constrain the range of values that can be stored in the column. Nor does it prevent values wider than the column display width from being displayed correctly. For example, a column specified as `SMALLINT(3)` has the usual `SMALLINT` range of `-32768` to `32767`, and values outside the range permitted by three digits are displayed in full using more than three digits.

When used in conjunction with the optional (nonstandard) attribute `ZEROFILL`, the default padding of spaces is replaced with zeros. For example, for a column declared as `INT(4) ZEROFILL`, a value of `5` is retrieved as `0005`.

> **Note**
>
> The `ZEROFILL` attribute is ignored when a column is involved in expressions or `UNION` queries.
>
> If you store values larger than the display width in an integer column that has the `ZEROFILL` attribute, you may experience problems when MySQL generates temporary tables for some complicated joins. In these cases, MySQL assumes that the data values fit within the column display width.

All integer types can have an optional (nonstandard) attribute `UNSIGNED`. Unsigned type can be used to permit only nonnegative numbers in a column or when you need a larger upper numeric range for the column. For example, if an `INT` column is `UNSIGNED`, the size of the column's range is the same but its endpoints shift from `-2147483648` and `2147483647` up to `0` and `4294967295`.

Floating-point and fixed-point types also can be `UNSIGNED`. As with integer types, this attribute prevents negative values from being stored in the column. Unlike the integer types, the upper range of column values remains the same.

If you specify `ZEROFILL` for a numeric column, MySQL automatically adds the `UNSIGNED` attribute to the column.

Integer or floating-point data types can have the additional attribute `AUTO_INCREMENT`. When you insert a value of `NULL` (recommended) or `0` into an indexed `AUTO_INCREMENT` column, the column is set to the next sequence value. Typically this is *value*+1, where *value* is the largest value for the column currently in the table. `AUTO_INCREMENT` sequences begin with `1`. (Inserting `NULL` to generate `AUTO_INCREMENT` values requires that the column be declared `NOT NULL`. If the column is declared `NULL`, inserting `NULL` stores a `NULL`.) When you insert any other value into an `AUTO_INCREMENT` column, the column is set to that value and the sequence is reset so that the next automatically generated value follows sequentially from the inserted value.

As of MySQL 5.1.67, negative values for `AUTO_INCREMENT` columns are not supported.

11.2.6 Out-of-Range and Overflow Handling

When MySQL stores a value in a numeric column that is outside the permissible range of the column data type, the result depends on the SQL mode in effect at the time:

- If strict SQL mode is enabled, MySQL rejects the out-of-range value with an error, and the insert fails, in accordance with the SQL standard.

- If no restrictive modes are enabled, MySQL clips the value to the appropriate endpoint of the range and stores the resulting value instead.

  When an out-of-range value is assigned to an integer column, MySQL stores the value representing the corresponding endpoint of the column data type range. If you store 256 into a `TINYINT` or `TINYINT UNSIGNED` column, MySQL stores 127 or 255, respectively.

  When a floating-point or fixed-point column is assigned a value that exceeds the range implied by the specified (or default) precision and scale, MySQL stores the value representing the corresponding endpoint of that range.

Column-assignment conversions that occur due to clipping when MySQL is not operating in strict mode are reported as warnings for `ALTER TABLE`, `LOAD DATA INFILE`, `UPDATE`, and multiple-row `INSERT` statements. In strict mode, these statements fail, and some or all the values will not be inserted or changed, depending on whether the table is a transactional table and other factors. For details, see Section 5.1.7, "Server SQL Modes".

Overflow handling during numeric expression evaluation depends on the types of the operands:

- Integer overflow results in silent wraparound.

- DECIMAL overflow results in a truncated result and a warning.

- Floating-point overflow produces a NULL result. Before MySQL 5.1.24, overflow for some operations results in +INF, -INF, or NaN.

For example, the largest signed BIGINT value is 9223372036854775807, so the following expression wraps around to the minimum BIGINT value:

```
mysql> SELECT 9223372036854775807 + 1;
+------------------------+
| 9223372036854775807 + 1 |
+------------------------+
|   -9223372036854775808 |
+------------------------+
```

To enable the operation to succeed in this case, convert the value to unsigned;

```
mysql> SELECT CAST(9223372036854775807 AS UNSIGNED) + 1;
+------------------------------------------+
| CAST(9223372036854775807 AS UNSIGNED) + 1 |
+------------------------------------------+
|                     9223372036854775808 |
+------------------------------------------+
```

Whether overflow occurs depends on the range of the operands, so another way to handle the preceding expression is to use exact-value arithmetic because DECIMAL values have a larger range than integers:

```
mysql> SELECT 9223372036854775807.0 + 1;
+--------------------------+
| 9223372036854775807.0 + 1 |
+--------------------------+
|     9223372036854775808.0 |
+--------------------------+
```

Subtraction between integer values, where one is of type UNSIGNED, produces an unsigned result by default. If the result would otherwise have been negative, it becomes the maximum integer value. If the NO_UNSIGNED_SUBTRACTION SQL mode is enabled, the result is negative.

```
mysql> SET sql_mode = '';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+------------------------+
|    18446744073709551615 |
+------------------------+

mysql> SET sql_mode = 'NO_UNSIGNED_SUBTRACTION';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+------------------------+
|                     -1 |
+------------------------+
```

If the result of such an operation is used to update an UNSIGNED integer column, the result is clipped to the maximum value for the column type, or clipped to 0 if NO_UNSIGNED_SUBTRACTION is enabled. If strict SQL mode is enabled, an error occurs and the column remains unchanged.

11.3 Date and Time Types

The date and time types for representing temporal values are `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, and `YEAR`. Each temporal type has a range of valid values, as well as a "zero" value that may be used when you specify an invalid value that MySQL cannot represent. The `TIMESTAMP` type has special automatic updating behavior, described later. For temporal type storage requirements, see Section 11.7, "Data Type Storage Requirements".

Keep in mind these general considerations when working with date and time types:

- MySQL retrieves values for a given date or time type in a standard output format, but it attempts to interpret a variety of formats for input values that you supply (for example, when you specify a value to be assigned to or compared to a date or time type). For a description of the permitted formats for date and time types, see Section 9.1.3, "Date and Time Literals". It is expected that you supply valid values. Unpredictable results may occur if you use values in other formats.

- Although MySQL tries to interpret values in several formats, date parts must always be given in year-month-day order (for example, `'98-09-04'`), rather than in the month-day-year or day-month-year orders commonly used elsewhere (for example, `'09-04-98'`, `'04-09-98'`).

- Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:

  - Year values in the range `70-99` are converted to `1970-1999`.

  - Year values in the range `00-69` are converted to `2000-2069`.

  See also Section 11.3.8, "Two-Digit Years in Dates".

- Conversion of values from one temporal type to another occurs according to the rules in Section 11.3.7, "Conversion Between Date and Time Types".

- MySQL automatically converts a date or time value to a number if the value is used in a numeric context and vice versa.

- By default, when MySQL encounters a value for a date or time type that is out of range or otherwise invalid for the type, it converts the value to the "zero" value for that type. The exception is that out-of-range `TIME` values are clipped to the appropriate endpoint of the `TIME` range.

- By setting the SQL mode to the appropriate value, you can specify more exactly what kind of dates you want MySQL to support. (See Section 5.1.7, "Server SQL Modes".) You can get MySQL to accept certain dates, such as `'2009-11-31'`, by enabling the `ALLOW_INVALID_DATES` SQL mode. This is useful when you want to store a "possibly wrong" value which the user has specified (for example, in a web form) in the database for future processing. Under this mode, MySQL verifies only that the month is in the range from 1 to 12 and that the day is in the range from 1 to 31.

- MySQL permits you to store dates where the day or month and day are zero in a `DATE` or `DATETIME` column. This is useful for applications that need to store birthdates for which you may not know the exact date. In this case, you simply store the date as `'2009-00-00'` or `'2009-01-00'`. If you store dates such as these, you should not expect to get correct results for functions such as `DATE_SUB()` or `DATE_ADD()` that require complete dates. To disallow zero month or day parts in dates, enable the `NO_ZERO_IN_DATE` SQL mode.

- MySQL permits you to store a "zero" value of `'0000-00-00'` as a "dummy date." This is in some cases more convenient than using `NULL` values, and uses less data and index space. To disallow `'0000-00-00'`, enable the `NO_ZERO_DATE` SQL mode.

- "Zero" date or time values used through Connector/ODBC are converted automatically to `NULL` because ODBC cannot handle such values.

The following table shows the format of the "zero" value for each type. The "zero" values are special, but you can store or refer to them explicitly using the values shown in the table. You can also do this using the values `'0'` or `0`, which are easier to write. For temporal types that include a date part (`DATE`, `DATETIME`, and `TIMESTAMP`), use of these values produces warnings if the `NO_ZERO_DATE` SQL mode is enabled.

Data Type	"Zero" Value
`DATE`	`'0000-00-00'`
`TIME`	`'00:00:00'`
`DATETIME`	`'0000-00-00 00:00:00'`
`TIMESTAMP`	`'0000-00-00 00:00:00'`
`YEAR`	`0000`

11.3.1 The DATE, DATETIME, and TIMESTAMP Types

The `DATE`, `DATETIME`, and `TIMESTAMP` types are related. This section describes their characteristics, how they are similar, and how they differ. MySQL recognizes `DATE`, `DATETIME`, and `TIMESTAMP` values in several formats, described in Section 9.1.3, "Date and Time Literals". For the `DATE` and `DATETIME` range descriptions, "supported" means that although earlier values might work, there is no guarantee.

The `DATE` type is used for values with a date part but no time part. MySQL retrieves and displays `DATE` values in `'YYYY-MM-DD'` format. The supported range is `'1000-01-01'` to `'9999-12-31'`.

The `DATETIME` type is used for values that contain both date and time parts. MySQL retrieves and displays `DATETIME` values in `'YYYY-MM-DD HH:MM:SS'` format. The supported range is `'1000-01-01 00:00:00'` to `'9999-12-31 23:59:59'`.

The `TIMESTAMP` data type is used for values that contain both date and time parts. `TIMESTAMP` has a range of `'1970-01-01 00:00:01'` UTC to `'2038-01-19 03:14:07'` UTC.

MySQL converts `TIMESTAMP` values from the current time zone to UTC for storage, and back from UTC to the current time zone for retrieval. (This does not occur for other types such as `DATETIME`.) By default, the current time zone for each connection is the server's time. The time zone can be set on a per-connection basis. As long as the time zone setting remains constant, you get back the same value you store. If you store a `TIMESTAMP` value, and then change the time zone and retrieve the value, the retrieved value is different from the value you stored. This occurs because the same time zone was not used for conversion in both directions. The current time zone is available as the value of the `time_zone` system variable. For more information, see Section 10.6, "MySQL Server Time Zone Support".

The `TIMESTAMP` data type offers automatic initialization and updating to the current date and time. For more information, see Section 11.3.5, "Automatic Initialization and Updating for TIMESTAMP".

A `DATETIME` or `TIMESTAMP` value can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `DATETIME` or `TIMESTAMP` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, "Fractional Seconds in Time Values".

Invalid `DATE`, `DATETIME`, or `TIMESTAMP` values are converted to the "zero" value of the appropriate type (`'0000-00-00'` or `'0000-00-00 00:00:00'`).

Be aware of certain properties of date value interpretation in MySQL:

- MySQL permits a "relaxed" format for values specified as strings, in which any punctuation character may be used as the delimiter between date parts or time parts. In some cases, this syntax can be deceiving. For example, a value such as `'10:11:12'` might look like a time value because of the ":" delimiter, but is interpreted as the year `'2010-11-12'` if used in a date context. The value `'10:45:15'` is converted to `'0000-00-00'` because `'45'` is not a valid month.

- The server requires that month and day values be valid, and not merely in the range 1 to 12 and 1 to 31, respectively. With strict mode disabled, invalid dates such as `'2004-04-31'` are converted to `'0000-00-00'` and a warning is generated. With strict mode enabled, invalid dates generate an error. To permit such dates, enable `ALLOW_INVALID_DATES`. See Section 5.1.7, "Server SQL Modes", for more information.

- MySQL does not accept `TIMESTAMP` values that include a zero in the day or month column or values that are not a valid date. The sole exception to this rule is the special "zero" value `'0000-00-00 00:00:00'`.

- `CAST()` treats a `TIMESTAMP` value as a string when not selecting from a table. (This is true even if you specify `FROM DUAL`.) See Section 12.10, "Cast Functions and Operators".

- Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:

  - Year values in the range `00-69` are converted to `2000-2069`.

  - Year values in the range `70-99` are converted to `1970-1999`.

  See also Section 11.3.8, "Two-Digit Years in Dates".

  > **Note**
  >
  > The MySQL server can be run with the `MAXDB` SQL mode enabled. In this case, `TIMESTAMP` is identical with `DATETIME`. If this mode is enabled at the time that a table is created, `TIMESTAMP` columns are created as `DATETIME` columns. As a result, such columns use `DATETIME` display format, have the same range of values, and there is no automatic initialization or updating to the current date and time. See Section 5.1.7, "Server SQL Modes".

11.3.2 The TIME Type

MySQL retrieves and displays `TIME` values in `'HH:MM:SS'` format (or `'HHH:MM:SS'` format for large hours values). `TIME` values may range from `'-838:59:59'` to `'838:59:59'`. The hours part may be so large because the `TIME` type can be used not only to represent a time of day (which must be less than 24 hours), but also elapsed time or a time interval between two events (which may be much greater than 24 hours, or even negative).

MySQL recognizes `TIME` values in several formats, described in Section 9.1.3, "Date and Time Literals". Some of these formats can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `TIME` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, "Fractional Seconds in Time Values".

Be careful about assigning abbreviated values to a `TIME` column. MySQL interprets abbreviated `TIME` values with colons as time of the day. That is, `'11:12'` means `'11:12:00'`, not `'00:11:12'`. MySQL interprets abbreviated values without colons using the assumption that the two rightmost digits represent seconds (that is, as elapsed time rather than as time of day). For example, you might think of `'1112'` and `1112` as meaning `'11:12:00'` (12 minutes after 11 o'clock), but MySQL interprets them as `'00:11:12'` (11 minutes, 12 seconds). Similarly, `'12'` and `12` are interpreted as `'00:00:12'`.

By default, values that lie outside the `TIME` range but are otherwise valid are clipped to the closest endpoint of the range. For example, `'-850:00:00'` and `'850:00:00'` are converted to `'-838:59:59'` and `'838:59:59'`. Invalid `TIME` values are converted to `'00:00:00'`. Note that because `'00:00:00'` is itself a valid `TIME` value, there is no way to tell, from a value of `'00:00:00'` stored in a table, whether the original value was specified as `'00:00:00'` or whether it was invalid.

For more restrictive treatment of invalid `TIME` values, enable strict SQL mode to cause errors to occur. See Section 5.1.7, "Server SQL Modes".

11.3.3 The YEAR Type

The `YEAR` type is a 1-byte type used to represent year values. It can be declared as `YEAR(4)` or `YEAR(2)` to specify a display width of four or two characters. The default is four characters if no width is given.

> **Note**
>
> The `YEAR(2)` data type has certain issues that you should consider before choosing to use it. As of MySQL 5.1.65, `YEAR(2)` is deprecated. For more information, see Section 11.3.4, "YEAR(2) Limitations and Migrating to YEAR(4)".

`YEAR(4)` and `YEAR(2)` differ in display format, but have the same range of values. For 4-digit format, MySQL displays `YEAR` values in `YYYY` format, with a range of `1901` to `2155`, or `0000`. For 2-digit format, MySQL displays only the last two (least significant) digits; for example, `70` (1970 or 2070) or `69` (2069).

You can specify input `YEAR` values in a variety of formats:

- As a 4-digit number in the range `1901` to `2155`.

- As a 4-digit string in the range `'1901'` to `'2155'`.

- As a 1- or 2-digit number in the range `1` to `99`. MySQL converts values in the ranges `1` to `69` and `70` to `99` to `YEAR` values in the ranges `2001` to `2069` and `1970` to `1999`.

- As a 1- or 2-digit string in the range `'0'` to `'99'`. MySQL converts values in the ranges `'0'` to `'69'` and `'70'` to `'99'` to `YEAR` values in the ranges `2000` to `2069` and `1970` to `1999`.

- Inserting a numeric `0` has a different effect for `YEAR(2)` and `YEAR(4)`. For `YEAR(2)`, the result has a display value of `00` and an internal value of `2000`. For `YEAR(4)`, the result has a display value of `0000` and an internal value of `0000`. To specify zero for `YEAR(4)` and have it be interpreted as `2000`, specify it as a string `'0'` or `'00'`.

- As the result of a function that returns a value that is acceptable in a `YEAR` context, such as `NOW()`.

MySQL converts invalid `YEAR` values to `0000`.

See also Section 11.3.8, "Two-Digit Years in Dates".

11.3.4 YEAR(2) Limitations and Migrating to YEAR(4)

This section describes problems that can occur when using `YEAR(2)` and provides information about converting existing `YEAR(2)` columns to `YEAR(4)`.

Although the internal range of values for `YEAR(4)` and `YEAR(2)` is the same (`1901` to `2155`, and `0000`), the display width for `YEAR(2)` makes that type inherently ambiguous because displayed values indicate only the last two digits of the internal values and omit the century digits. The result can be a loss of information under certain circumstances. For this reason, consider avoiding `YEAR(2)` throughout your applications and using `YEAR(4)` wherever you need a `YEAR` data type. Note that conversion will become

necessary at some point because support for `YEAR` data types with display values other than 4, most notably `YEAR(2)`, is reduced as of MySQL 5.6.6 and will be removed entirely in a future release.

YEAR(2) Limitations

Issues with the `YEAR(2)` data type include ambiguity of displayed values, and possible loss of information when values are dumped and reloaded or converted to strings.

- Displayed `YEAR(2)` values can be ambiguous. It is possible for up to three `YEAR(2)` values that have different internal values to have the same displayed value, as the following example demonstrates:

```
mysql> CREATE TABLE t (y2 YEAR(2), y4 YEAR(4));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t (y2) VALUES(1912),(2012),(2112);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> UPDATE t SET y4 = y2;
Query OK, 3 rows affected (0.00 sec)
Rows matched: 3  Changed: 3  Warnings: 0

mysql> SELECT * FROM t;
+------+------+
| y2   | y4   |
+------+------+
|   12 | 1912 |
|   12 | 2012 |
|   12 | 2112 |
+------+------+
3 rows in set (0.00 sec)
```

- If you use `mysqldump` to dump the table created in the preceding item, the dump file represents all `y2` values using the same 2-digit representation (`12`). If you reload the table from the dump file, all resulting rows have internal value `2012` and display value `12`, thus losing the distinctions among them.

- Conversion of a `YEAR(2)` or `YEAR(4)` data value to string form uses the display width of the `YEAR` type. Suppose that `YEAR(2)` and `YEAR(4)` columns both contain the value `1970`. Assigning each column to a string results in a value of `'70'` or `'1970'`, respectively. That is, loss of information occurs for conversion from `YEAR(2)` to string.

- Values outside the range from `1970` to `2069` are stored incorrectly when inserted into a `YEAR(2)` column in a `CSV` table. For example, inserting `2111` results in a display value of `11` but an internal value of `2011`.

To avoid these problems, use `YEAR(4)` rather than `YEAR(2)`. Suggestions regarding migration strategies appear later in this section.

Migrating from YEAR(2) to YEAR(4)

To convert `YEAR(2)` columns to `YEAR(4)`, use `ALTER TABLE`. Suppose that a table `t1` has this definition:

```
CREATE TABLE t1 (ycol YEAR(2) NOT NULL DEFAULT '70');
```

Modify the column using `ALTER TABLE` as follows. Remember to include any column attributes such as `NOT NULL` or `DEFAULT`:

```
ALTER TABLE t1 MODIFY ycol YEAR(4) NOT NULL DEFAULT '1970';
```

The `ALTER TABLE` statement converts the table without changing `YEAR(2)` values. If the server is a replication master, the `ALTER TABLE` statement replicates to slaves and makes the corresponding table change on each one.

One migration method should be avoided: Do not dump your data with `mysqldump` and reload the dump file after upgrading. This has the potential to change `YEAR(2)` values, as described previously.

A migration from `YEAR(2)` to `YEAR(4)` should also involve examining application code for the possibility of changed behavior under conditions such as these:

- Code that expects selecting a `YEAR` column to produce exactly two digits.

- Code that does not account for different handling for inserts of numeric `0`: Inserting `0` into `YEAR(2)` or `YEAR(4)` results in an internal value of `2000` or `0000`, respectively.

11.3.5 Automatic Initialization and Updating for TIMESTAMP

> **Note**
>
> In older versions of MySQL (prior to 4.1), the properties of the `TIMESTAMP` data type differed significantly in several ways from what is described in this section (see the *MySQL 3.23, 4.0, 4.1 Reference Manual* for details); these include syntax extensions which are deprecated in MySQL 5.1, and no longer supported in MySQL 5.5. This has implications for performing a dump and restore or replicating between MySQL Server versions. If you are using columns that are defined using the old `TIMESTAMP(N)` syntax, see Section 2.13.1.1, "Changes Affecting Upgrades to 5.1", prior to upgrading to MySQL 5.1 or later.

The `TIMESTAMP` data type offers automatic initialization and updating to the current date and time (that is, the current timestamp). You can choose whether to use these properties and which column should have them:

- One `TIMESTAMP` column in a table can have the current timestamp as the default value for initializing the column, as the auto-update value, or both. It is not possible to have the current timestamp be the default value for one column and the auto-update value for another column.

- If the column is auto-initialized, it is set to the current timestamp for inserted rows that specify no value for the column.

- If the column is auto-updated, it is automatically updated to the current timestamp when the value of any other column in the row is changed from its current value. The column remains unchanged if all other columns are set to their current values. To prevent the column from updating when other columns change, explicitly set it to its current value. To update the column even when other columns do not change, explicitly set it to the value it should have (for example, set it to `CURRENT_TIMESTAMP`).

In addition, you can initialize or update any `TIMESTAMP` column to the current date and time by assigning it a `NULL` value, unless it has been defined with the `NULL` attribute to permit `NULL` values.

To specify automatic properties, use the `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP` clauses. The order of the clauses does not matter. If both are present in a column definition, either can occur first. Any of the synonyms for `CURRENT_TIMESTAMP` have the same meaning as `CURRENT_TIMESTAMP`. These are `CURRENT_TIMESTAMP()`, `NOW()`, `LOCALTIME`, `LOCALTIME()`, `LOCALTIMESTAMP`, and `LOCALTIMESTAMP()`.

Use of `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP` is specific to `TIMESTAMP`. The `DEFAULT` clause also can be used to specify a constant (nonautomatic) default value; for example, `DEFAULT 0` or `DEFAULT '2000-01-01 00:00:00'`.

> **Note**
>
> The following examples use `DEFAULT 0`, a default that can produce warnings or errors depending on whether strict SQL mode or the `NO_ZERO_DATE` SQL mode is enabled. Be aware that the `TRADITIONAL` SQL mode includes strict mode and `NO_ZERO_DATE`. See Section 5.1.7, "Server SQL Modes".

The following rules describe the possibilities for defining the first `TIMESTAMP` column in a table with the current timestamp for both the default and auto-update values, for one but not the other, or for neither:

- With both `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP`, the column has the current timestamp for its default value and is automatically updated to the current timestamp.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
);
```

- With neither `DEFAULT CURRENT_TIMESTAMP` nor `ON UPDATE CURRENT_TIMESTAMP`, it is the same as specifying both `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP`.

```
CREATE TABLE t1 (
  ts TIMESTAMP
);
```

- With a `DEFAULT` clause but no `ON UPDATE CURRENT_TIMESTAMP` clause, the column has the given default value and is not automatically updated to the current timestamp.

  The default depends on whether the `DEFAULT` clause specifies `CURRENT_TIMESTAMP` or a constant value. With `CURRENT_TIMESTAMP`, the default is the current timestamp.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP
);
```

  With a constant, the default is the given value. In this case, the column has no automatic properties at all.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT 0
);
```

- With an `ON UPDATE CURRENT_TIMESTAMP` clause and a constant `DEFAULT` clause, the column is automatically updated to the current timestamp and has the given constant default value.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT 0 ON UPDATE CURRENT_TIMESTAMP
);
```

- With an `ON UPDATE CURRENT_TIMESTAMP` clause but no `DEFAULT` clause, the column is automatically updated to the current timestamp. The default is 0 unless the column is defined with the `NULL` attribute, in which case the default is `NULL`.

```
CREATE TABLE t1 (
  ts TIMESTAMP ON UPDATE CURRENT_TIMESTAMP      -- default 0
);
CREATE TABLE t2 (
```

```
   ts TIMESTAMP NULL ON UPDATE CURRENT_TIMESTAMP -- default NULL
);
```

It need not be the first `TIMESTAMP` column in a table that is automatically initialized or updated to the current timestamp. However, to specify automatic initialization or updating for a different `TIMESTAMP` column, you must suppress the automatic properties for the first one. Then, for the other `TIMESTAMP` column, the rules for the `DEFAULT` and `ON UPDATE` clauses are the same as for the first `TIMESTAMP` column, except that if you omit both clauses, no automatic initialization or updating occurs.

To suppress automatic properties for the first `TIMESTAMP` column, do either of the following:

- Define the column with a `DEFAULT` clause that specifies a constant default value.

- Specify the `NULL` attribute. This also causes the column to permit `NULL` values, which means that you cannot assign the current timestamp by setting the column to `NULL`. Assigning `NULL` sets the column to `NULL`.

Consider these table definitions:

```
CREATE TABLE t1 (
  ts1 TIMESTAMP DEFAULT 0,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
              ON UPDATE CURRENT_TIMESTAMP);
CREATE TABLE t2 (
  ts1 TIMESTAMP NULL,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
              ON UPDATE CURRENT_TIMESTAMP);
CREATE TABLE t3 (
  ts1 TIMESTAMP NULL DEFAULT 0,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
              ON UPDATE CURRENT_TIMESTAMP);
```

The tables have these properties:

- In each table definition, the first `TIMESTAMP` column has no automatic initialization or updating.

- The tables differ in how the `ts1` column handles `NULL` values. For `t1`, `ts1` is `NOT NULL` and assigning it a value of `NULL` sets it to the current timestamp. For `t2` and `t3`, `ts1` permits `NULL` and assigning it a value of `NULL` sets it to `NULL`.

- `t2` and `t3` differ in the default value for `ts1`. For `t2`, `ts1` is defined to permit `NULL`, so the default is also `NULL` in the absence of an explicit `DEFAULT` clause. For `t3`, `ts1` permits `NULL` but has an explicit default of 0.

TIMESTAMP Initialization and the NULL Attribute

By default, `TIMESTAMP` columns are `NOT NULL`, cannot contain `NULL` values, and assigning `NULL` assigns the current timestamp. To permit a `TIMESTAMP` column to contain `NULL`, explicitly declare it with the `NULL` attribute. In this case, the default value also becomes `NULL` unless overridden with a `DEFAULT` clause that specifies a different default value. `DEFAULT NULL` can be used to explicitly specify `NULL` as the default value. (For a `TIMESTAMP` column not declared with the `NULL` attribute, `DEFAULT NULL` is invalid.) If a `TIMESTAMP` column permits `NULL` values, assigning `NULL` sets it to `NULL`, not to the current timestamp.

The following table contains several `TIMESTAMP` columns that permit `NULL` values:

```
CREATE TABLE t
(
  ts1 TIMESTAMP NULL DEFAULT NULL,
  ts2 TIMESTAMP NULL DEFAULT 0,
```

```
   ts3 TIMESTAMP NULL DEFAULT CURRENT_TIMESTAMP
);
```

A `TIMESTAMP` column that permits `NULL` values does *not* take on the current timestamp at insert time except under one of the following conditions:

- Its default value is defined as `CURRENT_TIMESTAMP` and no value is specified for the column

- `CURRENT_TIMESTAMP` or any of its synonyms such as `NOW()` is explicitly inserted into the column

In other words, a `TIMESTAMP` column defined to permit `NULL` values auto-initializes only if its definition includes `DEFAULT CURRENT_TIMESTAMP`:

```
CREATE TABLE t (ts TIMESTAMP NULL DEFAULT CURRENT_TIMESTAMP);
```

If the `TIMESTAMP` column permits `NULL` values but its definition does not include `DEFAULT CURRENT_TIMESTAMP`, you must explicitly insert a value corresponding to the current date and time. Suppose that tables `t1` and `t2` have these definitions:

```
CREATE TABLE t1 (ts TIMESTAMP NULL DEFAULT '0000-00-00 00:00:00');
CREATE TABLE t2 (ts TIMESTAMP NULL DEFAULT NULL);
```

To set the `TIMESTAMP` column in either table to the current timestamp at insert time, explicitly assign it that value. For example:

```
INSERT INTO t1 VALUES (NOW());
INSERT INTO t2 VALUES (CURRENT_TIMESTAMP);
```

11.3.6 Fractional Seconds in Time Values

A trailing fractional seconds part is permissible for temporal values in contexts such as literal values, and in the arguments to or return values from some temporal functions. Example:

```
mysql> SELECT MICROSECOND('2010-12-10 14:12:09.019473');
+-------------------------------------------+
| MICROSECOND('2010-12-10 14:12:09.019473') |
+-------------------------------------------+
|                                     19473 |
+-------------------------------------------+
```

However, when MySQL stores a value into a column of any temporal data type, it discards any fractional part and does not store it.

11.3.7 Conversion Between Date and Time Types

To some extent, you can convert a value from one temporal type to another. However, there may be some alteration of the value or loss of information. In all cases, conversion between temporal types is subject to the range of valid values for the resulting type. For example, although `DATE`, `DATETIME`, and `TIMESTAMP` values all can be specified using the same set of formats, the types do not all have the same range of values. `TIMESTAMP` values cannot be earlier than `1970` UTC or later than `'2038-01-19 03:14:07'` UTC. This means that a date such as `'1968-01-01'`, while valid as a `DATE` or `DATETIME` value, is not valid as a `TIMESTAMP` value and is converted to `0`.

Conversion of `DATE` values:

- Conversion to a `DATETIME` or `TIMESTAMP` value adds a time part of `'00:00:00'` because the `DATE` value contains no time information.

- Conversion to a `TIME` value is not useful; the result is `'00:00:00'`.

Conversion of `DATETIME` and `TIMESTAMP` values:

- Conversion to a `DATE` value discards the time part because the `DATE` type contains no time information.

- Conversion to a `TIME` value discards the date part because the `TIME` type contains no date information.

Conversion of `TIME` values:

MySQL converts a time value to a date or date-and-time value by parsing the string value of the time as a date or date-and-time. This is unlikely to be useful. For example, `'23:12:31'` interpreted as a date becomes `'2023-12-31'`. Time values not valid as dates become `'0000-00-00'` or `NULL`.

Prior to MySQL 5.1.18, when `DATE` values are compared with `DATETIME` values, the time portion of the `DATETIME` value is ignored, or the comparison could be performed as a string compare. Starting from MySQL 5.1.18, a `DATE` value is coerced to the `DATETIME` type by adding the time portion as `'00:00:00'`. To mimic the old behavior, use the `CAST()` function to cause the comparison operands to be treated as previously. For example:

```
date_col = CAST(datetime_col AS DATE)
```

Conversion of `TIME` or `DATETIME` values to numeric form (for example, by adding `+0`) results in a double-precision value with a microseconds part of `.000000`:

```
mysql> SELECT CURTIME(), CURTIME()+0;
+-----------+---------------+
| CURTIME() | CURTIME()+0   |
+-----------+---------------+
| 10:41:36  | 104136.000000 |
+-----------+---------------+
mysql> SELECT NOW(), NOW()+0;
+---------------------+-----------------------+
| NOW()               | NOW()+0               |
+---------------------+-----------------------+
| 2007-11-30 10:41:47 | 20071130104147.000000 |
+---------------------+-----------------------+
```

11.3.8 Two-Digit Years in Dates

Date values with two-digit years are ambiguous because the century is unknown. Such values must be interpreted into four-digit form because MySQL stores years internally using four digits.

For `DATETIME`, `DATE`, and `TIMESTAMP` types, MySQL interprets dates specified with ambiguous year values using these rules:

- Year values in the range `00-69` are converted to `2000-2069`.

- Year values in the range `70-99` are converted to `1970-1999`.

For `YEAR`, the rules are the same, with this exception: A numeric `00` inserted into `YEAR(4)` results in `0000` rather than `2000`. To specify zero for `YEAR(4)` and have it be interpreted as `2000`, specify it as a string `'0'` or `'00'`.

Remember that these rules are only heuristics that provide reasonable guesses as to what your data values mean. If the rules used by MySQL do not produce the values you require, you must provide unambiguous input containing four-digit year values.

`ORDER BY` properly sorts `YEAR` values that have two-digit years.

Some functions like `MIN()` and `MAX()` convert a `YEAR` to a number. This means that a value with a two-digit year does not work properly with these functions. The fix in this case is to convert the `YEAR` to four-digit year format.

11.4 String Types

The string types are `CHAR`, `VARCHAR`, `BINARY`, `VARBINARY`, `BLOB`, `TEXT`, `ENUM`, and `SET`. This section describes how these types work and how to use them in your queries. For string type storage requirements, see Section 11.7, "Data Type Storage Requirements".

11.4.1 The CHAR and VARCHAR Types

The `CHAR` and `VARCHAR` types are similar, but differ in the way they are stored and retrieved. They also differ in maximum length and in whether trailing spaces are retained.

The `CHAR` and `VARCHAR` types are declared with a length that indicates the maximum number of characters you want to store. For example, `CHAR(30)` can hold up to 30 characters.

The length of a `CHAR` column is fixed to the length that you declare when you create the table. The length can be any value from 0 to 255. When `CHAR` values are stored, they are right-padded with spaces to the specified length. When `CHAR` values are retrieved, trailing spaces are removed unless the `PAD_CHAR_TO_FULL_LENGTH` SQL mode is enabled.

Values in `VARCHAR` columns are variable-length strings. The length can be specified as a value from 0 to 65,535. The effective maximum length of a `VARCHAR` is subject to the maximum row size (65,535 bytes, which is shared among all columns) and the character set used. See Section C.7.4, "Limits on Table Column Count and Row Size".

In contrast to `CHAR`, `VARCHAR` values are stored as a 1-byte or 2-byte length prefix plus data. The length prefix indicates the number of bytes in the value. A column uses one length byte if values require no more than 255 bytes, two length bytes if values may require more than 255 bytes.

If strict SQL mode is not enabled and you assign a value to a `CHAR` or `VARCHAR` column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For truncation of nonspace characters, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.7, "Server SQL Modes".

For `VARCHAR` columns, trailing spaces in excess of the column length are truncated prior to insertion and a warning is generated, regardless of the SQL mode in use. For `CHAR` columns, truncation of excess trailing spaces from inserted values is performed silently regardless of the SQL mode.

`VARCHAR` values are not padded when they are stored. Trailing spaces are retained when values are stored and retrieved, in conformance with standard SQL.

The following table illustrates the differences between `CHAR` and `VARCHAR` by showing the result of storing various string values into `CHAR(4)` and `VARCHAR(4)` columns (assuming that the column uses a single-byte character set such as `latin1`).

Value	`CHAR(4)`	Storage Required	`VARCHAR(4)`	Storage Required
`' '`	`'    '`	4 bytes	`''`	1 byte
`'ab'`	`'ab  '`	4 bytes	`'ab'`	3 bytes
`'abcd'`	`'abcd'`	4 bytes	`'abcd'`	5 bytes
`'abcdefgh'`	`'abcd'`	4 bytes	`'abcd'`	5 bytes

The values shown as stored in the last row of the table apply *only when not using strict mode*; if MySQL is running in strict mode, values that exceed the column length are *not stored*, and an error results.

If a given value is stored into the `CHAR(4)` and `VARCHAR(4)` columns, the values retrieved from the columns are not always the same because trailing spaces are removed from `CHAR` columns upon retrieval. The following example illustrates this difference:

```
mysql> CREATE TABLE vc (v VARCHAR(4), c CHAR(4));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO vc VALUES ('ab  ', 'ab  ');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT CONCAT('(', v, ')'), CONCAT('(', c, ')') FROM vc;
+---------------------+---------------------+
| CONCAT('(', v, ')') | CONCAT('(', c, ')') |
+---------------------+---------------------+
| (ab  )              | (ab)                |
+---------------------+---------------------+
1 row in set (0.06 sec)
```

Values in `CHAR` and `VARCHAR` columns are sorted and compared according to the character set collation assigned to the column.

All MySQL collations are of type `PADSPACE`. This means that all `CHAR`, `VARCHAR`, and `TEXT` values in MySQL are compared without regard to any trailing spaces. "Comparison" in this context does not include the `LIKE` pattern-matching operator, for which trailing spaces are significant. For example:

```
mysql> CREATE TABLE names (myname CHAR(10));
Query OK, 0 rows affected (0.03 sec)

mysql> INSERT INTO names VALUES ('Monty');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT myname = 'Monty', myname = 'Monty  ' FROM names;
+------------------+--------------------+
| myname = 'Monty' | myname = 'Monty  ' |
+------------------+--------------------+
|                1 |                  1 |
+------------------+--------------------+
1 row in set (0.00 sec)

mysql> SELECT myname LIKE 'Monty', myname LIKE 'Monty  ' FROM names;
+---------------------+-----------------------+
| myname LIKE 'Monty' | myname LIKE 'Monty  ' |
+---------------------+-----------------------+
|                   1 |                     0 |
+---------------------+-----------------------+
1 row in set (0.00 sec)
```

This is true for all MySQL versions, and is not affected by the server SQL mode.

Note

For more information about MySQL character sets and collations, see Section 10.1, "Character Set Support". For additional information about storage requirements, see Section 11.7, "Data Type Storage Requirements".

For those cases where trailing pad characters are stripped or comparisons ignore them, if a column has an index that requires unique values, inserting into the column values that differ only in number of trailing

pad characters will result in a duplicate-key error. For example, if a table contains `'a'`, an attempt to store `'a '` causes a duplicate-key error.

11.4.2 The BINARY and VARBINARY Types

The `BINARY` and `VARBINARY` types are similar to `CHAR` and `VARCHAR`, except that they contain binary strings rather than nonbinary strings. That is, they contain byte strings rather than character strings. This means that they have no character set, and sorting and comparison are based on the numeric values of the bytes in the values.

The permissible maximum length is the same for `BINARY` and `VARBINARY` as it is for `CHAR` and `VARCHAR`, except that the length for `BINARY` and `VARBINARY` is a length in bytes rather than in characters.

The `BINARY` and `VARBINARY` data types are distinct from the `CHAR BINARY` and `VARCHAR BINARY` data types. For the latter types, the `BINARY` attribute does not cause the column to be treated as a binary string column. Instead, it causes the binary collation for the column character set to be used, and the column itself contains nonbinary character strings rather than binary byte strings. For example, `CHAR(5) BINARY` is treated as `CHAR(5) CHARACTER SET latin1 COLLATE latin1_bin`, assuming that the default character set is `latin1`. This differs from `BINARY(5)`, which stores 5-bytes binary strings that have no character set or collation. For information about differences between nonbinary string binary collations and binary strings, see Section 10.1.7.6, "The _bin and binary Collations".

If strict SQL mode is not enabled and you assign a value to a `BINARY` or `VARBINARY` column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For cases of truncation, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.7, "Server SQL Modes".

When `BINARY` values are stored, they are right-padded with the pad value to the specified length. The pad value is `0x00` (the zero byte). Values are right-padded with `0x00` on insert, and no trailing bytes are removed on select. All bytes are significant in comparisons, including `ORDER BY` and `DISTINCT` operations. `0x00` bytes and spaces are different in comparisons, with `0x00` < space.

Example: For a `BINARY(3)` column, `'a '` becomes `'a \0'` when inserted. `'a\0'` becomes `'a\0\0'` when inserted. Both inserted values remain unchanged when selected.

For `VARBINARY`, there is no padding on insert and no bytes are stripped on select. All bytes are significant in comparisons, including `ORDER BY` and `DISTINCT` operations. `0x00` bytes and spaces are different in comparisons, with `0x00` < space.

For those cases where trailing pad bytes are stripped or comparisons ignore them, if a column has an index that requires unique values, inserting into the column values that differ only in number of trailing pad bytes will result in a duplicate-key error. For example, if a table contains `'a'`, an attempt to store `'a\0'` causes a duplicate-key error.

You should consider the preceding padding and stripping characteristics carefully if you plan to use the `BINARY` data type for storing binary data and you require that the value retrieved be exactly the same as the value stored. The following example illustrates how `0x00`-padding of `BINARY` values affects column value comparisons:

```
mysql> CREATE TABLE t (c BINARY(3));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t SET c = 'a';
Query OK, 1 row affected (0.01 sec)

mysql> SELECT HEX(c), c = 'a', c = 'a\0\0' from t;
+--------+---------+-------------+
```

```
| HEX(c) | c = 'a' | c = 'a\0\0' |
+--------+---------+-------------+
| 610000 |       0 |           1 |
+--------+---------+-------------+
1 row in set (0.09 sec)
```

If the value retrieved must be the same as the value specified for storage with no padding, it might be preferable to use `VARBINARY` or one of the `BLOB` data types instead.

11.4.3 The BLOB and TEXT Types

A `BLOB` is a binary large object that can hold a variable amount of data. The four `BLOB` types are `TINYBLOB`, `BLOB`, `MEDIUMBLOB`, and `LONGBLOB`. These differ only in the maximum length of the values they can hold. The four `TEXT` types are `TINYTEXT`, `TEXT`, `MEDIUMTEXT`, and `LONGTEXT`. These correspond to the four `BLOB` types and have the same maximum lengths and storage requirements. See Section 11.7, "Data Type Storage Requirements".

`BLOB` values are treated as binary strings (byte strings). They have no character set, and sorting and comparison are based on the numeric values of the bytes in column values. `TEXT` values are treated as nonbinary strings (character strings). They have a character set, and values are sorted and compared based on the collation of the character set.

If strict SQL mode is not enabled and you assign a value to a `BLOB` or `TEXT` column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For truncation of nonspace characters, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.7, "Server SQL Modes".

Beginning with MySQL 5.1.24, truncation of excess trailing spaces from values to be inserted into `TEXT` columns always generates a warning, regardless of the SQL mode.

For `TEXT` and `BLOB` columns, there is no padding on insert and no bytes are stripped on select.

If a `TEXT` column is indexed, index entry comparisons are space-padded at the end. This means that, if the index requires unique values, duplicate-key errors will occur for values that differ only in the number of trailing spaces. For example, if a table contains `'a'`, an attempt to store `'a '` causes a duplicate-key error. This is not true for `BLOB` columns.

In most respects, you can regard a `BLOB` column as a `VARBINARY` column that can be as large as you like. Similarly, you can regard a `TEXT` column as a `VARCHAR` column. `BLOB` and `TEXT` differ from `VARBINARY` and `VARCHAR` in the following ways:

- For indexes on `BLOB` and `TEXT` columns, you must specify an index prefix length. For `CHAR` and `VARCHAR`, a prefix length is optional. See Section 8.3.4, "Column Indexes".

- `BLOB` and `TEXT` columns cannot have `DEFAULT` values.

If you use the `BINARY` attribute with a `TEXT` data type, the column is assigned the binary collation of the column character set.

`LONG` and `LONG VARCHAR` map to the `MEDIUMTEXT` data type. This is a compatibility feature.

MySQL Connector/ODBC defines `BLOB` values as `LONGVARBINARY` and `TEXT` values as `LONGVARCHAR`.

Because `BLOB` and `TEXT` values can be extremely long, you might encounter some constraints in using them:

- Only the first `max_sort_length` bytes of the column are used when sorting. The default value of `max_sort_length` is 1024. You can make more bytes significant in sorting or grouping by increasing

the value of `max_sort_length` at server startup or runtime. Any client can change the value of its session `max_sort_length` variable:

```
mysql> SET max_sort_length = 2000;
mysql> SELECT id, comment FROM t
    -> ORDER BY comment;
```

- Instances of `BLOB` or `TEXT` columns in the result of a query that is processed using a temporary table causes the server to use a table on disk rather than in memory because the `MEMORY` storage engine does not support those data types (see Section 8.4.4, "Internal Temporary Table Use in MySQL"). Use of disk incurs a performance penalty, so include `BLOB` or `TEXT` columns in the query result only if they are really needed. For example, avoid using `SELECT *`, which selects all columns.

- The maximum size of a `BLOB` or `TEXT` object is determined by its type, but the largest value you actually can transmit between the client and server is determined by the amount of available memory and the size of the communications buffers. You can change the message buffer size by changing the value of the `max_allowed_packet` variable, but you must do so for both the server and your client program. For example, both `mysql` and `mysqldump` enable you to change the client-side `max_allowed_packet` value. See Section 8.12.2, "Tuning Server Parameters", Section 4.5.1, "`mysql` — The MySQL Command-Line Tool", and Section 4.5.4, "`mysqldump` — A Database Backup Program". You may also want to compare the packet sizes and the size of the data objects you are storing with the storage requirements, see Section 11.7, "Data Type Storage Requirements"

Each `BLOB` or `TEXT` value is represented internally by a separately allocated object. This is in contrast to all other data types, for which storage is allocated once per column when the table is opened.

In some cases, it may be desirable to store binary data such as media files in `BLOB` or `TEXT` columns. You may find MySQL's string handling functions useful for working with such data. See Section 12.5, "String Functions". For security and other reasons, it is usually preferable to do so using application code rather than giving application users the `FILE` privilege. You can discuss specifics for various languages and platforms in the MySQL Forums (http://forums.mysql.com/).

11.4.4 The ENUM Type

An `ENUM` is a string object with a value chosen from a list of permitted values that are enumerated explicitly in the column specification at table creation time. It has these advantages:

- Compact data storage in situations where a column has a limited set of possible values. The strings you specify as input values are automatically encoded as numbers. See Section 11.7, "Data Type Storage Requirements" for the storage requirements for `ENUM` types.

- Readable queries and output. The numbers are translated back to the corresponding strings in query results.

and these potential issues to consider:

- If you make enumeration values that look like numbers, it is easy to mix up the literal values with their internal index numbers, as explained in Enumeration Limitations.

- Using `ENUM` columns in `ORDER BY` clauses requires extra care, as explained in Enumeration Sorting.

Creating and Using ENUM Columns

An enumeration value must be a quoted string literal. For example, you can create a table with an `ENUM` column like this:

```
CREATE TABLE shirts (
    name VARCHAR(40),
    size ENUM('x-small', 'small', 'medium', 'large', 'x-large')
);
INSERT INTO shirts (name, size) VALUES ('dress shirt','large'), ('t-shirt','medium'),
  ('polo shirt','small');
SELECT name, size FROM shirts WHERE size = 'medium';
+---------+--------+
| name    | size   |
+---------+--------+
| t-shirt | medium |
+---------+--------+
UPDATE shirts SET size = 'small' WHERE size = 'large';
COMMIT;
```

Inserting 1 million rows into this table with a value of `'medium'` would require 1 million bytes of storage, as opposed to 6 million bytes if you stored the actual string `'medium'` in a `VARCHAR` column.

Index Values for Enumeration Literals

Each enumeration value has an index:

- The elements listed in the column specification are assigned index numbers, beginning with 1.

- The index value of the empty string error value is 0. This means that you can use the following `SELECT` statement to find rows into which invalid `ENUM` values were assigned:

  ```
  mysql> SELECT * FROM tbl_name WHERE enum_col=0;
  ```

- The index of the `NULL` value is `NULL`.

- The term "index" here refers to a position within the list of enumeration values. It has nothing to do with table indexes.

For example, a column specified as `ENUM('Mercury', 'Venus', 'Earth')` can have any of the values shown here. The index of each value is also shown.

Value	Index
NULL	NULL
''	0
'Mercury'	1
'Venus'	2
'Earth'	3

An `ENUM` column can have a maximum of 65,535 distinct elements. (The practical limit is less than 3000.) A table can have no more than 255 unique element list definitions among its `ENUM` and `SET` columns considered as a group. For more information on these limits, see Section C.7.5, "Limits Imposed by .frm File Structure".

If you retrieve an `ENUM` value in a numeric context, the column value's index is returned. For example, you can retrieve numeric values from an `ENUM` column like this:

```
mysql> SELECT enum_col+0 FROM tbl_name;
```

Functions such as `SUM()` or `AVG()` that expect a numeric argument cast the argument to a number if necessary. For `ENUM` values, the index number is used in the calculation.

Handling of Enumeration Literals

Trailing spaces are automatically deleted from `ENUM` member values in the table definition when a table is created.

When retrieved, values stored into an `ENUM` column are displayed using the lettercase that was used in the column definition. Note that `ENUM` columns can be assigned a character set and collation. For binary or case-sensitive collations, lettercase is taken into account when assigning values to the column.

If you store a number into an `ENUM` column, the number is treated as the index into the possible values, and the value stored is the enumeration member with that index. (However, this does *not* work with `LOAD DATA`, which treats all input as strings.) If the numeric value is quoted, it is still interpreted as an index if there is no matching string in the list of enumeration values. For these reasons, it is not advisable to define an `ENUM` column with enumeration values that look like numbers, because this can easily become confusing. For example, the following column has enumeration members with string values of `'0'`, `'1'`, and `'2'`, but numeric index values of `1`, `2`, and `3`:

```
numbers ENUM('0','1','2')
```

If you store `2`, it is interpreted as an index value, and becomes `'1'` (the value with index 2). If you store `'2'`, it matches an enumeration value, so it is stored as `'2'`. If you store `'3'`, it does not match any enumeration value, so it is treated as an index and becomes `'2'` (the value with index 3).

```
mysql> INSERT INTO t (numbers) VALUES(2),('2'),('3');
mysql> SELECT * FROM t;
+---------+
| numbers |
+---------+
| 1       |
| 2       |
| 2       |
+---------+
```

To determine all possible values for an `ENUM` column, use `SHOW COLUMNS FROM` *tbl_name* `LIKE` `'enum_col'` and parse the `ENUM` definition in the `Type` column of the output.

In the C API, `ENUM` values are returned as strings. For information about using result set metadata to distinguish them from other strings, see Section 21.8.5, "C API Data Structures".

Empty or NULL Enumeration Values

An enumeration value can also be the empty string (`''`) or `NULL` under certain circumstances:

- If you insert an invalid value into an `ENUM` (that is, a string not present in the list of permitted values), the empty string is inserted instead as a special error value. This string can be distinguished from a "normal" empty string by the fact that this string has the numeric value 0. See Index Values for Enumeration Literals for details about the numeric indexes for the enumeration values.

  If strict SQL mode is enabled, attempts to insert invalid `ENUM` values result in an error.

- If an `ENUM` column is declared to permit `NULL`, the `NULL` value is a valid value for the column, and the default value is `NULL`. If an `ENUM` column is declared `NOT NULL`, its default value is the first element of the list of permitted values.

Enumeration Sorting

`ENUM` values are sorted based on their index numbers, which depend on the order in which the enumeration members were listed in the column specification. For example, `'b'` sorts before `'a'` for `ENUM('b', 'a')`. The empty string sorts before nonempty strings, and `NULL` values sort before all other enumeration values.

To prevent unexpected results when using the `ORDER BY` clause on an `ENUM` column, use one of these techniques:

- Specify the `ENUM` list in alphabetic order.

- Make sure that the column is sorted lexically rather than by index number by coding `ORDER BY CAST(`*`col`*` AS CHAR)` or `ORDER BY CONCAT(`*`col`*`)`.

Enumeration Limitations

An enumeration value cannot be an expression, even one that evaluates to a string value.

For example, this `CREATE TABLE` statement does *not* work because the `CONCAT` function cannot be used to construct an enumeration value:

```
CREATE TABLE sizes (
    size ENUM('small', CONCAT('med','ium'), 'large')
);
```

You also cannot employ a user variable as an enumeration value. This pair of statements do *not* work:

```
SET @mysize = 'medium';

CREATE TABLE sizes (
    size ENUM('small', @mysize, 'large')
);
```

We strongly recommend that you do *not* use numbers as enumeration values, because it does not save on storage over the appropriate `TINYINT` or `SMALLINT` type, and it is easy to mix up the strings and the underlying number values (which might not be the same) if you quote the `ENUM` values incorrectly. If you do use a number as an enumeration value, always enclose it in quotation marks. If the quotation marks are omitted, the number is regarded as an index. See Handling of Enumeration Literals to see how even a quoted number could be mistakenly used as a numeric index value.

Duplicate values in the definition cause a warning, or an error if strict SQL mode is enabled.

11.4.5 The SET Type

A `SET` is a string object that can have zero or more values, each of which must be chosen from a list of permitted values specified when the table is created. `SET` column values that consist of multiple set members are specified with members separated by commas (",""). A consequence of this is that `SET` member values should not themselves contain commas.

For example, a column specified as `SET('one', 'two') NOT NULL` can have any of these values:

```
''
'one'
'two'
```

```
'one,two'
```

A `SET` column can have a maximum of 64 distinct members. A table can have no more than 255 unique element list definitions among its `ENUM` and `SET` columns considered as a group. For more information on this limit, see Section C.7.5, "Limits Imposed by .frm File Structure".

Duplicate values in the definition cause a warning, or an error if strict SQL mode is enabled.

Trailing spaces are automatically deleted from `SET` member values in the table definition when a table is created.

When retrieved, values stored in a `SET` column are displayed using the lettercase that was used in the column definition. Note that `SET` columns can be assigned a character set and collation. For binary or case-sensitive collations, lettercase is taken into account when assigning values to the column.

MySQL stores `SET` values numerically, with the low-order bit of the stored value corresponding to the first set member. If you retrieve a `SET` value in a numeric context, the value retrieved has bits set corresponding to the set members that make up the column value. For example, you can retrieve numeric values from a `SET` column like this:

```
mysql> SELECT set_col+0 FROM tbl_name;
```

If a number is stored into a `SET` column, the bits that are set in the binary representation of the number determine the set members in the column value. For a column specified as `SET('a','b','c','d')`, the members have the following decimal and binary values.

`SET` Member	Decimal Value	Binary Value
`'a'`	1	0001
`'b'`	2	0010
`'c'`	4	0100
`'d'`	8	1000

If you assign a value of `9` to this column, that is `1001` in binary, so the first and fourth `SET` value members `'a'` and `'d'` are selected and the resulting value is `'a,d'`.

For a value containing more than one `SET` element, it does not matter what order the elements are listed in when you insert the value. It also does not matter how many times a given element is listed in the value. When the value is retrieved later, each element in the value appears once, with elements listed according to the order in which they were specified at table creation time. For example, suppose that a column is specified as `SET('a','b','c','d')`:

```
mysql> CREATE TABLE myset (col SET('a', 'b', 'c', 'd'));
```

If you insert the values `'a,d'`, `'d,a'`, `'a,d,d'`, `'a,d,a'`, and `'d,a,d'`:

```
mysql> INSERT INTO myset (col) VALUES
-> ('a,d'), ('d,a'), ('a,d,a'), ('a,d,d'), ('d,a,d');
Query OK, 5 rows affected (0.01 sec)
Records: 5  Duplicates: 0  Warnings: 0
```

Then all these values appear as `'a,d'` when retrieved:

```
mysql> SELECT col FROM myset;
+------+
| col  |
+------+
| a,d  |
| a,d  |
| a,d  |
| a,d  |
| a,d  |
+------+
5 rows in set (0.04 sec)
```

If you set a SET column to an unsupported value, the value is ignored and a warning is issued:

```
mysql> INSERT INTO myset (col) VALUES ('a,d,d,s');
Query OK, 1 row affected, 1 warning (0.03 sec)

mysql> SHOW WARNINGS;
+---------+------+------------------------------------------+
| Level   | Code | Message                                  |
+---------+------+------------------------------------------+
| Warning | 1265 | Data truncated for column 'col' at row 1 |
+---------+------+------------------------------------------+
1 row in set (0.04 sec)

mysql> SELECT col FROM myset;
+------+
| col  |
+------+
| a,d  |
| a,d  |
| a,d  |
| a,d  |
| a,d  |
| a,d  |
+------+
6 rows in set (0.01 sec)
```

If strict SQL mode is enabled, attempts to insert invalid SET values result in an error.

SET values are sorted numerically. NULL values sort before non-NULL SET values.

Functions such as SUM() or AVG() that expect a numeric argument cast the argument to a number if necessary. For SET values, the cast operation causes the numeric value to be used.

Normally, you search for SET values using the FIND_IN_SET() function or the LIKE operator:

```
mysql> SELECT * FROM tbl_name WHERE FIND_IN_SET('value',set_col)>0;
mysql> SELECT * FROM tbl_name WHERE set_col LIKE '%value%';
```

The first statement finds rows where set_col contains the value set member. The second is similar, but not the same: It finds rows where set_col contains value anywhere, even as a substring of another set member.

The following statements also are permitted:

```
mysql> SELECT * FROM tbl_name WHERE set_col & 1;
mysql> SELECT * FROM tbl_name WHERE set_col = 'val1,val2';
```

The first of these statements looks for values containing the first set member. The second looks for an exact match. Be careful with comparisons of the second type. Comparing set values to 'val1,val2'

returns different results than comparing values to `'val2,val1'`. You should specify the values in the same order they are listed in the column definition.

To determine all possible values for a `SET` column, use `SHOW COLUMNS FROM tbl_name LIKE set_col` and parse the `SET` definition in the `Type` column of the output.

In the C API, `SET` values are returned as strings. For information about using result set metadata to distinguish them from other strings, see Section 21.8.5, "C API Data Structures".

11.5 Extensions for Spatial Data

The Open Geospatial Consortium (OGC) is an international consortium of more than 250 companies, agencies, and universities participating in the development of publicly available conceptual solutions that can be useful with all kinds of applications that manage spatial data.

The Open Geospatial Consortium publishes the *OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 2: SQL option*, a document that proposes several conceptual ways for extending an SQL RDBMS to support spatial data. This specification is available from the OGC Web site at http://www.opengeospatial.org/standards/sfs.

Following the OGC specification, MySQL implements spatial extensions as a subset of the **SQL with Geometry Types** environment. This term refers to an SQL environment that has been extended with a set of geometry types. A geometry-valued SQL column is implemented as a column that has a geometry type. The specification describes a set of SQL geometry types, as well as functions on those types to create and analyze geometry values.

MySQL spatial extensions enable the generation, storage, and analysis of geographic features:

* Data types for representing spatial values

* Functions for manipulating spatial values

* Spatial indexing for improved access times to spatial columns

The data types and functions are available for `MyISAM`, `InnoDB`, `NDB`, and `ARCHIVE` tables. For indexing spatial columns, `MyISAM` supports both `SPATIAL` and non-`SPATIAL` indexes. The other storage engines support non-`SPATIAL` indexes, as described in Section 13.1.13, "CREATE INDEX Syntax".

A **geographic feature** is anything in the world that has a location. A feature can be:

* An entity. For example, a mountain, a pond, a city.

* A space. For example, town district, the tropics.

* A definable location. For example, a crossroad, as a particular place where two streets intersect.

Some documents use the term **geospatial feature** to refer to geographic features.

Geometry is another word that denotes a geographic feature. Originally the word **geometry** meant measurement of the earth. Another meaning comes from cartography, referring to the geometric features that cartographers use to map the world.

The discussion here considers these terms synonymous: **geographic feature**, **geospatial feature**, **feature**, or **geometry**. The term most commonly used is **geometry**, defined as *a point or an aggregate of points representing anything in the world that has a location*.

The following material covers these topics:

- The spatial data types implemented in MySQL model

- The basis of the spatial extensions in the OpenGIS geometry model

- Data formats for representing spatial data

- How to use spatial data in MySQL

- Use of indexing for spatial data

- MySQL differences from the OpenGIS specification

For information about functions that operate on spatial data, see Section 12.15, "Spatial Analysis Functions".

MySQL GIS Conformance and Compatibility

MySQL does not implement the following GIS features:

- Additional Metadata Views

  OpenGIS specifications propose several additional metadata views. For example, a system view named `GEOMETRY_COLUMNS` contains a description of geometry columns, one row for each geometry column in the database.

- The OpenGIS function `Length()` on `LineString` and `MultiLineString` should be called in MySQL as `GLength()`

  The problem is that there is an existing SQL function `Length()` that calculates the length of string values, and sometimes it is not possible to distinguish whether the function is called in a textual or spatial context.

Additional Resources

- The Open Geospatial Consortium publishes the *OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 2: SQL option*, a document that proposes several conceptual ways for extending an SQL RDBMS to support spatial data. The Open Geospatial Consortium (OGC) maintains a Web site at http://www.opengeospatial.org/. The specification is available there at http://www.opengeospatial.org/standards/sfs. It contains additional information relevant to the material here.

- If you have questions or concerns about the use of the spatial extensions to MySQL, you can discuss them in the GIS forum: http://forums.mysql.com/list.php?23.

11.5.1 Spatial Data Types

MySQL has data types that correspond to OpenGIS classes. Some of these types hold single geometry values:

- `GEOMETRY`

- `POINT`

- `LINESTRING`

- `POLYGON`

`GEOMETRY` can store geometry values of any type. The other single-value types (`POINT`, `LINESTRING`, and `POLYGON`) restrict their values to a particular geometry type.

The other data types hold collections of values:

- `MULTIPOINT`

- `MULTILINESTRING`

- `MULTIPOLYGON`

- `GEOMETRYCOLLECTION`

`GEOMETRYCOLLECTION` can store a collection of objects of any type. The other collection types (`MULTIPOINT`, `MULTILINESTRING`, `MULTIPOLYGON`, and `GEOMETRYCOLLECTION`) restrict collection members to those having a particular geometry type.

MySQL spatial data types have their basis in the OpenGIS geometry model, described in Section 11.5.2, "The OpenGIS Geometry Model". For examples showing how to use spatial data types in MySQL, see Section 11.5.3, "Using Spatial Data".

11.5.2 The OpenGIS Geometry Model

The set of geometry types proposed by OGC's **SQL with Geometry Types** environment is based on the **OpenGIS Geometry Model**. In this model, each geometric object has the following general properties:

- It is associated with a Spatial Reference System, which describes the coordinate space in which the object is defined.

- It belongs to some geometry class.

11.5.2.1 The Geometry Class Hierarchy

The geometry classes define a hierarchy as follows:

- `Geometry` (noninstantiable)
  - `Point` (instantiable)
  - `Curve` (noninstantiable)
    - `LineString` (instantiable)
      - `Line`
      - `LinearRing`
  - `Surface` (noninstantiable)
    - `Polygon` (instantiable)
  - `GeometryCollection` (instantiable)
    - `MultiPoint` (instantiable)
    - `MultiCurve` (noninstantiable)
      - `MultiLineString` (instantiable)

- `MultiSurface` (noninstantiable)

  - `MultiPolygon` (instantiable)

It is not possible to create objects in noninstantiable classes. It is possible to create objects in instantiable classes. All classes have properties, and instantiable classes may also have assertions (rules that define valid class instances).

`Geometry` is the base class. It is an abstract class. The instantiable subclasses of `Geometry` are restricted to zero-, one-, and two-dimensional geometric objects that exist in two-dimensional coordinate space. All instantiable geometry classes are defined so that valid instances of a geometry class are topologically closed (that is, all defined geometries include their boundary).

The base `Geometry` class has subclasses for `Point`, `Curve`, `Surface`, and `GeometryCollection`:

- `Point` represents zero-dimensional objects.

- `Curve` represents one-dimensional objects, and has subclass `LineString`, with sub-subclasses `Line` and `LinearRing`.

- `Surface` is designed for two-dimensional objects and has subclass `Polygon`.

- `GeometryCollection` has specialized zero-, one-, and two-dimensional collection classes named `MultiPoint`, `MultiLineString`, and `MultiPolygon` for modeling geometries corresponding to collections of `Points`, `LineStrings`, and `Polygons`, respectively. `MultiCurve` and `MultiSurface` are introduced as abstract superclasses that generalize the collection interfaces to handle `Curves` and `Surfaces`.

`Geometry`, `Curve`, `Surface`, `MultiCurve`, and `MultiSurface` are defined as noninstantiable classes. They define a common set of methods for their subclasses and are included for extensibility.

`Point`, `LineString`, `Polygon`, `GeometryCollection`, `MultiPoint`, `MultiLineString`, and `MultiPolygon` are instantiable classes.

11.5.2.2 Geometry Class

`Geometry` is the root class of the hierarchy. It is a noninstantiable class but has a number of properties, described in the following list, that are common to all geometry values created from any of the `Geometry` subclasses. Particular subclasses have their own specific properties, described later.

Geometry Properties

A geometry value has the following properties:

- Its **type**. Each geometry belongs to one of the instantiable classes in the hierarchy.

- Its **SRID**, or Spatial Reference Identifier. This value identifies the geometry's associated Spatial Reference System that describes the coordinate space in which the geometry object is defined.

  In MySQL, the SRID value is an integer associated with the geometry value. All calculations are done assuming Euclidean (planar) geometry. The maximum usable SRID value is $2^{32}-1$. If a larger value is given, only the lower 32 bits are used.

- Its **coordinates** in its Spatial Reference System, represented as double-precision (8-byte) numbers. All nonempty geometries include at least one pair of (X,Y) coordinates. Empty geometries contain no coordinates.

Coordinates are related to the SRID. For example, in different coordinate systems, the distance between two objects may differ even when objects have the same coordinates, because the distance on the **planar** coordinate system and the distance on the **geodetic** system (coordinates on the Earth's surface) are different things.

- Its **interior**, **boundary**, and **exterior**.

  Every geometry occupies some position in space. The exterior of a geometry is all space not occupied by the geometry. The interior is the space occupied by the geometry. The boundary is the interface between the geometry's interior and exterior.

- Its **MBR** (minimum bounding rectangle), or envelope. This is the bounding geometry, formed by the minimum and maximum (X,Y) coordinates:

```
((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
```

- Whether the value is **simple** or **nonsimple**. Geometry values of types (`LineString`, `MultiPoint`, `MultiLineString`) are either simple or nonsimple. Each type determines its own assertions for being simple or nonsimple.

- Whether the value is **closed** or **not closed**. Geometry values of types (`LineString`, `MultiString`) are either closed or not closed. Each type determines its own assertions for being closed or not closed.

- Whether the value is **empty** or **nonempty** A geometry is empty if it does not have any points. Exterior, interior, and boundary of an empty geometry are not defined (that is, they are represented by a `NULL` value). An empty geometry is defined to be always simple and has an area of 0.

- Its **dimension**. A geometry can have a dimension of −1, 0, 1, or 2:

  - −1 for an empty geometry.

  - 0 for a geometry with no length and no area.

  - 1 for a geometry with nonzero length and zero area.

  - 2 for a geometry with nonzero area.

  `Point` objects have a dimension of zero. `LineString` objects have a dimension of 1. `Polygon` objects have a dimension of 2. The dimensions of `MultiPoint`, `MultiLineString`, and `MultiPolygon` objects are the same as the dimensions of the elements they consist of.

11.5.2.3 Point Class

A `Point` is a geometry that represents a single location in coordinate space.

`Point` Examples

- Imagine a large-scale map of the world with many cities. A `Point` object could represent each city.

- On a city map, a `Point` object could represent a bus stop.

`Point` Properties

- X-coordinate value.

- Y-coordinate value.

- `Point` is defined as a zero-dimensional geometry.

- The boundary of a `Point` is the empty set.

11.5.2.4 Curve Class

A `Curve` is a one-dimensional geometry, usually represented by a sequence of points. Particular subclasses of `Curve` define the type of interpolation between points. `Curve` is a noninstantiable class.

`Curve` Properties

- A `Curve` has the coordinates of its points.

- A `Curve` is defined as a one-dimensional geometry.

- A `Curve` is simple if it does not pass through the same point twice, with the exception that a curve can still be simple if the start and end points are the same.

- A `Curve` is closed if its start point is equal to its endpoint.

- The boundary of a closed `Curve` is empty.

- The boundary of a nonclosed `Curve` consists of its two endpoints.

- A `Curve` that is simple and closed is a `LinearRing`.

11.5.2.5 LineString Class

A `LineString` is a `Curve` with linear interpolation between points.

`LineString` Examples

- On a world map, `LineString` objects could represent rivers.

- In a city map, `LineString` objects could represent streets.

`LineString` Properties

- A `LineString` has coordinates of segments, defined by each consecutive pair of points.

- A `LineString` is a `Line` if it consists of exactly two points.

- A `LineString` is a `LinearRing` if it is both closed and simple.

11.5.2.6 Surface Class

A `Surface` is a two-dimensional geometry. It is a noninstantiable class. Its only instantiable subclass is `Polygon`.

`Surface` Properties

- A `Surface` is defined as a two-dimensional geometry.

- The OpenGIS specification defines a simple `Surface` as a geometry that consists of a single "patch" that is associated with a single exterior boundary and zero or more interior boundaries.

- The boundary of a simple `Surface` is the set of closed curves corresponding to its exterior and interior boundaries.

11.5.2.7 Polygon Class

A `Polygon` is a planar `Surface` representing a multisided geometry. It is defined by a single exterior boundary and zero or more interior boundaries, where each interior boundary defines a hole in the `Polygon`.

`Polygon` Examples

- On a region map, `Polygon` objects could represent forests, districts, and so on.

`Polygon` Assertions

- The boundary of a `Polygon` consists of a set of `LinearRing` objects (that is, `LineString` objects that are both simple and closed) that make up its exterior and interior boundaries.

- A `Polygon` has no rings that cross. The rings in the boundary of a `Polygon` may intersect at a `Point`, but only as a tangent.

- A `Polygon` has no lines, spikes, or punctures.

- A `Polygon` has an interior that is a connected point set.

- A `Polygon` may have holes. The exterior of a `Polygon` with holes is not connected. Each hole defines a connected component of the exterior.

The preceding assertions make a `Polygon` a simple geometry.

11.5.2.8 GeometryCollection Class

A `GeometryCollection` is a geometry that is a collection of one or more geometries of any class.

All the elements in a `GeometryCollection` must be in the same Spatial Reference System (that is, in the same coordinate system). There are no other constraints on the elements of a `GeometryCollection`, although the subclasses of `GeometryCollection` described in the following sections may restrict membership. Restrictions may be based on:

- Element type (for example, a `MultiPoint` may contain only `Point` elements)

- Dimension

- Constraints on the degree of spatial overlap between elements

11.5.2.9 MultiPoint Class

A `MultiPoint` is a geometry collection composed of `Point` elements. The points are not connected or ordered in any way.

`MultiPoint` Examples

- On a world map, a `MultiPoint` could represent a chain of small islands.

- On a city map, a `MultiPoint` could represent the outlets for a ticket office.

`MultiPoint` Properties

- A `MultiPoint` is a zero-dimensional geometry.

- A `MultiPoint` is simple if no two of its `Point` values are equal (have identical coordinate values).

- The boundary of a `MultiPoint` is the empty set.

11.5.2.10 MultiCurve Class

A `MultiCurve` is a geometry collection composed of `Curve` elements. `MultiCurve` is a noninstantiable class.

`MultiCurve` Properties

- A `MultiCurve` is a one-dimensional geometry.

- A `MultiCurve` is simple if and only if all of its elements are simple; the only intersections between any two elements occur at points that are on the boundaries of both elements.

- A `MultiCurve` boundary is obtained by applying the "mod 2 union rule" (also known as the "odd-even rule"): A point is in the boundary of a `MultiCurve` if it is in the boundaries of an odd number of `Curve` elements.

- A `MultiCurve` is closed if all of its elements are closed.

- The boundary of a closed `MultiCurve` is always empty.

11.5.2.11 MultiLineString Class

A `MultiLineString` is a `MultiCurve` geometry collection composed of `LineString` elements.

`MultiLineString` Examples

- On a region map, a `MultiLineString` could represent a river system or a highway system.

11.5.2.12 MultiSurface Class

A `MultiSurface` is a geometry collection composed of surface elements. `MultiSurface` is a noninstantiable class. Its only instantiable subclass is `MultiPolygon`.

`MultiSurface` Assertions

- Surfaces within a `MultiSurface` have no interiors that intersect.

- Surfaces within a `MultiSurface` have boundaries that intersect at most at a finite number of points.

11.5.2.13 MultiPolygon Class

A `MultiPolygon` is a `MultiSurface` object composed of `Polygon` elements.

`MultiPolygon` Examples

- On a region map, a `MultiPolygon` could represent a system of lakes.

`MultiPolygon` Assertions

- A `MultiPolygon` has no two `Polygon` elements with interiors that intersect.

- A `MultiPolygon` has no two `Polygon` elements that cross (crossing is also forbidden by the previous assertion), or that touch at an infinite number of points.

- A `MultiPolygon` may not have cut lines, spikes, or punctures. A `MultiPolygon` is a regular, closed point set.

- A `MultiPolygon` that has more than one `Polygon` has an interior that is not connected. The number of connected components of the interior of a `MultiPolygon` is equal to the number of `Polygon` values in the `MultiPolygon`.

`MultiPolygon` Properties

- A `MultiPolygon` is a two-dimensional geometry.

- A `MultiPolygon` boundary is a set of closed curves (`LineString` values) corresponding to the boundaries of its `Polygon` elements.

- Each `Curve` in the boundary of the `MultiPolygon` is in the boundary of exactly one `Polygon` element.

- Every `Curve` in the boundary of an `Polygon` element is in the boundary of the `MultiPolygon`.

11.5.3 Using Spatial Data

This section describes how to create tables that include spatial data type columns, and how to manipulate spatial information.

11.5.3.1 Supported Spatial Data Formats

Two standard spatial data formats are used to represent geometry objects in queries:

- Well-Known Text (WKT) format

- Well-Known Binary (WKB) format

Internally, MySQL stores geometry values in a format that is not identical to either WKT or WKB format.

There are functions available to convert between different data formats; see Section 12.15.6, "Geometry Format Conversion Functions".

Well-Known Text (WKT) Format

The Well-Known Text (WKT) representation of geometry values is designed for exchanging geometry data in ASCII form. The OpenGIS specification provides a Backus-Naur grammar that specifies the formal production rules for writing WKT values (see Section 11.5, "Extensions for Spatial Data").

Examples of WKT representations of geometry objects:

- A `Point`:

```
POINT(15 20)
```

The point coordinates are specified with no separating comma. This differs from the syntax for the SQL `Point()` function, which requires a comma between the coordinates. Take care to use the syntax appropriate to the context of a given spatial operation. For example, the following statements both extract the X-coordinate from a `Point` object. The first produces the object directly using the `Point()` function. The second uses a WKT representation converted to a `Point` with `GeomFromText()`.

```
mysql> SELECT X(Point(15, 20));
+------------------+
| X(POINT(15, 20)) |
+------------------+
|               15 |
+------------------+
```

```
mysql> SELECT X(GeomFromText('POINT(15 20)'));
+--------------------------------+
| X(GeomFromText('POINT(15 20)')) |
+--------------------------------+
|                             15 |
+--------------------------------+
```

- A `LineString` with four points:

```
LINESTRING(0 0, 10 10, 20 25, 50 60)
```

The point coordinate pairs are separated by commas.

- A `Polygon` with one exterior ring and one interior ring:

```
POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))
```

- A `MultiPoint` with three `Point` values:

```
MULTIPOINT(0 0, 20 20, 60 60)
```

- A `MultiLineString` with two `LineString` values:

```
MULTILINESTRING((10 10, 20 20), (15 15, 30 15))
```

- A `MultiPolygon` with two `Polygon` values:

```
MULTIPOLYGON(((0 0,10 0,10 10,0 10,0 0)),((5 5,7 5,7 7,5 7, 5 5)))
```

- A `GeometryCollection` consisting of two `Point` values and one `LineString`:

```
GEOMETRYCOLLECTION(POINT(10 10), POINT(30 30), LINESTRING(15 15, 20 20))
```

Well-Known Binary (WKB) Format

The Well-Known Binary (WKB) representation of geometric values is used for exchanging geometry data as binary streams represented by `BLOB` values containing geometric WKB information. This format is defined by the OpenGIS specification (see Section 11.5, "Extensions for Spatial Data"). It is also defined in the ISO *SQL/MM Part 3: Spatial* standard.

WKB uses 1-byte unsigned integers, 4-byte unsigned integers, and 8-byte double-precision numbers (IEEE 754 format). A byte is eight bits.

For example, a WKB value that corresponds to `POINT(1 1)` consists of this sequence of 21 bytes, each represented by two hex digits:

```
0101000000000000000000F03F000000000000F03F
```

The sequence consists of these components:

```
Byte order:    01
WKB type:      01000000
X coordinate: 000000000000F03F
Y coordinate: 000000000000F03F
```

Component representation is as follows:

- The byte order is either 1 or 0 to indicate little-endian or big-endian storage. The little-endian and big-endian byte orders are also known as Network Data Representation (NDR) and External Data Representation (XDR), respectively.

- The WKB type is a code that indicates the geometry type. Values from 1 through 7 indicate `Point`, `LineString`, `Polygon`, `MultiPoint`, `MultiLineString`, `MultiPolygon`, and `GeometryCollection`.

- A `Point` value has X and Y coordinates, each represented as a double-precision value.

WKB values for more complex geometry values have more complex data structures, as detailed in the OpenGIS specification.

11.5.3.2 Creating Spatial Columns

MySQL provides a standard way of creating spatial columns for geometry types, for example, with `CREATE TABLE` or `ALTER TABLE`. Spatial columns are supported for `MyISAM`, `InnoDB`, `NDB`, and `ARCHIVE` tables. See also the notes about spatial indexes under Section 11.5.3.6, "Creating Spatial Indexes".

- Use the `CREATE TABLE` statement to create a table with a spatial column:

```
CREATE TABLE geom (g GEOMETRY);
```

- Use the `ALTER TABLE` statement to add or drop a spatial column to or from an existing table:

```
ALTER TABLE geom ADD pt POINT;
ALTER TABLE geom DROP pt;
```

11.5.3.3 Populating Spatial Columns

After you have created spatial columns, you can populate them with spatial data.

Values should be stored in internal geometry format, but you can convert them to that format from either Well-Known Text (WKT) or Well-Known Binary (WKB) format. The following examples demonstrate how to insert geometry values into a table by converting WKT values to internal geometry format:

- Perform the conversion directly in the `INSERT` statement:

```
INSERT INTO geom VALUES (GeomFromText('POINT(1 1)'));

SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (GeomFromText(@g));
```

- Perform the conversion prior to the `INSERT`:

```
SET @g = GeomFromText('POINT(1 1)');
INSERT INTO geom VALUES (@g);
```

The following examples insert more complex geometries into the table:

```
SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (GeomFromText(@g));
```

```
SET @g = 'POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))';
INSERT INTO geom VALUES (GeomFromText(@g));

SET @g =
'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0 0,1 1,2 2,3 3,4 4))';
INSERT INTO geom VALUES (GeomFromText(@g));
```

The preceding examples use `GeomFromText()` to create geometry values. You can also use type-specific functions:

```
SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (PointFromText(@g));

SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (LineStringFromText(@g));

SET @g = 'POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))';
INSERT INTO geom VALUES (PolygonFromText(@g));

SET @g =
'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0 0,1 1,2 2,3 3,4 4))';
INSERT INTO geom VALUES (GeomCollFromText(@g));
```

A client application program that wants to use WKB representations of geometry values is responsible for sending correctly formed WKB in queries to the server. There are several ways to satisfy this requirement. For example:

- Inserting a `POINT(1 1)` value with hex literal syntax:

```
mysql> INSERT INTO geom VALUES
    -> (GeomFromWKB(0x0101000000000000000000F03F000000000000F03F));
```

- An ODBC application can send a WKB representation, binding it to a placeholder using an argument of `BLOB` type:

```
INSERT INTO geom VALUES (GeomFromWKB(?))
```

Other programming interfaces may support a similar placeholder mechanism.

- In a C program, you can escape a binary value using `mysql_real_escape_string()` and include the result in a query string that is sent to the server. See Section 21.8.7.53, "mysql_real_escape_string()".

11.5.3.4 Fetching Spatial Data

Geometry values stored in a table can be fetched in internal format. You can also convert them to WKT or WKB format.

- Fetching spatial data in internal format:

    Fetching geometry values using internal format can be useful in table-to-table transfers:

    ```
    CREATE TABLE geom2 (g GEOMETRY) SELECT g FROM geom;
    ```

- Fetching spatial data in WKT format:

    The `AsText()` function converts a geometry from internal format to a WKT string.

```
SELECT AsText(g) FROM geom;
```

- Fetching spatial data in WKB format:

The `AsBinary()` function converts a geometry from internal format to a `BLOB` containing the WKB value.

```
SELECT AsBinary(g) FROM geom;
```

11.5.3.5 Optimizing Spatial Analysis

For `MyISAM` tables, search operations in columns containing spatial data can be optimized using `SPATIAL` indexes. The most typical operations are:

- Point queries that search for all objects that contain a given point

- Region queries that search for all objects that overlap a given region

MySQL uses **R-Trees with quadratic splitting** for `SPATIAL` indexes on spatial columns. A `SPATIAL` index is built using the minimum bounding rectangle (MBR) of a geometry. For most geometries, the MBR is a minimum rectangle that surrounds the geometries. For a horizontal or a vertical linestring, the MBR is a rectangle degenerated into the linestring. For a point, the MBR is a rectangle degenerated into the point.

It is also possible to create normal indexes on spatial columns. In a non-`SPATIAL` index, you must declare a prefix for any spatial column except for `POINT` columns.

`MyISAM` supports both `SPATIAL` and non-`SPATIAL` indexes. Other storage engines support non-`SPATIAL` indexes, as described in Section 13.1.13, "CREATE INDEX Syntax".

11.5.3.6 Creating Spatial Indexes

For `MyISAM` tables, MySQL can create spatial indexes using syntax similar to that for creating regular indexes, but using the `SPATIAL` keyword. Columns in spatial indexes must be declared `NOT NULL`. The following examples demonstrate how to create spatial indexes:

- With `CREATE TABLE`:

```
CREATE TABLE geom (g GEOMETRY NOT NULL, SPATIAL INDEX(g)) ENGINE=MyISAM;
```

- With `ALTER TABLE`:

```
ALTER TABLE geom ADD SPATIAL INDEX(g);
```

- With `CREATE INDEX`:

```
CREATE SPATIAL INDEX sp_index ON geom (g);
```

`SPATIAL INDEX` creates an R-tree index. For storage engines that support nonspatial indexing of spatial columns, the engine creates a B-tree index. A B-tree index on spatial values is useful for exact-value lookups, but not for range scans.

For more information on indexing spatial columns, see Section 13.1.13, "CREATE INDEX Syntax".

To drop spatial indexes, use `ALTER TABLE` or `DROP INDEX`:

- With `ALTER TABLE`:

```
ALTER TABLE geom DROP INDEX g;
```

- With `DROP INDEX`:

```
DROP INDEX sp_index ON geom;
```

Example: Suppose that a table `geom` contains more than 32,000 geometries, which are stored in the column `g` of type `GEOMETRY`. The table also has an `AUTO_INCREMENT` column `fid` for storing object ID values.

```
mysql> DESCRIBE geom;
+-------+----------+------+-----+---------+----------------+
| Field | Type     | Null | Key | Default | Extra          |
+-------+----------+------+-----+---------+----------------+
| fid   | int(11)  |      | PRI | NULL    | auto_increment |
| g     | geometry |      |     |         |                |
+-------+----------+------+-----+---------+----------------+
2 rows in set (0.00 sec)

mysql> SELECT COUNT(*) FROM geom;
+----------+
| count(*) |
+----------+
|    32376 |
+----------+
1 row in set (0.00 sec)
```

To add a spatial index on the column `g`, use this statement:

```
mysql> ALTER TABLE geom ADD SPATIAL INDEX(g) ENGINE=MyISAM;
Query OK, 32376 rows affected (4.05 sec)
Records: 32376  Duplicates: 0  Warnings: 0
```

11.5.3.7 Using Spatial Indexes

The optimizer investigates whether available spatial indexes can be involved in the search for queries that use a function such as `MBRContains()` or `MBRWithin()` in the `WHERE` clause. The following query finds all objects that are in the given rectangle:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
                 30000 16000,
                 30000 15000))';
mysql> SELECT fid,AsText(g) FROM geom WHERE
    -> MBRContains(GeomFromText(@poly),g);
+-----+-----------------------------------------------------------+
| fid | AsText(g)                                                 |
+-----+-----------------------------------------------------------+
|  21 | LINESTRING(30350.4 15828.8,30350.6 15845,30333.8 15845,30 ... |
|  22 | LINESTRING(30350.6 15871.4,30350.6 15887.8,30334 15887.8, ... |
|  23 | LINESTRING(30350.6 15914.2,30350.6 15930.4,30334 15930.4, ... |
|  24 | LINESTRING(30290.2 15823,30290.2 15839.4,30273.4 15839.4, ... |
|  25 | LINESTRING(30291.4 15866.2,30291.6 15882.4,30274.8 15882. ... |
|  26 | LINESTRING(30291.6 15918.2,30291.6 15934.4,30275 15934.4, ... |
| 249 | LINESTRING(30337.8 15938.6,30337.8 15946.8,30320.4 15946. ... |
|   1 | LINESTRING(30250.4 15129.2,30248.8 15138.4,30238.2 15136. ... |
|   2 | LINESTRING(30220.2 15122.8,30217.2 15137.8,30207.6 15136, ... |
```

```
|     3 | LINESTRING(30179 15114.4,30176.6 15129.4,30167 15128,3016 ... |
|     4 | LINESTRING(30155.2 15121.4,30140.4 15118.6,30142 15109,30 ... |
|     5 | LINESTRING(30192.4 15085,30177.6 15082.2,30179.2 15072.4, ... |
|     6 | LINESTRING(30244 15087,30229 15086.2,30229.4 15076.4,3024 ... |
|     7 | LINESTRING(30200.6 15059.4,30185.6 15058.6,30186 15048.8, ... |
|    10 | LINESTRING(30179.6 15017.8,30181 15002.8,30190.8 15003.6, ... |
|    11 | LINESTRING(30154.2 15000.4,30168.6 15004.8,30166 15014.2, ... |
|    13 | LINESTRING(30105 15065.8,30108.4 15050.8,30118 15053,3011 ... |
|   154 | LINESTRING(30276.2 15143.8,30261.4 15141,30263 15131.4,30 ... |
|   155 | LINESTRING(30269.8 15084,30269.4 15093.4,30258.6 15093,30 ... |
|   157 | LINESTRING(30128.2 15011,30113.2 15010.2,30113.6 15000.4, ... |
+-----+---------------------------------------------------------------+
20 rows in set (0.00 sec)
```

Use EXPLAIN to check the way this query is executed:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
                 30000 16000,
                 30000 15000))';
mysql> EXPLAIN SELECT fid,AsText(g) FROM geom WHERE
    -> MBRContains(GeomFromText(@poly),g)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: geom
         type: range
possible_keys: g
          key: g
      key_len: 32
          ref: NULL
         rows: 50
        Extra: Using where
1 row in set (0.00 sec)
```

Check what would happen without a spatial index:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
                 30000 16000,
                 30000 15000))';
mysql> EXPLAIN SELECT fid,AsText(g) FROM g IGNORE INDEX (g) WHERE
    -> MBRContains(GeomFromText(@poly),g)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: geom
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 32376
        Extra: Using where
1 row in set (0.00 sec)
```

Executing the SELECT statement without the spatial index yields the same result but causes the execution time to rise from 0.00 seconds to 0.46 seconds:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                31000 15000,
                31000 16000,
                30000 16000,
                30000 15000))';
mysql> SELECT fid,AsText(g) FROM geom IGNORE INDEX (g) WHERE
    -> MBRContains(GeomFromText(@poly),g);
+-----+--------------------------------------------------------------+
| fid | AsText(g)                                                    |
+-----+--------------------------------------------------------------+
|   1 | LINESTRING(30250.4 15129.2,30248.8 15138.4,30238.2 15136. ... |
|   2 | LINESTRING(30220.2 15122.8,30217.2 15137.8,30207.6 15136, ... |
|   3 | LINESTRING(30179 15114.4,30176.6 15129.4,30167 15128,3016 ... |
|   4 | LINESTRING(30155.2 15121.4,30140.4 15118.6,30142 15109,30 ... |
|   5 | LINESTRING(30192.4 15085,30177.6 15082.2,30179.2 15072.4, ... |
|   6 | LINESTRING(30244 15087,30229 15086.2,30229.4 15076.4,3024 ... |
|   7 | LINESTRING(30200.6 15059.4,30185.6 15058.6,30186 15048.8, ... |
|  10 | LINESTRING(30179.6 15017.8,30181 15002.8,30190.8 15003.6, ... |
|  11 | LINESTRING(30154.2 15000.4,30168.6 15004.8,30166 15014.2, ... |
|  13 | LINESTRING(30105 15065.8,30108.4 15050.8,30118 15053,3011 ... |
|  21 | LINESTRING(30350.4 15828.8,30350.6 15845,30333.8 15845,30 ... |
|  22 | LINESTRING(30350.6 15871.4,30350.6 15887.8,30334 15887.8, ... |
|  23 | LINESTRING(30350.6 15914.2,30350.6 15930.4,30334 15930.4, ... |
|  24 | LINESTRING(30290.2 15823,30290.2 15839.4,30273.4 15839.4, ... |
|  25 | LINESTRING(30291.4 15866.2,30291.6 15882.4,30274.8 15882. ... |
|  26 | LINESTRING(30291.6 15918.2,30291.6 15934.4,30275 15934.4, ... |
| 154 | LINESTRING(30276.2 15143.8,30261.4 15141,30263 15131.4,30 ... |
| 155 | LINESTRING(30269.8 15084,30269.4 15093.4,30258.6 15093,30 ... |
| 157 | LINESTRING(30128.2 15011,30113.2 15010.2,30113.6 15000.4, ... |
| 249 | LINESTRING(30337.8 15938.6,30337.8 15946.8,30320.4 15946. ... |
+-----+--------------------------------------------------------------+
20 rows in set (0.46 sec)
```

11.6 Data Type Default Values

The `DEFAULT value` clause in a data type specification indicates a default value for a column. With one exception, the default value must be a constant; it cannot be a function or an expression. This means, for example, that you cannot set the default for a date column to be the value of a function such as `NOW()` or `CURRENT_DATE`. The exception is that you can specify `CURRENT_TIMESTAMP` as the default for a `TIMESTAMP` column. See Section 11.3.5, "Automatic Initialization and Updating for TIMESTAMP".

`BLOB` and `TEXT` columns cannot be assigned a default value.

If a column definition includes no explicit `DEFAULT` value, MySQL determines the default value as follows:

If the column can take `NULL` as a value, the column is defined with an explicit `DEFAULT NULL` clause.

If the column cannot take `NULL` as the value, MySQL defines the column with no explicit `DEFAULT` clause. Exception: If the column is defined as part of a `PRIMARY KEY` but not explicitly as `NOT NULL`, MySQL creates it as a `NOT NULL` column (because `PRIMARY KEY` columns must be `NOT NULL`), but also assigns it a `DEFAULT` clause using the implicit default value. To prevent this, include an explicit `NOT NULL` in the definition of any `PRIMARY KEY` column.

For data entry into a `NOT NULL` column that has no explicit `DEFAULT` clause, if an `INSERT` or `REPLACE` statement includes no value for the column, or an `UPDATE` statement sets the column to `NULL`, MySQL handles the column according to the SQL mode in effect at the time:

• If strict SQL mode is enabled, an error occurs for transactional tables and the statement is rolled back. For nontransactional tables, an error occurs, but if this happens for the second or subsequent row of a multiple-row statement, the preceding rows will have been inserted.

- If strict mode is not enabled, MySQL sets the column to the implicit default value for the column data type.

Suppose that a table `t` is defined as follows:

```
CREATE TABLE t (i INT NOT NULL);
```

In this case, `i` has no explicit default, so in strict mode each of the following statements produce an error and no row is inserted. When not using strict mode, only the third statement produces an error; the implicit default is inserted for the first two statements, but the third fails because `DEFAULT(i)` cannot produce a value:

```
INSERT INTO t VALUES();
INSERT INTO t VALUES(DEFAULT);
INSERT INTO t VALUES(DEFAULT(i));
```

See Section 5.1.7, "Server SQL Modes".

For a given table, you can use the `SHOW CREATE TABLE` statement to see which columns have an explicit `DEFAULT` clause.

Implicit defaults are defined as follows:

- For numeric types, the default is `0`, with the exception that for integer or floating-point types declared with the `AUTO_INCREMENT` attribute, the default is the next value in the sequence.

- For date and time types other than `TIMESTAMP`, the default is the appropriate "zero" value for the type. For the first `TIMESTAMP` column in a table, the default value is the current date and time. See Section 11.3, "Date and Time Types".

- For string types other than `ENUM`, the default value is the empty string. For `ENUM`, the default is the first enumeration value.

`SERIAL DEFAULT VALUE` in the definition of an integer column is an alias for `NOT NULL AUTO_INCREMENT UNIQUE`.

11.7 Data Type Storage Requirements

The storage requirements for data vary, according to the storage engine being used for the table in question. Different storage engines use different methods for recording the raw data and different data types. In addition, some engines may compress the information in a given row, either on a column or entire row basis, making calculation of the storage requirements for a given table or column structure.

However, all storage engines must communicate and exchange information on a given row within a table using the same structure, and this information is consistent, irrespective of the storage engine used to write the information to disk.

This sections includes some guideliness and information for the storage requirements for each data type supported by MySQL, including details for the internal format and the sizes used by storage engines that used a fixed size representation for different types. Information is listed by category or storage engine.

The internal representation of a table has a maximum row size of 65,535 bytes, even if the storage engine is capable of supporting larger rows. This figure excludes `BLOB` or `TEXT` columns, which contribute only 9 to 12 bytes toward this size. For `BLOB` and `TEXT` data, the information is stored internally in a different

area of memory than the row buffer. Different storage engines handle the allocation and storage of this data in different ways, according to the method they use for handling the corresponding types. For more information, see Chapter 14, *Storage Engines*, and Section C.7.4, "Limits on Table Column Count and Row Size".

Storage Requirements for InnoDB Tables

See Physical Row Structure for information about storage requirements for `InnoDB` tables.

Storage Requirements for NDBCLUSTER Tables

> **Important**
>
> For tables using the `NDBCLUSTER` storage engine, there is the factor of *4-byte alignment* to be taken into account when calculating storage requirements. This means that all `NDB` data storage is done in multiples of 4 bytes. Thus, a column value that would take 15 bytes in a table using a storage engine other than `NDB` requires 16 bytes in an `NDB` table. This requirement applies in addition to any other considerations that are discussed in this section. For example, in `NDBCLUSTER` tables, the `TINYINT`, `SMALLINT`, `MEDIUMINT`, and `INTEGER` (`INT`) column types each require 4 bytes storage per record due to the alignment factor.
>
> An exception to this rule is the `BIT` type, which is *not* 4-byte aligned. In MySQL Cluster tables, a `BIT(M)` column takes M bits of storage space. However, if a table definition contains 1 or more `BIT` columns (up to 32 `BIT` columns), then `NDBCLUSTER` reserves 4 bytes (32 bits) per row for these. If a table definition contains more than 32 `BIT` columns (up to 64 such columns), then `NDBCLUSTER` reserves 8 bytes (that is, 64 bits) per row.
>
> In addition, while a `NULL` itself does not require any storage space, `NDBCLUSTER` reserves 4 bytes per row if the table definition contains any columns defined as `NULL`, up to 32 `NULL` columns. (If a MySQL Cluster table is defined with more than 32 `NULL` columns up to 64 `NULL` columns, then 8 bytes per row is reserved.)

When calculating storage requirements for MySQL Cluster tables, you must also remember that every table using the `NDBCLUSTER` storage engine requires a primary key; if no primary key is defined by the user, then a "hidden" primary key will be created by `NDB`. This hidden primary key consumes 31-35 bytes per table record.

You may find the `ndb_size.pl` utility to be useful for estimating `NDB` storage requirements. This Perl script connects to a current MySQL (non-Cluster) database and creates a report on how much space that database would require if it used the `NDBCLUSTER` storage engine. See Section 17.4.24, "`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator", for more information.

Storage Requirements for Numeric Types

Data Type	Storage Required
`TINYINT`	1 byte
`SMALLINT`	2 bytes
`MEDIUMINT`	3 bytes
`INT`, `INTEGER`	4 bytes
`BIGINT`	8 bytes

Data Type	Storage Required
FLOAT(*p*)	4 bytes if 0 <= *p* <= 24, 8 bytes if 25 <= *p* <= 53
FLOAT	4 bytes
DOUBLE [PRECISION], REAL	8 bytes
DECIMAL(*M*,*D*), NUMERIC(*M*,*D*)	Varies; see following discussion
BIT(*M*)	approximately (*M*+7)/8 bytes

Values for DECIMAL (and NUMERIC) columns are represented using a binary format that packs nine decimal (base 10) digits into four bytes. Storage for the integer and fractional parts of each value are determined separately. Each multiple of nine digits requires four bytes, and the "leftover" digits require some fraction of four bytes. The storage required for excess digits is given by the following table.

Leftover Digits	Number of Bytes
0	0
1	1
2	1
3	2
4	2
5	3
6	3
7	4
8	4

Storage Requirements for Date and Time Types

Data Type	Storage Required
DATE	3 bytes
TIME	3 bytes
DATETIME	8 bytes
TIMESTAMP	4 bytes
YEAR	1 byte

For details about internal representation of temporal values, see MySQL Internals: Important Algorithms and Structures.

Storage Requirements for String Types

In the following table, *M* represents the declared column length in characters for nonbinary string types and bytes for binary string types. *L* represents the actual length in bytes of a given string value.

Data Type	Storage Required
CHAR(*M*)	*M* × *w* bytes, 0 <= *M* <= 255, where *w* is the number of bytes required for the maximum-length character in the character set. See Physical Row Structure for information about CHAR data type storage requirements for InnoDB tables.

Data Type	Storage Required
`BINARY(M)`	M bytes, $0 <= M <= 255$
`VARCHAR(M)`, `VARBINARY(M)`	L + 1 bytes if column values require 0 − 255 bytes, L + 2 bytes if values may require more than 255 bytes
`TINYBLOB`, `TINYTEXT`	L + 1 bytes, where $L < 2^8$
`BLOB`, `TEXT`	L + 2 bytes, where $L < 2^{16}$
`MEDIUMBLOB`, `MEDIUMTEXT`	L + 3 bytes, where $L < 2^{24}$
`LONGBLOB`, `LONGTEXT`	L + 4 bytes, where $L < 2^{32}$
`ENUM('value1','value2',...)`	1 or 2 bytes, depending on the number of enumeration values (65,535 values maximum)
`SET('value1','value2',...)`	1, 2, 3, 4, or 8 bytes, depending on the number of set members (64 members maximum)

Variable-length string types are stored using a length prefix plus data. The length prefix requires from one to four bytes depending on the data type, and the value of the prefix is L (the byte length of the string). For example, storage for a `MEDIUMTEXT` value requires L bytes to store the value plus three bytes to store the length of the value.

To calculate the number of bytes used to store a particular `CHAR`, `VARCHAR`, or `TEXT` column value, you must take into account the character set used for that column and whether the value contains multibyte characters. In particular, when using the `utf8` Unicode character set, you must keep in mind that not all characters use the same number of bytes and can require up to three bytes per character. For a breakdown of the storage used for different categories of `utf8` characters, see Section 10.1.10, "Unicode Support".

`VARCHAR`, `VARBINARY`, and the `BLOB` and `TEXT` types are variable-length types. For each, the storage requirements depend on these factors:

- The actual length of the column value

- The column's maximum possible length

- The character set used for the column, because some character sets contain multibyte characters

For example, a `VARCHAR(255)` column can hold a string with a maximum length of 255 characters. Assuming that the column uses the `latin1` character set (one byte per character), the actual storage required is the length of the string (L), plus one byte to record the length of the string. For the string `'abcd'`, L is 4 and the storage requirement is five bytes. If the same column is instead declared to use the `ucs2` double-byte character set, the storage requirement is 10 bytes: The length of `'abcd'` is eight bytes and the column requires two bytes to store lengths because the maximum length is greater than 255 (up to 510 bytes).

The effective maximum number of *bytes* that can be stored in a `VARCHAR` or `VARBINARY` column is subject to the maximum row size of 65,535 bytes, which is shared among all columns. For a `VARCHAR` column that stores multibyte characters, the effective maximum number of *characters* is less. For example, `utf8` characters can require up to three bytes per character, so a `VARCHAR` column that uses the `utf8` character set can be declared to be a maximum of 21,844 characters. See Section C.7.4, "Limits on Table Column Count and Row Size".

The `NDBCLUSTER` storage engine in MySQL 5.1 supports variable-width columns. This means that a `VARCHAR` column in a MySQL Cluster table requires the same amount of storage as it would using any other storage engine, with the exception that such values are 4-byte aligned. Thus, the string `'abcd'`

stored in a `VARCHAR(50)` column using the `latin1` character set requires 8 bytes (rather than 5 bytes for the same column value in a `MyISAM` table). This represents a change in behavior from earlier versions of `NDBCLUSTER`, where a `VARCHAR(50)` column would require 52 bytes storage per record regardless of the length of the string being stored.

`TEXT` and `BLOB` columns are implemented differently in the NDB Cluster storage engine, wherein each row in a `TEXT` column is made up of two separate parts. One of these is of fixed size (256 bytes), and is actually stored in the original table. The other consists of any data in excess of 256 bytes, which is stored in a hidden table. The rows in this second table are always 2,000 bytes long. This means that the size of a `TEXT` column is 256 if $size$ <= 256 (where $size$ represents the size of the row); otherwise, the size is 256 + $size$ + (2000 − ($size$ − 256) % 2000).

The size of an `ENUM` object is determined by the number of different enumeration values. One byte is used for enumerations with up to 255 possible values. Two bytes are used for enumerations having between 256 and 65,535 possible values. See Section 11.4.4, "The ENUM Type".

The size of a `SET` object is determined by the number of different set members. If the set size is N, the object occupies `(N+7)/8` bytes, rounded up to 1, 2, 3, 4, or 8 bytes. A `SET` can have a maximum of 64 members. See Section 11.4.5, "The SET Type".

11.8 Choosing the Right Type for a Column

For optimum storage, you should try to use the most precise type in all cases. For example, if an integer column is used for values in the range from `1` to `99999`, `MEDIUMINT UNSIGNED` is the best type. Of the types that represent all the required values, this type uses the least amount of storage.

All basic calculations (`+`, `−`, `*`, and `/`) with `DECIMAL` columns are done with precision of 65 decimal (base 10) digits. See Section 11.1.1, "Numeric Type Overview".

If accuracy is not too important or if speed is the highest priority, the `DOUBLE` type may be good enough. For high precision, you can always convert to a fixed-point type stored in a `BIGINT`. This enables you to do all calculations with 64-bit integers and then convert results back to floating-point values as necessary.

`PROCEDURE ANALYSE` can be used to obtain suggestions for optimal column data types. For more information, see Section 8.4.2.4, "Using PROCEDURE ANALYSE".

11.9 Using Data Types from Other Database Engines

To facilitate the use of code written for SQL implementations from other vendors, MySQL maps data types as shown in the following table. These mappings make it easier to import table definitions from other database systems into MySQL.

Other Vendor Type	MySQL Type
`BOOL`	`TINYINT`
`BOOLEAN`	`TINYINT`
`CHARACTER VARYING(M)`	`VARCHAR(M)`
`FIXED`	`DECIMAL`
`FLOAT4`	`FLOAT`
`FLOAT8`	`DOUBLE`
`INT1`	`TINYINT`
`INT2`	`SMALLINT`

Other Vendor Type	MySQL Type
INT3	MEDIUMINT
INT4	INT
INT8	BIGINT
LONG VARBINARY	MEDIUMBLOB
LONG VARCHAR	MEDIUMTEXT
LONG	MEDIUMTEXT
MIDDLEINT	MEDIUMINT
NUMERIC	DECIMAL

Data type mapping occurs at table creation time, after which the original type specifications are discarded. If you create a table with types used by other vendors and then issue a DESCRIBE *tbl_name* statement, MySQL reports the table structure using the equivalent MySQL types. For example:

```
mysql> CREATE TABLE t (a BOOL, b FLOAT8, c LONG VARCHAR, d NUMERIC);
Query OK, 0 rows affected (0.00 sec)

mysql> DESCRIBE t;
+-------+--------------+------+-----+---------+-------+
| Field | Type         | Null | Key | Default | Extra |
+-------+--------------+------+-----+---------+-------+
| a     | tinyint(1)   | YES  |     | NULL    |       |
| b     | double       | YES  |     | NULL    |       |
| c     | mediumtext   | YES  |     | NULL    |       |
| d     | decimal(10,0)| YES  |     | NULL    |       |
+-------+--------------+------+-----+---------+-------+
4 rows in set (0.01 sec)
```

Chapter 12 Functions and Operators

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Expressions can be used at several points in SQL statements, such as in the `ORDER BY` or `HAVING` clauses of `SELECT` statements, in the `WHERE` clause of a `SELECT`, `DELETE`, or `UPDATE` statement, or in `SET` statements. Expressions can be written using literal values, column values, `NULL`, built-in functions, stored functions, user-defined functions, and operators. This chapter describes the functions and operators that are permitted for writing expressions in MySQL. Instructions for writing stored functions and user-defined functions are given in Section 19.2, "Using Stored Routines (Procedures and Functions)", and Section 22.3, "Adding New Functions to MySQL". See Section 9.2.4, "Function Name Parsing and Resolution", for the rules describing how the server interprets references to different kinds of functions.

An expression that contains `NULL` always produces a `NULL` value unless otherwise indicated in the documentation for a particular function or operator.

> **Note**
>
> By default, there must be no whitespace between a function name and the parenthesis following it. This helps the MySQL parser distinguish between function calls and references to tables or columns that happen to have the same name as a function. However, spaces around function arguments are permitted.

You can tell the MySQL server to accept spaces after function names by starting it with the `--sql-mode=IGNORE_SPACE` option. (See Section 5.1.7, "Server SQL Modes".) Individual client programs can request this behavior by using the `CLIENT_IGNORE_SPACE` option for `mysql_real_connect()`. In either case, all function names become reserved words.

For the sake of brevity, most examples in this chapter display the output from the `mysql` program in abbreviated form. Rather than showing examples in this format:

```
mysql> SELECT MOD(29,9);
+-----------+
| mod(29,9) |
+-----------+
|         2 |
+-----------+
1 rows in set (0.00 sec)
```

This format is used instead:

```
mysql> SELECT MOD(29,9);
        -> 2
```

12.1 Function and Operator Reference

Table 12.1 Functions/Operators

Name	Description
ABS()	Return the absolute value
ACOS()	Return the arc cosine
ADDDATE()	Add time values (intervals) to a date value
ADDTIME()	Add time
AES_DECRYPT()	Decrypt using AES
AES_ENCRYPT()	Encrypt using AES

Name	Description
`AND, &&`	Logical AND
`Area()`	Return Polygon or MultiPolygon area
`AsBinary(), AsWKB()`	Convert from internal geometry format to WKB
`ASCII()`	Return numeric value of left-most character
`ASIN()`	Return the arc sine
`=`	Assign a value (as part of a `SET` statement, or as part of the `SET` clause in an `UPDATE` statement)
`:=`	Assign a value
`AsText(), AsWKT()`	Convert from internal geometry format to WKT
`ATAN()`	Return the arc tangent
`ATAN2(), ATAN()`	Return the arc tangent of the two arguments
`AVG()`	Return the average value of the argument
`BENCHMARK()`	Repeatedly execute an expression
`BETWEEN ... AND ...`	Check whether a value is within a range of values
`BIN()`	Return a string containing binary representation of a number
`BINARY`	Cast a string to a binary string
`BIT_AND()`	Return bitwise AND
`BIT_COUNT()`	Return the number of bits that are set
`BIT_LENGTH()`	Return length of argument in bits
`BIT_OR()`	Return bitwise OR
`BIT_XOR()`	Return bitwise XOR
`&`	Bitwise AND
`~`	Bitwise inversion
`|`	Bitwise OR
`^`	Bitwise XOR
`CASE`	Case operator
`CAST()`	Cast a value as a certain type
`CEIL()`	Return the smallest integer value not less than the argument
`CEILING()`	Return the smallest integer value not less than the argument
`Centroid()`	Return centroid as a point
`CHAR()`	Return the character for each integer passed
`CHAR_LENGTH()`	Return number of characters in argument
`CHARACTER_LENGTH()`	Synonym for CHAR_LENGTH()
`CHARSET()`	Return the character set of the argument
`COALESCE()`	Return the first non-NULL argument
`COERCIBILITY()`	Return the collation coercibility value of the string argument
`COLLATION()`	Return the collation of the string argument
`COMPRESS()`	Return result as a binary string

Name	Description
CONCAT()	Return concatenated string
CONCAT_WS()	Return concatenate with separator
CONNECTION_ID()	Return the connection ID (thread ID) for the connection
Contains()	Whether MBR of one geometry contains MBR of another
CONV()	Convert numbers between different number bases
CONVERT()	Cast a value as a certain type
CONVERT_TZ()	Convert from one timezone to another
COS()	Return the cosine
COT()	Return the cotangent
COUNT()	Return a count of the number of rows returned
COUNT(DISTINCT)	Return the count of a number of different values
CRC32()	Compute a cyclic redundancy check value
Crosses()	Whether one geometry crosses another
CURDATE()	Return the current date
CURRENT_DATE(), CURRENT_DATE	Synonyms for CURDATE()
CURRENT_TIME(), CURRENT_TIME	Synonyms for CURTIME()
CURRENT_TIMESTAMP(), CURRENT_TIMESTAMP	Synonyms for NOW()
CURRENT_USER(), CURRENT_USER	The authenticated user name and host name
CURTIME()	Return the current time
DATABASE()	Return the default (current) database name
DATE()	Extract the date part of a date or datetime expression
DATE_ADD()	Add time values (intervals) to a date value
DATE_FORMAT()	Format date as specified
DATE_SUB()	Subtract a time value (interval) from a date
DATEDIFF()	Subtract two dates
DAY()	Synonym for DAYOFMONTH()
DAYNAME()	Return the name of the weekday
DAYOFMONTH()	Return the day of the month (0-31)
DAYOFWEEK()	Return the weekday index of the argument
DAYOFYEAR()	Return the day of the year (1-366)
DECODE()	Decodes a string encrypted using ENCODE()
DEFAULT()	Return the default value for a table column
DEGREES()	Convert radians to degrees
DES_DECRYPT()	Decrypt a string
DES_ENCRYPT()	Encrypt a string
Dimension()	Dimension of geometry
Disjoint()	Whether MBRs of two geometries are disjoint

Name	Description
DIV	Integer division
/	Division operator
ELT()	Return string at index number
ENCODE()	Encode a string
ENCRYPT()	Encrypt a string
EndPoint()	End Point of LineString
Envelope()	Return MBR of geometry
=	Equal operator
<=>	NULL-safe equal to operator
Equals()	Whether MBRs of two geometries are equal
EXP()	Raise to the power of
EXPORT_SET()	Return a string such that for every bit set in the value bits, you get an on string and for every unset bit, you get an off string
ExteriorRing()	Return exterior ring of Polygon
EXTRACT()	Extract part of a date
ExtractValue()	Extracts a value from an XML string using XPath notation
FIELD()	Return the index (position) of the first argument in the subsequent arguments
FIND_IN_SET()	Return the index position of the first argument within the second argument
FLOOR()	Return the largest integer value not greater than the argument
FORMAT()	Return a number formatted to specified number of decimal places
FOUND_ROWS()	For a SELECT with a LIMIT clause, the number of rows that would be returned were there no LIMIT clause
FROM_DAYS()	Convert a day number to a date
FROM_UNIXTIME()	Format UNIX timestamp as a date
GeomCollFromText(), GeometryCollectionFromText()	Return geometry collection from WKT
GeomCollFromWKB(), GeometryCollectionFromWKB()	Return geometry collection from WKB
GeometryCollection()	Construct geometry collection from geometries
GeometryN()	Return N-th geometry from geometry collection
GeometryType()	Return name of geometry type
GeomFromText(), GeometryFromText()	Return geometry from WKT
GeomFromWKB(), GeometryFromWKB()	Return geometry from WKB
GET_FORMAT()	Return a date format string
GET_LOCK()	Get a named lock

Name	Description
GLength()	Return length of LineString
>	Greater than operator
>=	Greater than or equal operator
GREATEST()	Return the largest argument
GROUP_CONCAT()	Return a concatenated string
HEX()	Return a hexadecimal representation of a decimal or string value
HOUR()	Extract the hour
IF()	If/else construct
IFNULL()	Null if/else construct
IN()	Check whether a value is within a set of values
INET_ATON()	Return the numeric value of an IP address
INET_NTOA()	Return the IP address from a numeric value
INSERT()	Insert a substring at the specified position up to the specified number of characters
INSTR()	Return the index of the first occurrence of substring
InteriorRingN()	Return N-th interior ring of Polygon
Intersects()	Whether MBRs of two geometries intersect
INTERVAL()	Return the index of the argument that is less than the first argument
IS	Test a value against a boolean
IS_FREE_LOCK()	Whether the named lock is free
IS NOT	Test a value against a boolean
IS NOT NULL	NOT NULL value test
IS NULL	NULL value test
IS_USED_LOCK()	Whether the named lock is in use; return connection identifier if true
IsClosed()	Whether a geometry is closed and simple
IsEmpty()	Placeholder function
ISNULL()	Test whether the argument is NULL
IsSimple()	Whether a geometry is simple
LAST_DAY	Return the last day of the month for the argument
LAST_INSERT_ID()	Value of the AUTOINCREMENT column for the last INSERT
LCASE()	Synonym for LOWER()
LEAST()	Return the smallest argument
LEFT()	Return the leftmost number of characters as specified
<<	Left shift
LENGTH()	Return the length of a string in bytes
<	Less than operator

Name	Description
`<=`	Less than or equal operator
`LIKE`	Simple pattern matching
`LineFromText(), LineStringFromText()`	Construct LineString from WKT
`LineFromWKB(), LineStringFromWKB()`	Construct LineString from WKB
`LineString()`	Construct LineString from Point values
`LN()`	Return the natural logarithm of the argument
`LOAD_FILE()`	Load the named file
`LOCALTIME(), LOCALTIME`	Synonym for NOW()
`LOCALTIMESTAMP, LOCALTIMESTAMP()`	Synonym for NOW()
`LOCATE()`	Return the position of the first occurrence of substring
`LOG()`	Return the natural logarithm of the first argument
`LOG10()`	Return the base-10 logarithm of the argument
`LOG2()`	Return the base-2 logarithm of the argument
`LOWER()`	Return the argument in lowercase
`LPAD()`	Return the string argument, left-padded with the specified string
`LTRIM()`	Remove leading spaces
`MAKE_SET()`	Return a set of comma-separated strings that have the corresponding bit in bits set
`MAKEDATE()`	Create a date from the year and day of year
`MAKETIME()`	Create time from hour, minute, second
`MASTER_POS_WAIT()`	Block until the slave has read and applied all updates up to the specified position
`MATCH`	Perform full-text search
`MAX()`	Return the maximum value
`MBRContains()`	Whether MBR of one geometry contains MBR of another
`MBRDisjoint()`	Whether MBRs of two geometries are disjoint
`MBREqual()`	Whether MBRs of two geometries are equal
`MBRIntersects()`	Whether MBRs of two geometries intersect
`MBROverlaps()`	Whether MBRs of two geometries overlap
`MBRTouches()`	Whether MBRs of two geometries touch
`MBRWithin()`	Whether MBR of one geometry is within MBR of another
`MD5()`	Calculate MD5 checksum
`MICROSECOND()`	Return the microseconds from argument
`MID()`	Return a substring starting from the specified position
`MIN()`	Return the minimum value

Name	Description
`-`	Minus operator
`MINUTE()`	Return the minute from the argument
`MLineFromText()`, `MultiLineStringFromText()`	Construct MultiLineString from WKT
`MLineFromWKB()`, `MultiLineStringFromWKB()`	Construct MultiLineString from WKB
`MOD()`	Return the remainder
`%, MOD`	Modulo operator
`MONTH()`	Return the month from the date passed
`MONTHNAME()`	Return the name of the month
`MPointFromText()`, `MultiPointFromText()`	Construct MultiPoint from WKT
`MPointFromWKB()`, `MultiPointFromWKB()`	Construct MultiPoint from WKB
`MPolyFromText()`, `MultiPolygonFromText()`	Construct MultiPolygon from WKT
`MPolyFromWKB()`, `MultiPolygonFromWKB()`	Construct MultiPolygon from WKB
`MultiLineString()`	Contruct MultiLineString from LineString values
`MultiPoint()`	Construct MultiPoint from Point values
`MultiPolygon()`	Construct MultiPolygon from Polygon values
`NAME_CONST()`	Causes the column to have the given name
`NOT, !`	Negates value
`NOT BETWEEN ... AND ...`	Check whether a value is not within a range of values
`!=, <>`	Not equal operator
`NOT IN()`	Check whether a value is not within a set of values
`NOT LIKE`	Negation of simple pattern matching
`NOT REGEXP`	Negation of REGEXP
`NOW()`	Return the current date and time
`NULLIF()`	Return NULL if expr1 = expr2
`NumGeometries()`	Return number of geometries in geometry collection
`NumInteriorRings()`	Return number of interior rings in Polygon
`NumPoints()`	Return number of points in LineString
`OCT()`	Return a string containing octal representation of a number
`OCTET_LENGTH()`	Synonym for LENGTH()
`OLD_PASSWORD()`	Return the value of the pre-4.1 implementation of PASSWORD
`||, OR`	Logical OR
`ORD()`	Return character code for leftmost character of the argument
`Overlaps()`	Whether MBRs of two geometries overlap

Name	Description
`PASSWORD()`	Calculate and return a password string
`PERIOD_ADD()`	Add a period to a year-month
`PERIOD_DIFF()`	Return the number of months between periods
`PI()`	Return the value of pi
`+`	Addition operator
`Point()`	Construct Point from coordinates
`PointFromText()`	Construct Point from WKT
`PointFromWKB()`	Construct Point from WKB
`PointN()`	Return N-th point from LineString
`PolyFromText()`, `PolygonFromText()`	Construct Polygon from WKT
`PolyFromWKB()`, `PolygonFromWKB()`	Construct Polygon from WKB
`Polygon()`	Construct Polygon from LineString arguments
`POSITION()`	Synonym for LOCATE()
`POW()`	Return the argument raised to the specified power
`POWER()`	Return the argument raised to the specified power
`PROCEDURE ANALYSE()`	Analyze the results of a query
`QUARTER()`	Return the quarter from a date argument
`QUOTE()`	Escape the argument for use in an SQL statement
`RADIANS()`	Return argument converted to radians
`RAND()`	Return a random floating-point value
`REGEXP`	Pattern matching using regular expressions
`RELEASE_LOCK()`	Releases the named lock
`REPEAT()`	Repeat a string the specified number of times
`REPLACE()`	Replace occurrences of a specified string
`REVERSE()`	Reverse the characters in a string
`RIGHT()`	Return the specified rightmost number of characters
`>>`	Right shift
`RLIKE`	Synonym for REGEXP
`ROUND()`	Round the argument
`ROW_COUNT()`	The number of rows updated
`RPAD()`	Append string the specified number of times
`RTRIM()`	Remove trailing spaces
`SCHEMA()`	Synonym for DATABASE()
`SEC_TO_TIME()`	Converts seconds to 'HH:MM:SS' format
`SECOND()`	Return the second (0-59)
`SESSION_USER()`	Synonym for USER()
`SHA1()`, `SHA()`	Calculate an SHA-1 160-bit checksum

Name	Description
SIGN()	Return the sign of the argument
SIN()	Return the sine of the argument
SLEEP()	Sleep for a number of seconds
SOUNDEX()	Return a soundex string
SOUNDS LIKE	Compare sounds
SPACE()	Return a string of the specified number of spaces
SQRT()	Return the square root of the argument
SRID()	Return spatial reference system ID for geometry
StartPoint()	Start Point of LineString
STD()	Return the population standard deviation
STDDEV()	Return the population standard deviation
STDDEV_POP()	Return the population standard deviation
STDDEV_SAMP()	Return the sample standard deviation
STR_TO_DATE()	Convert a string to a date
STRCMP()	Compare two strings
SUBDATE()	Synonym for DATE_SUB() when invoked with three arguments
SUBSTR()	Return the substring as specified
SUBSTRING()	Return the substring as specified
SUBSTRING_INDEX()	Return a substring from a string before the specified number of occurrences of the delimiter
SUBTIME()	Subtract times
SUM()	Return the sum
SYSDATE()	Return the time at which the function executes
SYSTEM_USER()	Synonym for USER()
TAN()	Return the tangent of the argument
TIME()	Extract the time portion of the expression passed
TIME_FORMAT()	Format as time
TIME_TO_SEC()	Return the argument converted to seconds
TIMEDIFF()	Subtract time
*	Multiplication operator
TIMESTAMP()	With a single argument, this function returns the date or datetime expression; with two arguments, the sum of the arguments
TIMESTAMPADD()	Add an interval to a datetime expression
TIMESTAMPDIFF()	Subtract an interval from a datetime expression
TO_DAYS()	Return the date argument converted to days
Touches()	Whether one geometry touches another
TRIM()	Remove leading and trailing spaces
TRUNCATE()	Truncate to specified number of decimal places

Name	Description
`UCASE()`	Synonym for UPPER()
`-`	Change the sign of the argument
`UNCOMPRESS()`	Uncompress a string compressed
`UNCOMPRESSED_LENGTH()`	Return the length of a string before compression
`UNHEX()`	Return a string containing hex representation of a number
`UNIX_TIMESTAMP()`	Return a UNIX timestamp
`UpdateXML()`	Return replaced XML fragment
`UPPER()`	Convert to uppercase
`USER()`	The user name and host name provided by the client
`UTC_DATE()`	Return the current UTC date
`UTC_TIME()`	Return the current UTC time
`UTC_TIMESTAMP()`	Return the current UTC date and time
`UUID()`	Return a Universal Unique Identifier (UUID)
`UUID_SHORT()`	Return an integer-valued universal identifier
`VALUES()`	Defines the values to be used during an INSERT
`VAR_POP()`	Return the population standard variance
`VAR_SAMP()`	Return the sample variance
`VARIANCE()`	Return the population standard variance
`VERSION()`	Return a string that indicates the MySQL server version
`WEEK()`	Return the week number
`WEEKDAY()`	Return the weekday index
`WEEKOFYEAR()`	Return the calendar week of the date (1-53)
`Within()`	Whether MBR of one geometry is within MBR of another
`X()`	Return X coordinate of Point
`XOR`	Logical XOR
`Y()`	Return Y coordinate of Point
`YEAR()`	Return the year
`YEARWEEK()`	Return the year and week

12.2 Type Conversion in Expression Evaluation

When an operator is used with operands of different types, type conversion occurs to make the operands compatible. Some conversions occur implicitly. For example, MySQL automatically converts numbers to strings as necessary, and vice versa.

```
mysql> SELECT 1+'1';
        -> 2
mysql> SELECT CONCAT(2,' test');
        -> '2 test'
```

It is also possible to convert a number to a string explicitly using the `CAST()` function. Conversion occurs implicitly with the `CONCAT()` function because it expects string arguments.

```
mysql> SELECT 38.8, CAST(38.8 AS CHAR);
        -> 38.8, '38.8'
mysql> SELECT 38.8, CONCAT(38.8);
        -> 38.8, '38.8'
```

See later in this section for information about the character set of implicit number-to-string conversions, and for modified rules that apply to CREATE TABLE ... SELECT statements.

The following rules describe how conversion occurs for comparison operations:

- If one or both arguments are NULL, the result of the comparison is NULL, except for the NULL-safe <=> equality comparison operator. For NULL <=> NULL, the result is true. No conversion is needed.

- If both arguments in a comparison operation are strings, they are compared as strings.

- If both arguments are integers, they are compared as integers.

- Hexadecimal values are treated as binary strings if not compared to a number.

- If one of the arguments is a TIMESTAMP or DATETIME column and the other argument is a constant, the constant is converted to a timestamp before the comparison is performed. This is done to be more ODBC-friendly. Note that this is not done for the arguments to IN()! To be safe, always use complete datetime, date, or time strings when doing comparisons. For example, to achieve best results when using BETWEEN with date or time values, use CAST() to explicitly convert the values to the desired data type.

- If one of the arguments is a decimal value, comparison depends on the other argument. The arguments are compared as decimal values if the other argument is a decimal or integer value, or as floating-point values if the other argument is a floating-point value.

- In all other cases, the arguments are compared as floating-point (real) numbers.

For information about conversion of values from one temporal type to another, see Section 11.3.7, "Conversion Between Date and Time Types".

The following examples illustrate conversion of strings to numbers for comparison operations:

```
mysql> SELECT 1 > '6x';
        -> 0
mysql> SELECT 7 > '6x';
        -> 1
mysql> SELECT 0 > 'x6';
        -> 0
mysql> SELECT 0 = 'x6';
        -> 1
```

For comparisons of a string column with a number, MySQL cannot use an index on the column to look up the value quickly. If str_col is an indexed string column, the index cannot be used when performing the lookup in the following statement:

```
SELECT * FROM tbl_name WHERE str_col=1;
```

The reason for this is that there are many different strings that may convert to the value 1, such as '1', ' 1', or '1a'.

Comparisons that use floating-point numbers (or values that are converted to floating-point numbers) are approximate because such numbers are inexact. This might lead to results that appear inconsistent:

```
mysql> SELECT '18015376320243458' = 18015376320243458;
        -> 1
mysql> SELECT '18015376320243459' = 18015376320243459;
        -> 0
```

Such results can occur because the values are converted to floating-point numbers, which have only 53 bits of precision and are subject to rounding:

```
mysql> SELECT '18015376320243459'+0.0;
        -> 1.8015376320243e+16
```

Furthermore, the conversion from string to floating-point and from integer to floating-point do not necessarily occur the same way. The integer may be converted to floating-point by the CPU, whereas the string is converted digit by digit in an operation that involves floating-point multiplications.

The results shown will vary on different systems, and can be affected by factors such as computer architecture or the compiler version or optimization level. One way to avoid such problems is to use `CAST()` so that a value is not converted implicitly to a float-point number:

```
mysql> SELECT CAST('18015376320243459' AS UNSIGNED) = 18015376320243459;
        -> 1
```

For more information about floating-point comparisons, see Section B.5.4.8, "Problems with Floating-Point Values".

Implicit conversion of a numeric or temporal value to a string produces a binary string (a `BINARY`, `VARBINARY`, or `BLOB` value). Such implicit conversions to string typically occur for functions that are passed numeric or temporal values when string values are more usual, and thus can have effects beyond the type of the converted value. Consider the expression `CONCAT(1, 'abc')`. The numeric argument `1` is converted to the binary string `'1'` and the concatenation of that value with the nonbinary string `'abc'` produces the binary string `'1abc'`.

For integer expressions, the preceding remarks about expression *evaluation* apply somewhat differently for expression *assignment*; for example, in a statement such as this:

```
CREATE TABLE t SELECT integer_expr;
```

In this case, the table in the column resulting from the expression has type `INT` or `BIGINT` depending on the length of the integer expression. If the maximum length of the expression does not fit in an `INT`, `BIGINT` is used instead. The length is taken from the `max_length` value of the `SELECT` result set metadata (see Section 21.8.5, "C API Data Structures"). This means that you can force a `BIGINT` rather than `INT` by use of a sufficiently long expression:

```
CREATE TABLE t SELECT 000000000000000000000;
```

12.3 Operators

Table 12.2 Operators

Name	Description
AND, &&	Logical AND
=	Assign a value (as part of a `SET` statement, or as part of the `SET` clause in an `UPDATE` statement)
:=	Assign a value
BETWEEN ... AND ...	Check whether a value is within a range of values

Name	Description
BINARY	Cast a string to a binary string
&	Bitwise AND
~	Bitwise inversion
|	Bitwise OR
^	Bitwise XOR
CASE	Case operator
DIV	Integer division
/	Division operator
=	Equal operator
<=>	NULL-safe equal to operator
>	Greater than operator
>=	Greater than or equal operator
IS	Test a value against a boolean
IS NOT	Test a value against a boolean
IS NOT NULL	NOT NULL value test
IS NULL	NULL value test
<<	Left shift
<	Less than operator
<=	Less than or equal operator
LIKE	Simple pattern matching
-	Minus operator
%, MOD	Modulo operator
NOT, !	Negates value
NOT BETWEEN ... AND ...	Check whether a value is not within a range of values
!=, <>	Not equal operator
NOT LIKE	Negation of simple pattern matching
NOT REGEXP	Negation of REGEXP
||, OR	Logical OR
+	Addition operator
REGEXP	Pattern matching using regular expressions
>>	Right shift
RLIKE	Synonym for REGEXP
SOUNDS LIKE	Compare sounds
*	Multiplication operator
-	Change the sign of the argument
XOR	Logical XOR

12.3.1 Operator Precedence

Operator precedences are shown in the following list, from highest precedence to the lowest. Operators that are shown together on a line have the same precedence.

```
INTERVAL
BINARY, COLLATE
!
- (unary minus), ~ (unary bit inversion)
^
*, /, DIV, %, MOD
-, +
<<, >>
&
|
= (comparison), <=>, >=, >, <=, <, <>, !=, IS, LIKE, REGEXP, IN
BETWEEN, CASE, WHEN, THEN, ELSE
NOT
AND, &&
XOR
OR, ||
= (assignment), :=
```

The precedence of `=` depends on whether it is used as a comparison operator (`=`) or as an assignment operator (`=`). When used as a comparison operator, it has the same precedence as `<=>`, `>=`, `>`, `<=`, `<`, `<>`, `!=`, `IS`, `LIKE`, `REGEXP`, and `IN`. When used as an assignment operator, it has the same precedence as `:=`. Section 13.7.4.1, "SET Syntax for Variable Assignment", and Section 9.4, "User-Defined Variables", explain how MySQL determines which interpretation of `=` should apply.

For operators that occur at the same precedence level within an expression, evaluation proceeds left to right, with the exception that assignments evaluate right to left.

The meaning of some operators depends on the SQL mode:

- By default, `||` is a logical `OR` operator. With `PIPES_AS_CONCAT` enabled, `||` is string concatenation, with a precedence between `^` and the unary operators.

- By default, `!` has a higher precedence than `NOT`. With `HIGH_NOT_PRECEDENCE` enabled, `!` and `NOT` have the same precedence.

See Section 5.1.7, "Server SQL Modes".

The precedence of operators determines the order of evaluation of terms in an expression. To override this order and group terms explicitly, use parentheses. For example:

```
mysql> SELECT 1+2*3;
        -> 7
mysql> SELECT (1+2)*3;
        -> 9
```

12.3.2 Comparison Functions and Operators

Table 12.3 Comparison Operators

Name	Description
BETWEEN ... AND ...	Check whether a value is within a range of values
COALESCE()	Return the first non-NULL argument
=	Equal operator
<=>	NULL-safe equal to operator
>	Greater than operator

Name	Description
`>=`	Greater than or equal operator
`GREATEST()`	Return the largest argument
`IN()`	Check whether a value is within a set of values
`INTERVAL()`	Return the index of the argument that is less than the first argument
`IS`	Test a value against a boolean
`IS NOT`	Test a value against a boolean
`IS NOT NULL`	NOT NULL value test
`IS NULL`	NULL value test
`ISNULL()`	Test whether the argument is NULL
`LEAST()`	Return the smallest argument
`<`	Less than operator
`<=`	Less than or equal operator
`LIKE`	Simple pattern matching
`NOT BETWEEN ... AND ...`	Check whether a value is not within a range of values
`!=, <>`	Not equal operator
`NOT IN()`	Check whether a value is not within a set of values
`NOT LIKE`	Negation of simple pattern matching
`STRCMP()`	Compare two strings

Comparison operations result in a value of `1` (`TRUE`), `0` (`FALSE`), or `NULL`. These operations work for both numbers and strings. Strings are automatically converted to numbers and numbers to strings as necessary.

The following relational comparison operators can be used to compare not only scalar operands, but row operands:

```
=  >  <  >=  <=  <>  !=
```

The descriptions for those operators later in this section detail how they work with row operands. For additional examples of row comparisons in the context of row subqueries, see Section 13.2.9.5, "Row Subqueries".

Some of the functions in this section return values other than `1` (`TRUE`), `0` (`FALSE`), or `NULL`. For example, `LEAST()` and `GREATEST()`. However, the value they return is based on comparison operations performed according to the rules described in Section 12.2, "Type Conversion in Expression Evaluation".

To convert a value to a specific type for comparison purposes, you can use the `CAST()` function. String values can be converted to a different character set using `CONVERT()`. See Section 12.10, "Cast Functions and Operators".

By default, string comparisons are not case sensitive and use the current character set. The default is `latin1` (cp1252 West European), which also works well for English.

- `=`

  Equal:

```
mysql> SELECT 1 = 0;
        -> 0
mysql> SELECT '0' = 0;
        -> 1
mysql> SELECT '0.0' = 0;
        -> 1
mysql> SELECT '0.01' = 0;
        -> 0
mysql> SELECT '.01' = 0.01;
        -> 1
```

For row comparisons, `(a, b) = (x, y)` is equivalent to:

```
(a = x) AND (b = y)
```

- `<=>`

  `NULL`-safe equal. This operator performs an equality comparison like the `=` operator, but returns `1` rather than `NULL` if both operands are `NULL`, and `0` rather than `NULL` if one operand is `NULL`.

  The `<=>` operator is equivalent to the standard SQL `IS NOT DISTINCT FROM` operator.

  ```
  mysql> SELECT 1 <=> 1, NULL <=> NULL, 1 <=> NULL;
          -> 1, 1, 0
  mysql> SELECT 1 = 1, NULL = NULL, 1 = NULL;
          -> 1, NULL, NULL
  ```

  For row comparisons, `(a, b) <=> (x, y)` is equivalent to:

  ```
  (a <=> x) AND (b <=> y)
  ```

- `<>`, `!=`

  Not equal:

  ```
  mysql> SELECT '.01' <> '0.01';
          -> 1
  mysql> SELECT .01 <> '0.01';
          -> 0
  mysql> SELECT 'zapp' <> 'zappp';
          -> 1
  ```

  For row comparisons, `(a, b) <> (x, y)` and `(a, b) != (x, y)` are equivalent to:

  ```
  (a <> x) OR (b <> y)
  ```

- `<=`

  Less than or equal:

  ```
  mysql> SELECT 0.1 <= 2;
          -> 1
  ```

  For row comparisons, `(a, b) <= (x, y)` is equivalent to:

```
(a < x) OR ((a = x) AND (b <= y))
```

- `<`

  Less than:

  ```
  mysql> SELECT 2 < 2;
          -> 0
  ```

  For row comparisons, `(a, b) < (x, y)` is equivalent to:

  ```
  (a < x) OR ((a = x) AND (b < y))
  ```

- `>=`

  Greater than or equal:

  ```
  mysql> SELECT 2 >= 2;
          -> 1
  ```

  For row comparisons, `(a, b) >= (x, y)` is equivalent to:

  ```
  (a > x) OR ((a = x) AND (b >= y))
  ```

- `>`

  Greater than:

  ```
  mysql> SELECT 2 > 2;
          -> 0
  ```

  For row comparisons, `(a, b) > (x, y)` is equivalent to:

  ```
  (a > x) OR ((a = x) AND (b > y))
  ```

- `IS boolean_value`

  Tests a value against a boolean value, where `boolean_value` can be `TRUE`, `FALSE`, or `UNKNOWN`.

  ```
  mysql> SELECT 1 IS TRUE, 0 IS FALSE, NULL IS UNKNOWN;
          -> 1, 1, 1
  ```

- `IS NOT boolean_value`

  Tests a value against a boolean value, where `boolean_value` can be `TRUE`, `FALSE`, or `UNKNOWN`.

  ```
  mysql> SELECT 1 IS NOT UNKNOWN, 0 IS NOT UNKNOWN, NULL IS NOT UNKNOWN;
          -> 1, 1, 0
  ```

- `IS NULL`

  Tests whether a value is `NULL`.

  ```
  mysql> SELECT 1 IS NULL, 0 IS NULL, NULL IS NULL;
  ```

```
          -> 0, 0, 1
```

To work well with ODBC programs, MySQL supports the following extra features when using `IS NULL`:

- If `sql_auto_is_null` variable is set to 1 (the default), then after a statement that successfully inserts an automatically generated `AUTO_INCREMENT` value, you can find that value by issuing a statement of the following form:

```
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

  If the statement returns a row, the value returned is the same as if you invoked the `LAST_INSERT_ID()` function. For details, including the return value after a multiple-row insert, see Section 12.14, "Information Functions". If no `AUTO_INCREMENT` value was successfully inserted, the `SELECT` statement returns no row.

  The behavior of retrieving an `AUTO_INCREMENT` value by using an `IS NULL` comparison can be disabled by setting `sql_auto_is_null = 0`. See Section 5.1.4, "Server System Variables".

- For `DATE` and `DATETIME` columns that are declared as `NOT NULL`, you can find the special date `'0000-00-00'` by using a statement like this:

```
SELECT * FROM tbl_name WHERE date_column IS NULL
```

  This is needed to get some ODBC applications to work because ODBC does not support a `'0000-00-00'` date value.

  See Obtaining Auto-Increment Values, and the description for the `FLAG_AUTO_IS_NULL` option at Connector/ODBC Connection Parameters.

- `IS NOT NULL`

  Tests whether a value is not `NULL`.

```
mysql> SELECT 1 IS NOT NULL, 0 IS NOT NULL, NULL IS NOT NULL;
        -> 1, 1, 0
```

- `expr BETWEEN min AND max`

  If `expr` is greater than or equal to `min` and `expr` is less than or equal to `max`, `BETWEEN` returns `1`, otherwise it returns `0`. This is equivalent to the expression `(min <= expr AND expr <= max)` if all the arguments are of the same type. Otherwise type conversion takes place according to the rules described in Section 12.2, "Type Conversion in Expression Evaluation", but applied to all the three arguments.

```
mysql> SELECT 2 BETWEEN 1 AND 3, 2 BETWEEN 3 and 1;
        -> 1, 0
mysql> SELECT 1 BETWEEN 2 AND 3;
        -> 0
mysql> SELECT 'b' BETWEEN 'a' AND 'c';
        -> 1
mysql> SELECT 2 BETWEEN 2 AND '3';
        -> 1
mysql> SELECT 2 BETWEEN 2 AND 'x-3';
        -> 0
```

For best results when using `BETWEEN` with date or time values, use `CAST()` to explicitly convert the values to the desired data type. Examples: If you compare a `DATETIME` to two `DATE` values, convert the `DATE` values to `DATETIME` values. If you use a string constant such as `'2001-1-1'` in a comparison to a `DATE`, cast the string to a `DATE`.

- `expr` NOT BETWEEN `min` AND `max`

  This is the same as NOT (`expr` BETWEEN `min` AND `max`).

- COALESCE(`value`,...)

  Returns the first non-`NULL` value in the list, or `NULL` if there are no non-`NULL` values.

  ```
  mysql> SELECT COALESCE(NULL,1);
          -> 1
  mysql> SELECT COALESCE(NULL,NULL,NULL);
          -> NULL
  ```

- GREATEST(`value1`,`value2`,...)

  With two or more arguments, returns the largest (maximum-valued) argument. The arguments are compared using the same rules as for `LEAST()`.

  ```
  mysql> SELECT GREATEST(2,0);
          -> 2
  mysql> SELECT GREATEST(34.0,3.0,5.0,767.0);
          -> 767.0
  mysql> SELECT GREATEST('B','A','C');
          -> 'C'
  ```

  GREATEST() returns `NULL` if any argument is `NULL`.

- `expr` IN (`value`,...)

  Returns `1` if `expr` is equal to any of the values in the `IN` list, else returns `0`. If all values are constants, they are evaluated according to the type of `expr` and sorted. The search for the item then is done using a binary search. This means `IN` is very quick if the `IN` value list consists entirely of constants. Otherwise, type conversion takes place according to the rules described in Section 12.2, "Type Conversion in Expression Evaluation", but applied to all the arguments.

  ```
  mysql> SELECT 2 IN (0,3,5,7);
          -> 0
  mysql> SELECT 'wefwf' IN ('wee','wefwf','weg');
          -> 1
  ```

  `IN` can be used to compare row constructors:

  ```
  mysql> SELECT (3,4) IN ((1,2), (3,4));
          -> 1
  mysql> SELECT (3,4) IN ((1,2), (3,5));
          -> 0
  ```

  You should never mix quoted and unquoted values in an `IN` list because the comparison rules for quoted values (such as strings) and unquoted values (such as numbers) differ. Mixing types may therefore lead to inconsistent results. For example, do not write an `IN` expression like this:

```
SELECT val1 FROM tbl1 WHERE val1 IN (1,2,'a');
```

Instead, write it like this:

```
SELECT val1 FROM tbl1 WHERE val1 IN ('1','2','a');
```

The number of values in the `IN` list is only limited by the `max_allowed_packet` value.

To comply with the SQL standard, `IN` returns `NULL` not only if the expression on the left hand side is `NULL`, but also if no match is found in the list and one of the expressions in the list is `NULL`.

`IN()` syntax can also be used to write certain types of subqueries. See Section 13.2.9.3, "Subqueries with ANY, IN, or SOME".

- `expr NOT IN (value,...)`

  This is the same as `NOT (expr IN (value,...))`.

- `ISNULL(expr)`

  If `expr` is `NULL`, `ISNULL()` returns `1`, otherwise it returns `0`.

  ```
  mysql> SELECT ISNULL(1+1);
          -> 0
  mysql> SELECT ISNULL(1/0);
          -> 1
  ```

  `ISNULL()` can be used instead of `=` to test whether a value is `NULL`. (Comparing a value to `NULL` using `=` always yields false.)

  The `ISNULL()` function shares some special behaviors with the `IS NULL` comparison operator. See the description of `IS NULL`.

- `INTERVAL(N,N1,N2,N3,...)`

  Returns `0` if $N < N1$, `1` if $N < N2$ and so on or `-1` if N is `NULL`. All arguments are treated as integers. It is required that $N1 < N2 < N3 < ... < Nn$ for this function to work correctly. This is because a binary search is used (very fast).

  ```
  mysql> SELECT INTERVAL(23, 1, 15, 17, 30, 44, 200);
          -> 3
  mysql> SELECT INTERVAL(10, 1, 10, 100, 1000);
          -> 2
  mysql> SELECT INTERVAL(22, 23, 30, 44, 200);
          -> 0
  ```

- `LEAST(value1,value2,...)`

  With two or more arguments, returns the smallest (minimum-valued) argument. The arguments are compared using the following rules:

  - If any argument is `NULL`, the result is `NULL`. No comparison is needed.

  - If the return value is used in an `INTEGER` context or all arguments are integer-valued, they are compared as integers.

- If the return value is used in a `REAL` context or all arguments are real-valued, they are compared as reals.

- If the arguments comprise a mix of numbers and strings, they are compared as numbers.

- If any argument is a nonbinary (character) string, the arguments are compared as nonbinary strings.

- In all other cases, the arguments are compared as binary strings.

```
mysql> SELECT LEAST(2,0);
        -> 0
mysql> SELECT LEAST(34.0,3.0,5.0,767.0);
        -> 3.0
mysql> SELECT LEAST('B','A','C');
        -> 'A'
```

Note that the preceding conversion rules can produce strange results in some borderline cases:

```
mysql> SELECT CAST(LEAST(3600, 9223372036854775808.0) AS SIGNED);
        -> -9223372036854775808
```

This happens because MySQL reads `9223372036854775808.0` in an integer context. The integer representation is not good enough to hold the value, so it wraps to a signed integer.

12.3.3 Logical Operators

Table 12.4 Logical Operators

Name	Description
AND, &&	Logical AND
NOT, !	Negates value
||, OR	Logical OR
XOR	Logical XOR

In SQL, all logical operators evaluate to `TRUE`, `FALSE`, or `NULL` (`UNKNOWN`). In MySQL, these are implemented as 1 (`TRUE`), 0 (`FALSE`), and `NULL`. Most of this is common to different SQL database servers, although some servers may return any nonzero value for `TRUE`.

MySQL evaluates any nonzero, non-`NULL` value to `TRUE`. For example, the following statements all assess to `TRUE`:

```
mysql> SELECT 10 IS TRUE;
-> 1
mysql> SELECT -10 IS TRUE;
-> 1
mysql> SELECT 'string' IS NOT NULL;
-> 1
```

- `NOT, !`

  Logical NOT. Evaluates to `1` if the operand is `0`, to `0` if the operand is nonzero, and `NOT NULL` returns `NULL`.

```
mysql> SELECT NOT 10;
        -> 0
mysql> SELECT NOT 0;
        -> 1
mysql> SELECT NOT NULL;
        -> NULL
mysql> SELECT ! (1+1);
        -> 0
mysql> SELECT ! 1+1;
        -> 1
```

The last example produces `1` because the expression evaluates the same way as `(!1)+1`.

- AND, &&

  Logical AND. Evaluates to `1` if all operands are nonzero and not `NULL`, to `0` if one or more operands are `0`, otherwise `NULL` is returned.

  ```
  mysql> SELECT 1 AND 1;
          -> 1
  mysql> SELECT 1 AND 0;
          -> 0
  mysql> SELECT 1 AND NULL;
          -> NULL
  mysql> SELECT 0 AND NULL;
          -> 0
  mysql> SELECT NULL AND 0;
          -> 0
  ```

- OR, ||

  Logical OR. When both operands are non-`NULL`, the result is `1` if any operand is nonzero, and `0` otherwise. With a `NULL` operand, the result is `1` if the other operand is nonzero, and `NULL` otherwise. If both operands are `NULL`, the result is `NULL`.

  ```
  mysql> SELECT 1 OR 1;
          -> 1
  mysql> SELECT 1 OR 0;
          -> 1
  mysql> SELECT 0 OR 0;
          -> 0
  mysql> SELECT 0 OR NULL;
          -> NULL
  mysql> SELECT 1 OR NULL;
          -> 1
  ```

- XOR

  Logical XOR. Returns `NULL` if either operand is `NULL`. For non-`NULL` operands, evaluates to `1` if an odd number of operands is nonzero, otherwise `0` is returned.

  ```
  mysql> SELECT 1 XOR 1;
          -> 0
  mysql> SELECT 1 XOR 0;
          -> 1
  mysql> SELECT 1 XOR NULL;
          -> NULL
  mysql> SELECT 1 XOR 1 XOR 1;
          -> 1
  ```

  `a XOR b` is mathematically equal to `(a AND (NOT b)) OR ((NOT a) and b)`.

12.3.4 Assignment Operators

Table 12.5 Assignment Operators

Name	Description
=	Assign a value (as part of a `SET` statement, or as part of the `SET` clause in an `UPDATE` statement)
:=	Assign a value

- `:=`

  Assignment operator. Causes the user variable on the left hand side of the operator to take on the value to its right. The value on the right hand side may be a literal value, another variable storing a value, or any legal expression that yields a scalar value, including the result of a query (provided that this value is a scalar value). You can perform multiple assignments in the same `SET` statement. You can perform multiple assignments in the same statement.

  Unlike `=`, the `:=` operator is never interpreted as a comparison operator. This means you can use `:=` in any valid SQL statement (not just in `SET` statements) to assign a value to a variable.

  ```
  mysql> SELECT @var1, @var2;
          -> NULL, NULL
  mysql> SELECT @var1 := 1, @var2;
          -> 1, NULL
  mysql> SELECT @var1, @var2;
          -> 1, NULL
  mysql> SELECT @var1, @var2 := @var1;
          -> 1, 1
  mysql> SELECT @var1, @var2;
          -> 1, 1

  mysql> SELECT @var1:=COUNT(*) FROM t1;
          -> 4
  mysql> SELECT @var1;
          -> 4
  ```

  You can make value assignments using `:=` in other statements besides `SELECT`, such as `UPDATE`, as shown here:

  ```
  mysql> SELECT @var1;
          -> 4
  mysql> SELECT * FROM t1;
          -> 1, 3, 5, 7

  mysql> UPDATE t1 SET c1 = 2 WHERE c1 = @var1:= 1;
  Query OK, 1 row affected (0.00 sec)
  Rows matched: 1  Changed: 1  Warnings: 0

  mysql> SELECT @var1;
          -> 1
  mysql> SELECT * FROM t1;
          -> 2, 3, 5, 7
  ```

  While it is also possible both to set and to read the value of the same variable in a single SQL statement using the `:=` operator, this is not recommended. Section 9.4, "User-Defined Variables", explains why you should avoid doing this.

- `=`

This operator is used to perform value assignments in two cases, described in the next two paragraphs.

Within a `SET` statement, `=` is treated as an assignment operator that causes the user variable on the left hand side of the operator to take on the value to its right. (In other words, when used in a `SET` statement, `=` is treated identically to `:=`.) The value on the right hand side may be a literal value, another variable storing a value, or any legal expression that yields a scalar value, including the result of a query (provided that this value is a scalar value). You can perform multiple assignments in the same `SET` statement.

In the `SET` clause of an `UPDATE` statement, `=` also acts as an assignment operator; in this case, however, it causes the column named on the left hand side of the operator to assume the value given to the right, provided any `WHERE` conditions that are part of the `UPDATE` are met. You can make multiple assignments in the same `SET` clause of an `UPDATE` statement.

In any other context, `=` is treated as a comparison operator.

```
mysql> SELECT @var1, @var2;
        -> NULL, NULL
mysql> SELECT @var1 := 1, @var2;
        -> 1, NULL
mysql> SELECT @var1, @var2;
        -> 1, NULL
mysql> SELECT @var1, @var2 := @var1;
        -> 1, 1
mysql> SELECT @var1, @var2;
        -> 1, 1
```

For more information, see Section 13.7.4.1, "SET Syntax for Variable Assignment", Section 13.2.10, "UPDATE Syntax", and Section 13.2.9, "Subquery Syntax".

12.4 Control Flow Functions

Table 12.6 Flow Control Operators

Name	Description
CASE	Case operator
IF()	If/else construct
IFNULL()	Null if/else construct
NULLIF()	Return NULL if expr1 = expr2

- `CASE value WHEN [compare_value] THEN result [WHEN [compare_value] THEN result ...] [ELSE result] END`

  `CASE WHEN [condition] THEN result [WHEN [condition] THEN result ...] [ELSE result] END`

  The first version returns the `result` where `value=compare_value`. The second version returns the result for the first condition that is true. If there was no matching result value, the result after `ELSE` is returned, or `NULL` if there is no `ELSE` part.

```
mysql> SELECT CASE 1 WHEN 1 THEN 'one'
    ->     WHEN 2 THEN 'two' ELSE 'more' END;
        -> 'one'
mysql> SELECT CASE WHEN 1>0 THEN 'true' ELSE 'false' END;
        -> 'true'
```

```
mysql> SELECT CASE BINARY 'B'
    ->     WHEN 'a' THEN 1 WHEN 'b' THEN 2 END;
        -> NULL
```

The return type of a `CASE` expression is the compatible aggregated type of all return values, but also depends on the context in which it is used. If used in a string context, the result is returned as a string. If used in a numeric context, the result is returned as a decimal, real, or integer value.

> **Note**
>
> The syntax of the `CASE` *expression* shown here differs slightly from that of the SQL `CASE` *statement* described in Section 13.6.5.1, "CASE Syntax", for use inside stored programs. The `CASE` statement cannot have an `ELSE NULL` clause, and it is terminated with `END CASE` instead of `END`.

- `IF(expr1,expr2,expr3)`

  If *expr1* is TRUE (*expr1 <> 0* and *expr1 <> NULL*) then `IF()` returns *expr2*; otherwise it returns *expr3*. `IF()` returns a numeric or string value, depending on the context in which it is used.

  ```
  mysql> SELECT IF(1>2,2,3);
          -> 3
  mysql> SELECT IF(1<2,'yes','no');
          -> 'yes'
  mysql> SELECT IF(STRCMP('test','test1'),'no','yes');
          -> 'no'
  ```

  If only one of *expr2* or *expr3* is explicitly NULL, the result type of the `IF()` function is the type of the non-NULL expression.

  The default return type of `IF()` (which may matter when it is stored into a temporary table) is calculated as follows.

Expression	Return Value
expr2 or *expr3* returns a string	string
expr2 or *expr3* returns a floating-point value	floating-point
expr2 or *expr3* returns an integer	integer

  If *expr2* and *expr3* are both strings, the result is case sensitive if either string is case sensitive.

  > **Note**
  >
  > There is also an `IF` *statement*, which differs from the `IF()` *function* described here. See Section 13.6.5.2, "IF Syntax".

- `IFNULL(expr1,expr2)`

  If *expr1* is not NULL, `IFNULL()` returns *expr1*; otherwise it returns *expr2*. `IFNULL()` returns a numeric or string value, depending on the context in which it is used.

  ```
  mysql> SELECT IFNULL(1,0);
          -> 1
  mysql> SELECT IFNULL(NULL,10);
          -> 10
  mysql> SELECT IFNULL(1/0,10);
          -> 10
  ```

```
mysql> SELECT IFNULL(1/0,'yes');
        -> 'yes'
```

The default result value of `IFNULL(expr1,expr2)` is the more "general" of the two expressions, in the order `STRING`, `REAL`, or `INTEGER`. Consider the case of a table based on expressions or where MySQL must internally store a value returned by `IFNULL()` in a temporary table:

```
mysql> CREATE TABLE tmp SELECT IFNULL(1,'test') AS test;
mysql> DESCRIBE tmp;
+-------+--------------+------+-----+---------+-------+
| Field | Type         | Null | Key | Default | Extra |
+-------+--------------+------+-----+---------+-------+
| test  | varbinary(4) | NO   |     |         |       |
+-------+--------------+------+-----+---------+-------+
```

In this example, the type of the `test` column is `VARBINARY(4)`.

- `NULLIF(expr1,expr2)`

  Returns `NULL` if `expr1 = expr2` is true, otherwise returns `expr1`. This is the same as `CASE WHEN expr1 = expr2 THEN NULL ELSE expr1 END`.

```
mysql> SELECT NULLIF(1,1);
        -> NULL
mysql> SELECT NULLIF(1,2);
        -> 1
```

  Note that MySQL evaluates `expr1` twice if the arguments are not equal.

12.5 String Functions

Table 12.7 String Operators

Name	Description
ASCII()	Return numeric value of left-most character
BIN()	Return a string containing binary representation of a number
BIT_LENGTH()	Return length of argument in bits
CHAR()	Return the character for each integer passed
CHAR_LENGTH()	Return number of characters in argument
CHARACTER_LENGTH()	Synonym for CHAR_LENGTH()
CONCAT()	Return concatenated string
CONCAT_WS()	Return concatenate with separator
ELT()	Return string at index number
EXPORT_SET()	Return a string such that for every bit set in the value bits, you get an on string and for every unset bit, you get an off string
FIELD()	Return the index (position) of the first argument in the subsequent arguments
FIND_IN_SET()	Return the index position of the first argument within the second argument
FORMAT()	Return a number formatted to specified number of decimal places

Name	Description
`HEX()`	Return a hexadecimal representation of a decimal or string value
`INSERT()`	Insert a substring at the specified position up to the specified number of characters
`INSTR()`	Return the index of the first occurrence of substring
`LCASE()`	Synonym for LOWER()
`LEFT()`	Return the leftmost number of characters as specified
`LENGTH()`	Return the length of a string in bytes
`LIKE`	Simple pattern matching
`LOAD_FILE()`	Load the named file
`LOCATE()`	Return the position of the first occurrence of substring
`LOWER()`	Return the argument in lowercase
`LPAD()`	Return the string argument, left-padded with the specified string
`LTRIM()`	Remove leading spaces
`MAKE_SET()`	Return a set of comma-separated strings that have the corresponding bit in bits set
`MATCH`	Perform full-text search
`MID()`	Return a substring starting from the specified position
`NOT LIKE`	Negation of simple pattern matching
`NOT REGEXP`	Negation of REGEXP
`OCT()`	Return a string containing octal representation of a number
`OCTET_LENGTH()`	Synonym for LENGTH()
`ORD()`	Return character code for leftmost character of the argument
`POSITION()`	Synonym for LOCATE()
`QUOTE()`	Escape the argument for use in an SQL statement
`REGEXP`	Pattern matching using regular expressions
`REPEAT()`	Repeat a string the specified number of times
`REPLACE()`	Replace occurrences of a specified string
`REVERSE()`	Reverse the characters in a string
`RIGHT()`	Return the specified rightmost number of characters
`RLIKE`	Synonym for REGEXP
`RPAD()`	Append string the specified number of times
`RTRIM()`	Remove trailing spaces
`SOUNDEX()`	Return a soundex string
`SOUNDS LIKE`	Compare sounds
`SPACE()`	Return a string of the specified number of spaces
`STRCMP()`	Compare two strings
`SUBSTR()`	Return the substring as specified

Name	Description
SUBSTRING()	Return the substring as specified
SUBSTRING_INDEX()	Return a substring from a string before the specified number of occurrences of the delimiter
TRIM()	Remove leading and trailing spaces
UCASE()	Synonym for UPPER()
UNHEX()	Return a string containing hex representation of a number
UPPER()	Convert to uppercase

String-valued functions return NULL if the length of the result would be greater than the value of the max_allowed_packet system variable. See Section 8.12.2, "Tuning Server Parameters".

For functions that operate on string positions, the first position is numbered 1.

For functions that take length arguments, noninteger arguments are rounded to the nearest integer.

- ASCII(*str*)

  Returns the numeric value of the leftmost character of the string *str*. Returns 0 if *str* is the empty string. Returns NULL if *str* is NULL. ASCII() works for 8-bit characters.

  ```
  mysql> SELECT ASCII('2');
          -> 50
  mysql> SELECT ASCII(2);
          -> 50
  mysql> SELECT ASCII('dx');
          -> 100
  ```

  See also the ORD() function.

- BIN(*N*)

  Returns a string representation of the binary value of *N*, where *N* is a longlong (BIGINT) number. This is equivalent to CONV(*N*,10,2). Returns NULL if *N* is NULL.

  ```
  mysql> SELECT BIN(12);
          -> '1100'
  ```

- BIT_LENGTH(*str*)

  Returns the length of the string *str* in bits.

  ```
  mysql> SELECT BIT_LENGTH('text');
          -> 32
  ```

- CHAR(*N*,... [USING *charset_name*])

  CHAR() interprets each argument *N* as an integer and returns a string consisting of the characters given by the code values of those integers. NULL values are skipped.

  ```
  mysql> SELECT CHAR(77,121,83,81,'76');
          -> 'MySQL'
  mysql> SELECT CHAR(77,77.3,'77.3');
          -> 'MMM'
  ```

`CHAR()` arguments larger than 255 are converted into multiple result bytes. For example, `CHAR(256)` is equivalent to `CHAR(1,0)`, and `CHAR(256*256)` is equivalent to `CHAR(1,0,0)`:

```
mysql> SELECT HEX(CHAR(1,0)), HEX(CHAR(256));
+----------------+----------------+
| HEX(CHAR(1,0)) | HEX(CHAR(256)) |
+----------------+----------------+
| 0100           | 0100           |
+----------------+----------------+
mysql> SELECT HEX(CHAR(1,0,0)), HEX(CHAR(256*256));
+------------------+--------------------+
| HEX(CHAR(1,0,0)) | HEX(CHAR(256*256)) |
+------------------+--------------------+
| 010000           | 010000             |
+------------------+--------------------+
```

By default, `CHAR()` returns a binary string. To produce a string in a given character set, use the optional `USING` clause:

```
mysql> SELECT CHARSET(CHAR(X'65')), CHARSET(CHAR(X'65' USING utf8));
+----------------------+---------------------------------+
| CHARSET(CHAR(X'65')) | CHARSET(CHAR(X'65' USING utf8)) |
+----------------------+---------------------------------+
| binary               | utf8                            |
+----------------------+---------------------------------+
```

If `USING` is given and the result string is illegal for the given character set, a warning is issued. Also, if strict SQL mode is enabled, the result from `CHAR()` becomes `NULL`.

- `CHAR_LENGTH(str)`

  Returns the length of the string `str`, measured in characters. A multibyte character counts as a single character. This means that for a string containing five 2-byte characters, `LENGTH()` returns `10`, whereas `CHAR_LENGTH()` returns `5`.

- `CHARACTER_LENGTH(str)`

  `CHARACTER_LENGTH()` is a synonym for `CHAR_LENGTH()`.

- `CONCAT(str1,str2,...)`

  Returns the string that results from concatenating the arguments. May have one or more arguments. If all arguments are nonbinary strings, the result is a nonbinary string. If the arguments include any binary strings, the result is a binary string. A numeric argument is converted to its equivalent binary string form; if you want to avoid that, you can use an explicit type cast, as in this example:

  ```
  SELECT CONCAT(CAST(int_col AS CHAR), char_col);
  ```

  `CONCAT()` returns `NULL` if any argument is `NULL`.

  ```
  mysql> SELECT CONCAT('My', 'S', 'QL');
          -> 'MySQL'
  mysql> SELECT CONCAT('My', NULL, 'QL');
          -> NULL
  mysql> SELECT CONCAT(14.3);
          -> '14.3'
  ```

For quoted strings, concatenation can be performed by placing the strings next to each other:

```
mysql> SELECT 'My' 'S' 'QL';
        -> 'MySQL'
```

- CONCAT_WS(*separator*,*str1*,*str2*,...)

  CONCAT_WS() stands for Concatenate With Separator and is a special form of CONCAT(). The first argument is the separator for the rest of the arguments. The separator is added between the strings to be concatenated. The separator can be a string, as can the rest of the arguments. If the separator is NULL, the result is NULL.

  ```
  mysql> SELECT CONCAT_WS(',','First name','Second name','Last Name');
          -> 'First name,Second name,Last Name'
  mysql> SELECT CONCAT_WS(',','First name',NULL,'Last Name');
          -> 'First name,Last Name'
  ```

  CONCAT_WS() does not skip empty strings. However, it does skip any NULL values after the separator argument.

- ELT(*N*,*str1*,*str2*,*str3*,...)

  ELT() returns the *N*th element of the list of strings: *str1* if *N* = 1, *str2* if *N* = 2, and so on. Returns NULL if *N* is less than 1 or greater than the number of arguments. ELT() is the complement of FIELD().

  ```
  mysql> SELECT ELT(1, 'ej', 'Heja', 'hej', 'foo');
          -> 'ej'
  mysql> SELECT ELT(4, 'ej', 'Heja', 'hej', 'foo');
          -> 'foo'
  ```

- EXPORT_SET(*bits*,*on*,*off*[,*separator*[,*number_of_bits*]])

  Returns a string such that for every bit set in the value *bits*, you get an *on* string and for every bit not set in the value, you get an *off* string. Bits in *bits* are examined from right to left (from low-order to high-order bits). Strings are added to the result from left to right, separated by the *separator* string (the default being the comma character ","). The number of bits examined is given by *number_of_bits*, which has a default of 64 if not specified. *number_of_bits* is silently clipped to 64 if larger than 64. It is treated as an unsigned integer, so a value of −1 is effectively the same as 64.

  ```
  mysql> SELECT EXPORT_SET(5,'Y','N',',',4);
          -> 'Y,N,Y,N'
  mysql> SELECT EXPORT_SET(6,'1','0',',',10);
          -> '0,1,1,0,0,0,0,0,0,0'
  ```

- FIELD(*str*,*str1*,*str2*,*str3*,...)

  Returns the index (position) of *str* in the *str1*, *str2*, *str3*, ... list. Returns 0 if *str* is not found.

  If all arguments to FIELD() are strings, all arguments are compared as strings. If all arguments are numbers, they are compared as numbers. Otherwise, the arguments are compared as double.

  If *str* is NULL, the return value is 0 because NULL fails equality comparison with any value. FIELD() is the complement of ELT().

  ```
  mysql> SELECT FIELD('ej', 'Hej', 'ej', 'Heja', 'hej', 'foo');
  ```

```
         -> 2
mysql> SELECT FIELD('fo', 'Hej', 'ej', 'Heja', 'hej', 'foo');
         -> 0
```

- FIND_IN_SET(*str*,*strlist*)

  Returns a value in the range of 1 to *N* if the string *str* is in the string list *strlist* consisting of *N* substrings. A string list is a string composed of substrings separated by ",", characters. If the first argument is a constant string and the second is a column of type SET, the FIND_IN_SET() function is optimized to use bit arithmetic. Returns 0 if *str* is not in *strlist* or if *strlist* is the empty string. Returns NULL if either argument is NULL. This function does not work properly if the first argument contains a comma (",") character.

  ```
  mysql> SELECT FIND_IN_SET('b','a,b,c,d');
           -> 2
  ```

- FORMAT(*X*,*D*)

  Formats the number *X* to a format like '#,###,###.##', rounded to *D* decimal places, and returns the result as a string. If *D* is 0, the result has no decimal point or fractional part.

  ```
  mysql> SELECT FORMAT(12332.123456, 4);
           -> '12,332.1235'
  mysql> SELECT FORMAT(12332.1,4);
           -> '12,332.1000'
  mysql> SELECT FORMAT(12332.2,0);
           -> '12,332'
  ```

- HEX(*str*), HEX(*N*)

  For a string argument *str*, HEX() returns a hexadecimal string representation of *str* where each byte of each character in *str* is converted to two hexadecimal digits. (Multibyte characters therefore become more than two digits.) The inverse of this operation is performed by the UNHEX() function.

  For a numeric argument *N*, HEX() returns a hexadecimal string representation of the value of *N* treated as a longlong (BIGINT) number. This is equivalent to CONV(*N*,10,16). The inverse of this operation is performed by CONV(HEX(*N*),16,10).

  ```
  mysql> SELECT X'616263', HEX('abc'), UNHEX(HEX('abc'));
           -> 'abc', 616263, 'abc'
  mysql> SELECT HEX(255), CONV(HEX(255),16,10);
           -> 'FF', 255
  ```

- INSERT(*str*,*pos*,*len*,*newstr*)

  Returns the string *str*, with the substring beginning at position *pos* and *len* characters long replaced by the string *newstr*. Returns the original string if *pos* is not within the length of the string. Replaces the rest of the string from position *pos* if *len* is not within the length of the rest of the string. Returns NULL if any argument is NULL.

  ```
  mysql> SELECT INSERT('Quadratic', 3, 4, 'What');
           -> 'QuWhattic'
  mysql> SELECT INSERT('Quadratic', -1, 4, 'What');
           -> 'Quadratic'
  mysql> SELECT INSERT('Quadratic', 3, 100, 'What');
           -> 'QuWhat'
  ```

This function is multibyte safe.

- `INSTR(`*`str`*`,`*`substr`*`)`

  Returns the position of the first occurrence of substring *`substr`* in string *`str`*. This is the same as the two-argument form of `LOCATE()`, except that the order of the arguments is reversed.

  ```
  mysql> SELECT INSTR('foobarbar', 'bar');
          -> 4
  mysql> SELECT INSTR('xbar', 'foobar');
          -> 0
  ```

  This function is multibyte safe, and is case sensitive only if at least one argument is a binary string.

- `LCASE(`*`str`*`)`

  `LCASE()` is a synonym for `LOWER()`.

- `LEFT(`*`str`*`,`*`len`*`)`

  Returns the leftmost *`len`* characters from the string *`str`*, or `NULL` if any argument is `NULL`.

  ```
  mysql> SELECT LEFT('foobarbar', 5);
          -> 'fooba'
  ```

  This function is multibyte safe.

- `LENGTH(`*`str`*`)`

  Returns the length of the string *`str`*, measured in bytes. A multibyte character counts as multiple bytes. This means that for a string containing five 2-byte characters, `LENGTH()` returns `10`, whereas `CHAR_LENGTH()` returns `5`.

  ```
  mysql> SELECT LENGTH('text');
          -> 4
  ```

  Note

  The `Length()` OpenGIS spatial function is named `GLength()` in MySQL.

- `LOAD_FILE(`*`file_name`*`)`

  Reads the file and returns the file contents as a string. To use this function, the file must be located on the server host, you must specify the full path name to the file, and you must have the `FILE` privilege. The file must be readable by all and its size less than `max_allowed_packet` bytes. If the `secure_file_priv` system variable is set to a nonempty directory name, the file to be loaded must be located in that directory.

  If the file does not exist or cannot be read because one of the preceding conditions is not satisfied, the function returns `NULL`.

  As of MySQL 5.1.6, the `character_set_filesystem` system variable controls interpretation of file names that are given as literal strings.

  ```
  mysql> UPDATE t
  ```

```
            SET blob_col=LOAD_FILE('/tmp/picture')
            WHERE id=1;
```

- `LOCATE(substr,str)`, `LOCATE(substr,str,pos)`

  The first syntax returns the position of the first occurrence of substring `substr` in string `str`. The second syntax returns the position of the first occurrence of substring `substr` in string `str`, starting at position `pos`. Returns `0` if `substr` is not in `str`.

  ```
  mysql> SELECT LOCATE('bar', 'foobarbar');
          -> 4
  mysql> SELECT LOCATE('xbar', 'foobar');
          -> 0
  mysql> SELECT LOCATE('bar', 'foobarbar', 5);
          -> 7
  ```

  This function is multibyte safe, and is case-sensitive only if at least one argument is a binary string.

- `LOWER(str)`

  Returns the string `str` with all characters changed to lowercase according to the current character set mapping. The default is `latin1` (cp1252 West European).

  ```
  mysql> SELECT LOWER('QUADRATICALLY');
          -> 'quadratically'
  ```

  `LOWER()` (and `UPPER()`) are ineffective when applied to binary strings (`BINARY`, `VARBINARY`, `BLOB`). To perform lettercase conversion, convert the string to a nonbinary string:

  ```
  mysql> SET @str = BINARY 'New York';
  mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING latin1));
  +-------------+-----------------------------------+
  | LOWER(@str) | LOWER(CONVERT(@str USING latin1)) |
  +-------------+-----------------------------------+
  | New York    | new york                          |
  +-------------+-----------------------------------+
  ```

  This function is multibyte safe.

- `LPAD(str,len,padstr)`

  Returns the string `str`, left-padded with the string `padstr` to a length of `len` characters. If `str` is longer than `len`, the return value is shortened to `len` characters.

  ```
  mysql> SELECT LPAD('hi',4,'??');
          -> '??hi'
  mysql> SELECT LPAD('hi',1,'??');
          -> 'h'
  ```

- `LTRIM(str)`

  Returns the string `str` with leading space characters removed.

  ```
  mysql> SELECT LTRIM('  barbar');
          -> 'barbar'
  ```

  This function is multibyte safe.

- MAKE_SET(*bits*,*str1*,*str2*,...)

  Returns a set value (a string containing substrings separated by "," characters) consisting of the strings that have the corresponding bit in *bits* set. *str1* corresponds to bit 0, *str2* to bit 1, and so on. NULL values in *str1*, *str2*, ... are not appended to the result.

  ```
  mysql> SELECT MAKE_SET(1,'a','b','c');
          -> 'a'
  mysql> SELECT MAKE_SET(1 | 4,'hello','nice','world');
          -> 'hello,world'
  mysql> SELECT MAKE_SET(1 | 4,'hello','nice',NULL,'world');
          -> 'hello'
  mysql> SELECT MAKE_SET(0,'a','b','c');
          -> ''
  ```

- MID(*str*,*pos*,*len*)

  MID(*str*,*pos*,*len*) is a synonym for SUBSTRING(*str*,*pos*,*len*).

- OCT(*N*)

  Returns a string representation of the octal value of *N*, where *N* is a longlong (BIGINT) number. This is equivalent to CONV(*N*,10,8). Returns NULL if *N* is NULL.

  ```
  mysql> SELECT OCT(12);
          -> '14'
  ```

- OCTET_LENGTH(*str*)

  OCTET_LENGTH() is a synonym for LENGTH().

- ORD(*str*)

  If the leftmost character of the string *str* is a multibyte character, returns the code for that character, calculated from the numeric values of its constituent bytes using this formula:

  ```
    (1st byte code)
  + (2nd byte code * 256)
  + (3rd byte code * 256²) ...
  ```

  If the leftmost character is not a multibyte character, ORD() returns the same value as the ASCII() function.

  ```
  mysql> SELECT ORD('2');
          -> 50
  ```

- POSITION(*substr* IN *str*)

  POSITION(*substr* IN *str*) is a synonym for LOCATE(*substr*,*str*).

- QUOTE(*str*)

  Quotes a string to produce a result that can be used as a properly escaped data value in an SQL statement. The string is returned enclosed by single quotation marks and with each instance of backslash ("\"), single quote ("'"), ASCII NUL, and Control+Z preceded by a backslash. If the argument is NULL, the return value is the word "NULL" without enclosing single quotation marks.

```
mysql> SELECT QUOTE('Don\'t!');
        -> 'Don\'t!'
mysql> SELECT QUOTE(NULL);
        -> NULL
```

For comparison, see the quoting rules for literal strings and within the C API in Section 9.1.1, "String Literals", and Section 21.8.7.53, "mysql_real_escape_string()".

- REPEAT(*str*,*count*)

  Returns a string consisting of the string *str* repeated *count* times. If *count* is less than 1, returns an empty string. Returns NULL if *str* or *count* are NULL.

  ```
  mysql> SELECT REPEAT('MySQL', 3);
          -> 'MySQLMySQLMySQL'
  ```

- REPLACE(*str*,*from_str*,*to_str*)

  Returns the string *str* with all occurrences of the string *from_str* replaced by the string *to_str*. REPLACE() performs a case-sensitive match when searching for *from_str*.

  ```
  mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
          -> 'WwWwWw.mysql.com'
  ```

  This function is multibyte safe.

- REVERSE(*str*)

  Returns the string *str* with the order of the characters reversed.

  ```
  mysql> SELECT REVERSE('abc');
          -> 'cba'
  ```

  This function is multibyte safe.

- RIGHT(*str*,*len*)

  Returns the rightmost *len* characters from the string *str*, or NULL if any argument is NULL.

  ```
  mysql> SELECT RIGHT('foobarbar', 4);
          -> 'rbar'
  ```

  This function is multibyte safe.

- RPAD(*str*,*len*,*padstr*)

  Returns the string *str*, right-padded with the string *padstr* to a length of *len* characters. If *str* is longer than *len*, the return value is shortened to *len* characters.

  ```
  mysql> SELECT RPAD('hi',5,'?');
          -> 'hi???'
  mysql> SELECT RPAD('hi',1,'?');
          -> 'h'
  ```

  This function is multibyte safe.

- RTRIM(*str*)

  Returns the string *str* with trailing space characters removed.

  ```
  mysql> SELECT RTRIM('barbar   ');
          -> 'barbar'
  ```

  This function is multibyte safe.

- SOUNDEX(*str*)

  Returns a soundex string from *str*. Two strings that sound almost the same should have identical soundex strings. A standard soundex string is four characters long, but the SOUNDEX() function returns an arbitrarily long string. You can use SUBSTRING() on the result to get a standard soundex string. All nonalphabetic characters in *str* are ignored. All international alphabetic characters outside the A-Z range are treated as vowels.

  > **Important**
  >
  > When using SOUNDEX(), you should be aware of the following limitations:

  - This function, as currently implemented, is intended to work well with strings that are in the English language only. Strings in other languages may not produce reliable results.

  - This function is not guaranteed to provide consistent results with strings that use multibyte character sets, including utf-8.

    We hope to remove these limitations in a future release. See Bug #22638 for more information.

  ```
  mysql> SELECT SOUNDEX('Hello');
          -> 'H400'
  mysql> SELECT SOUNDEX('Quadratically');
          -> 'Q36324'
  ```

  > **Note**
  >
  > This function implements the original Soundex algorithm, not the more popular enhanced version (also described by D. Knuth). The difference is that original version discards vowels first and duplicates second, whereas the enhanced version discards duplicates first and vowels second.

- *expr1* SOUNDS LIKE *expr2*

  This is the same as SOUNDEX(*expr1*) = SOUNDEX(*expr2*).

- SPACE(*N*)

  Returns a string consisting of *N* space characters.

  ```
  mysql> SELECT SPACE(6);
          -> '      '
  ```

- SUBSTR(*str*,*pos*), SUBSTR(*str* FROM *pos*), SUBSTR(*str*,*pos*,*len*), SUBSTR(*str* FROM *pos* FOR *len*)

  SUBSTR() is a synonym for SUBSTRING().

- SUBSTRING(*str*,*pos*), SUBSTRING(*str* FROM *pos*), SUBSTRING(*str*,*pos*,*len*), SUBSTRING(*str* FROM *pos* FOR *len*)

  The forms without a *len* argument return a substring from string *str* starting at position *pos*. The forms with a *len* argument return a substring *len* characters long from string *str*, starting at position *pos*. The forms that use FROM are standard SQL syntax. It is also possible to use a negative value for *pos*. In this case, the beginning of the substring is *pos* characters from the end of the string, rather than the beginning. A negative value may be used for *pos* in any of the forms of this function.

  For all forms of SUBSTRING(), the position of the first character in the string from which the substring is to be extracted is reckoned as 1.

  ```
  mysql> SELECT SUBSTRING('Quadratically',5);
          -> 'ratically'
  mysql> SELECT SUBSTRING('foobarbar' FROM 4);
          -> 'barbar'
  mysql> SELECT SUBSTRING('Quadratically',5,6);
          -> 'ratica'
  mysql> SELECT SUBSTRING('Sakila', -3);
          -> 'ila'
  mysql> SELECT SUBSTRING('Sakila', -5, 3);
          -> 'aki'
  mysql> SELECT SUBSTRING('Sakila' FROM -4 FOR 2);
          -> 'ki'
  ```

  This function is multibyte safe.

  If *len* is less than 1, the result is the empty string.

- SUBSTRING_INDEX(*str*,*delim*,*count*)

  Returns the substring from string *str* before *count* occurrences of the delimiter *delim*. If *count* is positive, everything to the left of the final delimiter (counting from the left) is returned. If *count* is negative, everything to the right of the final delimiter (counting from the right) is returned. SUBSTRING_INDEX() performs a case-sensitive match when searching for *delim*.

  ```
  mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', 2);
          -> 'www.mysql'
  mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', -2);
          -> 'mysql.com'
  ```

  This function is multibyte safe.

- TRIM([{BOTH | LEADING | TRAILING} [*remstr*] FROM] *str*), TRIM([*remstr* FROM] *str*)

  Returns the string *str* with all *remstr* prefixes or suffixes removed. If none of the specifiers BOTH, LEADING, or TRAILING is given, BOTH is assumed. *remstr* is optional and, if not specified, spaces are removed.

  ```
  mysql> SELECT TRIM('  bar   ');
          -> 'bar'
  mysql> SELECT TRIM(LEADING 'x' FROM 'xxxbarxxx');
          -> 'barxxx'
  mysql> SELECT TRIM(BOTH 'x' FROM 'xxxbarxxx');
          -> 'bar'
  mysql> SELECT TRIM(TRAILING 'xyz' FROM 'barxxyz');
          -> 'barx'
  ```

This function is multibyte safe.

- `UCASE(str)`

  `UCASE()` is a synonym for `UPPER()`.

- `UNHEX(str)`

  For a string argument `str`, `UNHEX(str)` interprets each pair of characters in the argument as a hexadecimal number and converts it to the byte represented by the number. The return value is a binary string.

  ```
  mysql> SELECT UNHEX('4D7953514C');
          -> 'MySQL'
  mysql> SELECT X'4D7953514C';
          -> 'MySQL'
  mysql> SELECT UNHEX(HEX('string'));
          -> 'string'
  mysql> SELECT HEX(UNHEX('1267'));
          -> '1267'
  ```

  The characters in the argument string must be legal hexadecimal digits: `'0'` .. `'9'`, `'A'` .. `'F'`, `'a'` .. `'f'`. If the argument contains any nonhexadecimal digits, the result is `NULL`:

  ```
  mysql> SELECT UNHEX('GG');
  +-------------+
  | UNHEX('GG') |
  +-------------+
  | NULL        |
  +-------------+
  ```

  A `NULL` result can occur if the argument to `UNHEX()` is a `BINARY` column, because values are padded with 0x00 bytes when stored but those bytes are not stripped on retrieval. For example, `'41'` is stored into a `CHAR(3)` column as `'41 '` and retrieved as `'41'` (with the trailing pad space stripped), so `UNHEX()` for the column value returns `'A'`. By contrast `'41'` is stored into a `BINARY(3)` column as `'41\0'` and retrieved as `'41\0'` (with the trailing pad `0x00` byte not stripped). `'\0'` is not a legal hexadecimal digit, so `UNHEX()` for the column value returns `NULL`.

  For a numeric argument `N`, the inverse of `HEX(N)` is not performed by `UNHEX()`. Use `CONV(HEX(N),16,10)` instead. See the description of `HEX()`.

- `UPPER(str)`

  Returns the string `str` with all characters changed to uppercase according to the current character set mapping. The default is `latin1` (cp1252 West European).

  ```
  mysql> SELECT UPPER('Hej');
          -> 'HEJ'
  ```

  See the description of `LOWER()` for information that also applies to `UPPER()`, such as information about how to perform lettercase conversion of binary strings (`BINARY`, `VARBINARY`, `BLOB`) for which these functions are ineffective.

  This function is multibyte safe.

12.5.1 String Comparison Functions

Table 12.8 String Comparison Operators

Name	Description
LIKE	Simple pattern matching
NOT LIKE	Negation of simple pattern matching
STRCMP()	Compare two strings

If a string function is given a binary string as an argument, the resulting string is also a binary string. A number converted to a string is treated as a binary string. This affects only comparisons.

Normally, if any expression in a string comparison is case sensitive, the comparison is performed in case-sensitive fashion.

- `expr LIKE pat [ESCAPE 'escape_char']`

  Pattern matching using an SQL pattern. Returns 1 (TRUE) or 0 (FALSE). If either `expr` or `pat` is NULL, the result is NULL.

  The pattern need not be a literal string. For example, it can be specified as a string expression or table column.

  Per the SQL standard, LIKE performs matching on a per-character basis, thus it can produce results different from the = comparison operator:

  ```
  mysql> SELECT 'ä' LIKE 'ae' COLLATE latin1_german2_ci;
  +----------------------------------------+
  | 'ä' LIKE 'ae' COLLATE latin1_german2_ci |
  +----------------------------------------+
  |                                      0 |
  +----------------------------------------+
  mysql> SELECT 'ä' = 'ae' COLLATE latin1_german2_ci;
  +-------------------------------------+
  | 'ä' = 'ae' COLLATE latin1_german2_ci |
  +-------------------------------------+
  |                                   1 |
  +-------------------------------------+
  ```

  In particular, trailing spaces are significant, which is not true for CHAR or VARCHAR comparisons performed with the = operator:

  ```
  mysql> SELECT 'a' = 'a ', 'a' LIKE 'a ';
  +------------+---------------+
  | 'a' = 'a ' | 'a' LIKE 'a ' |
  +------------+---------------+
  |          1 |             0 |
  +------------+---------------+
  1 row in set (0.00 sec)
  ```

  With LIKE you can use the following two wildcard characters in the pattern:

  - % matches any number of characters, even zero characters.

  - _ matches exactly one character.

  ```
  mysql> SELECT 'David!' LIKE 'David_';
          -> 1
  mysql> SELECT 'David!' LIKE '%D%v%';
          -> 1
  ```

To test for literal instances of a wildcard character, precede it by the escape character. If you do not specify the ESCAPE character, "\" is assumed.

- \% matches one "%" character.

- _ matches one "_" character.

```
mysql> SELECT 'David!' LIKE 'David\_';
        -> 0
mysql> SELECT 'David_' LIKE 'David\_';
        -> 1
```

To specify a different escape character, use the ESCAPE clause:

```
mysql> SELECT 'David_' LIKE 'David|_' ESCAPE '|';
        -> 1
```

The escape sequence should be empty or one character long. The expression must evaluate as a constant at execution time. As of MySQL 5.1.2, if the NO_BACKSLASH_ESCAPES SQL mode is enabled, the sequence cannot be empty.

The following two statements illustrate that string comparisons are not case sensitive unless one of the operands is a case sensitive (uses a case-sensitive collation or is a binary string):

```
mysql> SELECT 'abc' LIKE 'ABC';
        -> 1
mysql> SELECT 'abc' LIKE _latin1 'ABC' COLLATE latin1_general_cs;
        -> 0
mysql> SELECT 'abc' LIKE _latin1 'ABC' COLLATE latin1_bin;
        -> 0
mysql> SELECT 'abc' LIKE BINARY 'ABC';
        -> 0
```

As an extension to standard SQL, MySQL permits LIKE on numeric expressions.

```
mysql> SELECT 10 LIKE '1%';
        -> 1
```

Note

Because MySQL uses C escape syntax in strings (for example, "\n" to represent a newline character), you must double any "\" that you use in LIKE strings. For example, to search for "\n", specify it as "\\n". To search for "\", specify it as "\\\\"; this is because the backslashes are stripped once by the parser and again when the pattern match is made, leaving a single backslash to be matched against.

Exception: At the end of the pattern string, backslash can be specified as "\\". At the end of the string, backslash stands for itself because there is nothing following to escape. Suppose that a table contains the following values:

```
mysql> SELECT filename FROM t1;
+--------------+
| filename     |
+--------------+
```

```
| C:            |
| C:\           |
| C:\Programs   |
| C:\Programs\  |
+---------------+
```

To test for values that end with backslash, you can match the values using either of the following patterns:

```
mysql> SELECT filename, filename LIKE '%\\' FROM t1;
+--------------+---------------------+
| filename     | filename LIKE '%\\' |
+--------------+---------------------+
| C:           |                   0 |
| C:\          |                   1 |
| C:\Programs  |                   0 |
| C:\Programs\ |                   1 |
+--------------+---------------------+

mysql> SELECT filename, filename LIKE '%\\\\' FROM t1;
+--------------+-----------------------+
| filename     | filename LIKE '%\\\\' |
+--------------+-----------------------+
| C:           |                     0 |
| C:\          |                     1 |
| C:\Programs  |                     0 |
| C:\Programs\ |                     1 |
+--------------+-----------------------+
```

- *expr* NOT LIKE *pat* [ESCAPE '*escape_char*']

  This is the same as NOT (*expr* LIKE *pat* [ESCAPE '*escape_char*']).

  Note

  Aggregate queries involving NOT LIKE comparisons with columns containing NULL may yield unexpected results. For example, consider the following table and data:

  ```
  CREATE TABLE foo (bar VARCHAR(10));

  INSERT INTO foo VALUES (NULL), (NULL);
  ```

  The query SELECT COUNT(*) FROM foo WHERE bar LIKE '%baz%'; returns 0. You might assume that SELECT COUNT(*) FROM foo WHERE bar NOT LIKE '%baz%'; would return 2. However, this is not the case: The second query returns 0. This is because NULL NOT LIKE *expr* always returns NULL, regardless of the value of *expr*. The same is true for aggregate queries involving NULL and comparisons using NOT RLIKE or NOT REGEXP. In such cases, you must test explicitly for NOT NULL using OR (and not AND), as shown here:

  ```
  SELECT COUNT(*) FROM foo WHERE bar NOT LIKE '%baz%' OR bar IS NULL;
  ```

- STRCMP(*expr1*,*expr2*)

  STRCMP() returns 0 if the strings are the same, -1 if the first argument is smaller than the second according to the current sort order, and 1 otherwise.

```
mysql> SELECT STRCMP('text', 'text2');
        -> -1
mysql> SELECT STRCMP('text2', 'text');
        -> 1
mysql> SELECT STRCMP('text', 'text');
        -> 0
```

STRCMP() performs the comparison using the collation of the arguments.

```
mysql> SET @s1 = _latin1 'x' COLLATE latin1_general_ci;
mysql> SET @s2 = _latin1 'X' COLLATE latin1_general_ci;
mysql> SET @s3 = _latin1 'x' COLLATE latin1_general_cs;
mysql> SET @s4 = _latin1 'X' COLLATE latin1_general_cs;
mysql> SELECT STRCMP(@s1, @s2), STRCMP(@s3, @s4);
+------------------+------------------+
| STRCMP(@s1, @s2) | STRCMP(@s3, @s4) |
+------------------+------------------+
|                0 |                1 |
+------------------+------------------+
```

If the collations are incompatible, one of the arguments must be converted to be compatible with the other. See Section 10.1.7.5, "Collation of Expressions".

```
mysql> SELECT STRCMP(@s1, @s3);
ERROR 1267 (HY000): Illegal mix of collations (latin1_general_ci,IMPLICIT)
and (latin1_general_cs,IMPLICIT) for operation 'strcmp'
mysql> SELECT STRCMP(@s1, @s3 COLLATE latin1_general_ci);
+--------------------------------------------+
| STRCMP(@s1, @s3 COLLATE latin1_general_ci) |
+--------------------------------------------+
|                                          0 |
+--------------------------------------------+
```

12.5.2 Regular Expressions

Table 12.9 String Regular Expression Operators

Name	Description
NOT REGEXP	Negation of REGEXP
REGEXP	Pattern matching using regular expressions
RLIKE	Synonym for REGEXP

A regular expression is a powerful way of specifying a pattern for a complex search.

MySQL uses Henry Spencer's implementation of regular expressions, which is aimed at conformance with POSIX 1003.2. MySQL uses the extended version to support pattern-matching operations performed with the REGEXP operator in SQL statements.

This section summarizes, with examples, the special characters and constructs that can be used in MySQL for REGEXP operations. It does not contain all the details that can be found in Henry Spencer's regex(7) manual page. That manual page is included in MySQL source distributions, in the regex.7 file under the regex directory. See also Section 3.3.4.7, "Pattern Matching".

Regular Expression Operators

- *expr* NOT REGEXP *pat*, *expr* NOT RLIKE *pat*

  This is the same as NOT (*expr* REGEXP *pat*).

- *expr* `REGEXP` *pat*, *expr* `RLIKE` *pat*

  Performs a pattern match of a string expression *expr* against a pattern *pat*. The pattern can be an extended regular expression, the syntax for which is discussed later in this section. Returns `1` if *expr* matches *pat*; otherwise it returns `0`. If either *expr* or *pat* is `NULL`, the result is `NULL`. `RLIKE` is a synonym for `REGEXP`, provided for `mSQL` compatibility.

  The pattern need not be a literal string. For example, it can be specified as a string expression or table column.

  > **Note**
  >
  > Because MySQL uses the C escape syntax in strings (for example, "`\n`" to represent the newline character), you must double any "`\`" that you use in your `REGEXP` strings.

  `REGEXP` is not case sensitive, except when used with binary strings.

  ```
  mysql> SELECT 'Monty!' REGEXP '.*';
          -> 1
  mysql> SELECT 'new*\n*line' REGEXP 'new\\*.\\*line';
          -> 1
  mysql> SELECT 'a' REGEXP 'A', 'a' REGEXP BINARY 'A';
          -> 1  0
  mysql> SELECT 'a' REGEXP '^[a-d]';
          -> 1
  ```

  `REGEXP` and `RLIKE` use the character set and collations of the arguments when deciding the type of a character and performing the comparison. If the arguments have different character sets or collations, coercibility rules apply as described in Section 10.1.7.5, "Collation of Expressions".

  > **Warning**
  >
  > The `REGEXP` and `RLIKE` operators work in byte-wise fashion, so they are not multibyte safe and may produce unexpected results with multibyte character sets. In addition, these operators compare characters by their byte values and accented characters may not compare as equal even if a given collation treats them as equal.

Syntax of Regular Expressions

A regular expression describes a set of strings. The simplest regular expression is one that has no special characters in it. For example, the regular expression `hello` matches `hello` and nothing else.

Nontrivial regular expressions use certain special constructs so that they can match more than one string. For example, the regular expression `hello|word` matches either the string `hello` or the string `word`.

As a more complex example, the regular expression `B[an]*s` matches any of the strings `Bananas`, `Baaaaas`, `Bs`, and any other string starting with a `B`, ending with an `s`, and containing any number of `a` or `n` characters in between.

A regular expression for the `REGEXP` operator may use any of the following special characters and constructs:

- `^`

  Match the beginning of a string.

```
mysql> SELECT 'fo\nfo' REGEXP '^fo$';                      -> 0
mysql> SELECT 'fofo' REGEXP '^fo';                         -> 1
```

- $

  Match the end of a string.

```
mysql> SELECT 'fo\no' REGEXP '^fo\no$';                    -> 1
mysql> SELECT 'fo\no' REGEXP '^fo$';                       -> 0
```

- .

  Match any character (including carriage return and newline).

```
mysql> SELECT 'fofo' REGEXP '^f.*$';                       -> 1
mysql> SELECT 'fo\r\nfo' REGEXP '^f.*$';                   -> 1
```

- a*

  Match any sequence of zero or more a characters.

```
mysql> SELECT 'Ban' REGEXP '^Ba*n';                        -> 1
mysql> SELECT 'Baaan' REGEXP '^Ba*n';                      -> 1
mysql> SELECT 'Bn' REGEXP '^Ba*n';                         -> 1
```

- a+

  Match any sequence of one or more a characters.

```
mysql> SELECT 'Ban' REGEXP '^Ba+n';                        -> 1
mysql> SELECT 'Bn' REGEXP '^Ba+n';                         -> 0
```

- a?

  Match either zero or one a character.

```
mysql> SELECT 'Bn' REGEXP '^Ba?n';                         -> 1
mysql> SELECT 'Ban' REGEXP '^Ba?n';                        -> 1
mysql> SELECT 'Baan' REGEXP '^Ba?n';                       -> 0
```

- de|abc

  Match either of the sequences de or abc.

```
mysql> SELECT 'pi' REGEXP 'pi|apa';                        -> 1
mysql> SELECT 'axe' REGEXP 'pi|apa';                       -> 0
mysql> SELECT 'apa' REGEXP 'pi|apa';                       -> 1
mysql> SELECT 'apa' REGEXP '^(pi|apa)$';                   -> 1
mysql> SELECT 'pi' REGEXP '^(pi|apa)$';                    -> 1
mysql> SELECT 'pix' REGEXP '^(pi|apa)$';                   -> 0
```

- (abc)*

  Match zero or more instances of the sequence abc.

```
mysql> SELECT 'pi' REGEXP '^(pi)*$';                 -> 1
mysql> SELECT 'pip' REGEXP '^(pi)*$';                -> 0
mysql> SELECT 'pipi' REGEXP '^(pi)*$';               -> 1
```

- `{1}`, `{2,3}`

  `{n}` or `{m,n}` notation provides a more general way of writing regular expressions that match many occurrences of the previous atom (or "piece") of the pattern. `m` and `n` are integers.

  - `a*`

    Can be written as `a{0,}`.

  - `a+`

    Can be written as `a{1,}`.

  - `a?`

    Can be written as `a{0,1}`.

  To be more precise, `a{n}` matches exactly `n` instances of `a`. `a{n,}` matches `n` or more instances of `a`. `a{m,n}` matches `m` through `n` instances of `a`, inclusive.

  `m` and `n` must be in the range from `0` to `RE_DUP_MAX` (default 255), inclusive. If both `m` and `n` are given, `m` must be less than or equal to `n`.

  ```
  mysql> SELECT 'abcde' REGEXP 'a[bcd]{2}e';          -> 0
  mysql> SELECT 'abcde' REGEXP 'a[bcd]{3}e';          -> 1
  mysql> SELECT 'abcde' REGEXP 'a[bcd]{1,10}e';       -> 1
  ```

- `[a-dX]`, `[^a-dX]`

  Matches any character that is (or is not, if `^` is used) either `a`, `b`, `c`, `d` or `X`. A `-` character between two other characters forms a range that matches all characters from the first character to the second. For example, `[0-9]` matches any decimal digit. To include a literal `]` character, it must immediately follow the opening bracket `[`. To include a literal `-` character, it must be written first or last. Any character that does not have a defined special meaning inside a `[]` pair matches only itself.

  ```
  mysql> SELECT 'aXbc' REGEXP '[a-dXYZ]';             -> 1
  mysql> SELECT 'aXbc' REGEXP '^[a-dXYZ]$';           -> 0
  mysql> SELECT 'aXbc' REGEXP '^[a-dXYZ]+$';          -> 1
  mysql> SELECT 'aXbc' REGEXP '^[^a-dXYZ]+$';         -> 0
  mysql> SELECT 'gheis' REGEXP '^[^a-dXYZ]+$';        -> 1
  mysql> SELECT 'gheisa' REGEXP '^[^a-dXYZ]+$';       -> 0
  ```

- `[.characters.]`

  Within a bracket expression (written using `[` and `]`), matches the sequence of characters of that collating element. `characters` is either a single character or a character name like `newline`. The following table lists the permissible character names.

  The following table shows the permissible character names and the characters that they match. For characters given as numeric values, the values are represented in octal.

Name	Character	Name	Character
NUL	0	SOH	001

Name	Character	Name	Character
STX	002	ETX	003
EOT	004	ENQ	005
ACK	006	BEL	007
alert	007	BS	010
backspace	'\b'	HT	011
tab	'\t'	LF	012
newline	'\n'	VT	013
vertical-tab	'\v'	FF	014
form-feed	'\f'	CR	015
carriage-return	'\r'	SO	016
SI	017	DLE	020
DC1	021	DC2	022
DC3	023	DC4	024
NAK	025	SYN	026
ETB	027	CAN	030
EM	031	SUB	032
ESC	033	IS4	034
FS	034	IS3	035
GS	035	IS2	036
RS	036	IS1	037
US	037	space	' '
exclamation-mark	'!'	quotation-mark	'"'
number-sign	'#'	dollar-sign	'$'
percent-sign	'%'	ampersand	'&'
apostrophe	'\''	left-parenthesis	'('
right-parenthesis	')'	asterisk	'*'
plus-sign	'+'	comma	','
hyphen	'-'	hyphen-minus	'-'
period	'.'	full-stop	'.'
slash	'/'	solidus	'/'
zero	'0'	one	'1'
two	'2'	three	'3'
four	'4'	five	'5'
six	'6'	seven	'7'
eight	'8'	nine	'9'
colon	':'	semicolon	';'
less-than-sign	'<'	equals-sign	'='
greater-than-sign	'>'	question-mark	'?'

Name	Character	Name	Character
commercial-at	'@'	left-square-bracket	'['
backslash	'\\'	reverse-solidus	'\\'
right-square-bracket	']'	circumflex	'^'
circumflex-accent	'^'	underscore	'_'
low-line	'_'	grave-accent	'`'
left-brace	'{'	left-curly-bracket	'{'
vertical-line	'|'	right-brace	'}'
right-curly-bracket	'}'	tilde	'~'
DEL	177		

```
mysql> SELECT '~' REGEXP '[[.~.]]';                       -> 1
mysql> SELECT '~' REGEXP '[[.tilde.]]';                   -> 1
```

- [=character_class=]

  Within a bracket expression (written using [and]), [=character_class=] represents an equivalence class. It matches all characters with the same collation value, including itself. For example, if o and (+) are the members of an equivalence class, [[=o=]], [[=(+)=]], and [o(+)] are all synonymous. An equivalence class may not be used as an endpoint of a range.

- [:character_class:]

  Within a bracket expression (written using [and]), [:character_class:] represents a character class that matches all characters belonging to that class. The following table lists the standard class names. These names stand for the character classes defined in the ctype(3) manual page. A particular locale may provide other class names. A character class may not be used as an endpoint of a range.

Character Class Name	Meaning
alnum	Alphanumeric characters
alpha	Alphabetic characters
blank	Whitespace characters
cntrl	Control characters
digit	Digit characters
graph	Graphic characters
lower	Lowercase alphabetic characters
print	Graphic or space characters
punct	Punctuation characters
space	Space, tab, newline, and carriage return
upper	Uppercase alphabetic characters
xdigit	Hexadecimal digit characters

```
mysql> SELECT 'justalnums' REGEXP '[[:alnum:]]+';       -> 1
mysql> SELECT '!!' REGEXP '[[:alnum:]]+';               -> 0
```

- `[[:<:]]`, `[[:>:]]`

  These markers stand for word boundaries. They match the beginning and end of words, respectively. A word is a sequence of word characters that is not preceded by or followed by word characters. A word character is an alphanumeric character in the `alnum` class or an underscore (`_`).

```
mysql> SELECT 'a word a' REGEXP '[[:<:]]word[[:>:]]';   -> 1
mysql> SELECT 'a xword a' REGEXP '[[:<:]]word[[:>:]]';  -> 0
```

To use a literal instance of a special character in a regular expression, precede it by two backslash (\) characters. The MySQL parser interprets one of the backslashes, and the regular expression library interprets the other. For example, to match the string `1+2` that contains the special `+` character, only the last of the following regular expressions is the correct one:

```
mysql> SELECT '1+2' REGEXP '1+2';                        -> 0
mysql> SELECT '1+2' REGEXP '1\+2';                       -> 0
mysql> SELECT '1+2' REGEXP '1\\+2';                      -> 1
```

12.6 Numeric Functions and Operators

Table 12.10 Numeric Functions and Operators

Name	Description
`ABS()`	Return the absolute value
`ACOS()`	Return the arc cosine
`ASIN()`	Return the arc sine
`ATAN()`	Return the arc tangent
`ATAN2()`, `ATAN()`	Return the arc tangent of the two arguments
`CEIL()`	Return the smallest integer value not less than the argument
`CEILING()`	Return the smallest integer value not less than the argument
`CONV()`	Convert numbers between different number bases
`COS()`	Return the cosine
`COT()`	Return the cotangent
`CRC32()`	Compute a cyclic redundancy check value
`DEGREES()`	Convert radians to degrees
`DIV`	Integer division
`/`	Division operator
`EXP()`	Raise to the power of
`FLOOR()`	Return the largest integer value not greater than the argument
`LN()`	Return the natural logarithm of the argument
`LOG()`	Return the natural logarithm of the first argument
`LOG10()`	Return the base-10 logarithm of the argument
`LOG2()`	Return the base-2 logarithm of the argument

Name	Description
-	Minus operator
`MOD()`	Return the remainder
`%, MOD`	Modulo operator
`PI()`	Return the value of pi
+	Addition operator
`POW()`	Return the argument raised to the specified power
`POWER()`	Return the argument raised to the specified power
`RADIANS()`	Return argument converted to radians
`RAND()`	Return a random floating-point value
`ROUND()`	Round the argument
`SIGN()`	Return the sign of the argument
`SIN()`	Return the sine of the argument
`SQRT()`	Return the square root of the argument
`TAN()`	Return the tangent of the argument
*	Multiplication operator
`TRUNCATE()`	Truncate to specified number of decimal places
-	Change the sign of the argument

12.6.1 Arithmetic Operators

Table 12.11 Arithmetic Operators

Name	Description
`DIV`	Integer division
/	Division operator
-	Minus operator
`%, MOD`	Modulo operator
+	Addition operator
*	Multiplication operator
-	Change the sign of the argument

The usual arithmetic operators are available. The result is determined according to the following rules:

- In the case of `-`, `+`, and `*`, the result is calculated with `BIGINT` (64-bit) precision if both operands are integers.

- If both operands are integers and any of them are unsigned, the result is an unsigned integer. For subtraction, if the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled, the result is signed even if any operand is unsigned.

- If any of the operands of a `+`, `-`, `/`, `*`, `%` is a real or string value, the precision of the result is the precision of the operand with the maximum precision.

- In division performed with `/`, the scale of the result when using two exact-value operands is the scale of the first operand plus the value of the `div_precision_increment` system variable (which is 4 by

default). For example, the result of the expression `5.05 / 0.014` has a scale of six decimal places (`360.714286`).

These rules are applied for each operation, such that nested calculations imply the precision of each component. Hence, `(14620 / 9432456) / (24250 / 9432456)`, resolves first to `(0.0014) / (0.0026)`, with the final result having 8 decimal places (`0.60288653`).

Because of these rules and the way they are applied, care should be taken to ensure that components and subcomponents of a calculation use the appropriate level of precision. See Section 12.10, "Cast Functions and Operators".

For information about handling of overflow in numeric expression evaluation, see Section 11.2.6, "Out-of-Range and Overflow Handling".

Arithmetic operators apply to numbers. For other types of values, alternative operations may be available. For example, to add date values, use `DATE_ADD()`; see Section 12.7, "Date and Time Functions".

- `+`

  Addition:

  ```
  mysql> SELECT 3+5;
          -> 8
  ```

- `-`

  Subtraction:

  ```
  mysql> SELECT 3-5;
          -> -2
  ```

- `-`

  Unary minus. This operator changes the sign of the operand.

  ```
  mysql> SELECT - 2;
          -> -2
  ```

  > **Note**
  >
  > If this operator is used with a `BIGINT`, the return value is also a `BIGINT`. This means that you should avoid using `-` on integers that may have the value of -2^{63}.

- `*`

  Multiplication:

  ```
  mysql> SELECT 3*5;
          -> 15
  mysql> SELECT 18014398509481984*18014398509481984.0;
          -> 324518553658426726783156020576256.0
  ```

- `/`

  Division:

```
mysql> SELECT 3/5;
        -> 0.60
```

Division by zero produces a `NULL` result:

```
mysql> SELECT 102/(1-1);
        -> NULL
```

A division is calculated with `BIGINT` arithmetic only if performed in a context where its result is converted to an integer.

- `DIV`

  Integer division. Discards from the division result any fractional part to the right of the decimal point. Incorrect results may occur for noninteger operands that exceed `BIGINT` range.

  ```
  mysql> SELECT 5 DIV 2, -5 DIV 2, 5 DIV -2, -5 DIV -2;
          -> 2, -2, -2, 2
  ```

- *N* % *M*, *N* MOD *M*

  Modulo operation. Returns the remainder of *N* divided by *M*. For more information, see the description for the `MOD()` function in Section 12.6.2, "Mathematical Functions".

12.6.2 Mathematical Functions

Table 12.12 Mathematical Functions

Name	Description
ABS()	Return the absolute value
ACOS()	Return the arc cosine
ASIN()	Return the arc sine
ATAN()	Return the arc tangent
ATAN2(), ATAN()	Return the arc tangent of the two arguments
CEIL()	Return the smallest integer value not less than the argument
CEILING()	Return the smallest integer value not less than the argument
CONV()	Convert numbers between different number bases
COS()	Return the cosine
COT()	Return the cotangent
CRC32()	Compute a cyclic redundancy check value
DEGREES()	Convert radians to degrees
EXP()	Raise to the power of
FLOOR()	Return the largest integer value not greater than the argument
LN()	Return the natural logarithm of the argument
LOG()	Return the natural logarithm of the first argument
LOG10()	Return the base-10 logarithm of the argument
LOG2()	Return the base-2 logarithm of the argument
MOD()	Return the remainder

Name	Description
PI()	Return the value of pi
POW()	Return the argument raised to the specified power
POWER()	Return the argument raised to the specified power
RADIANS()	Return argument converted to radians
RAND()	Return a random floating-point value
ROUND()	Round the argument
SIGN()	Return the sign of the argument
SIN()	Return the sine of the argument
SQRT()	Return the square root of the argument
TAN()	Return the tangent of the argument
TRUNCATE()	Truncate to specified number of decimal places

All mathematical functions return NULL in the event of an error.

- ABS(X)

  Returns the absolute value of X.

  ```
  mysql> SELECT ABS(2);
          -> 2
  mysql> SELECT ABS(-32);
          -> 32
  ```

  This function is safe to use with BIGINT values.

- ACOS(X)

  Returns the arc cosine of X, that is, the value whose cosine is X. Returns NULL if X is not in the range -1 to 1.

  ```
  mysql> SELECT ACOS(1);
          -> 0
  mysql> SELECT ACOS(1.0001);
          -> NULL
  mysql> SELECT ACOS(0);
          -> 1.5707963267949
  ```

- ASIN(X)

  Returns the arc sine of X, that is, the value whose sine is X. Returns NULL if X is not in the range -1 to 1.

  ```
  mysql> SELECT ASIN(0.2);
          -> 0.20135792079033
  mysql> SELECT ASIN('foo');

  +-------------+
  | ASIN('foo') |
  +-------------+
  |           0 |
  +-------------+
  1 row in set, 1 warning (0.00 sec)

  mysql> SHOW WARNINGS;
  ```

```
+---------+------+-----------------------------------------+
| Level   | Code | Message                                 |
+---------+------+-----------------------------------------+
| Warning | 1292 | Truncated incorrect DOUBLE value: 'foo' |
+---------+------+-----------------------------------------+
```

- ATAN(*X*)

  Returns the arc tangent of *X*, that is, the value whose tangent is *X*.

  ```
  mysql> SELECT ATAN(2);
          -> 1.1071487177941
  mysql> SELECT ATAN(-2);
          -> -1.1071487177941
  ```

- ATAN(*Y*,*X*), ATAN2(*Y*,*X*)

  Returns the arc tangent of the two variables *X* and *Y*. It is similar to calculating the arc tangent of *Y* / *X*, except that the signs of both arguments are used to determine the quadrant of the result.

  ```
  mysql> SELECT ATAN(-2,2);
          -> -0.78539816339745
  mysql> SELECT ATAN2(PI(),0);
          -> 1.5707963267949
  ```

- CEIL(*X*)

  CEIL() is a synonym for CEILING().

- CEILING(*X*)

  Returns the smallest integer value not less than *X*.

  ```
  mysql> SELECT CEILING(1.23);
          -> 2
  mysql> SELECT CEILING(-1.23);
          -> -1
  ```

  For exact-value numeric arguments, the return value has an exact-value numeric type. For string or floating-point arguments, the return value has a floating-point type.

- CONV(*N*,*from_base*,*to_base*)

  Converts numbers between different number bases. Returns a string representation of the number *N*, converted from base *from_base* to base *to_base*. Returns NULL if any argument is NULL. The argument *N* is interpreted as an integer, but may be specified as an integer or a string. The minimum base is 2 and the maximum base is 36. If *from_base* is a negative number, *N* is regarded as a signed number. Otherwise, *N* is treated as unsigned. CONV() works with 64-bit precision.

  ```
  mysql> SELECT CONV('a',16,2);
          -> '1010'
  mysql> SELECT CONV('6E',18,8);
          -> '172'
  mysql> SELECT CONV(-17,10,-18);
          -> '-H'
  mysql> SELECT CONV(10+'10'+'10'+X'0a',10,10);
          -> '40'
  ```

- COS(*X*)

Returns the cosine of X, where X is given in radians.

```
mysql> SELECT COS(PI());
        -> -1
```

- COT(X)

Returns the cotangent of X.

```
mysql> SELECT COT(12);
        -> -1.5726734063977
mysql> SELECT COT(0);
        -> NULL
```

- CRC32($expr$)

Computes a cyclic redundancy check value and returns a 32-bit unsigned value. The result is NULL if the argument is NULL. The argument is expected to be a string and (if possible) is treated as one if it is not.

```
mysql> SELECT CRC32('MySQL');
        -> 3259397556
mysql> SELECT CRC32('mysql');
        -> 2501908538
```

- DEGREES(X)

Returns the argument X, converted from radians to degrees.

```
mysql> SELECT DEGREES(PI());
        -> 180
mysql> SELECT DEGREES(PI() / 2);
        -> 90
```

- EXP(X)

Returns the value of e (the base of natural logarithms) raised to the power of X. The inverse of this function is LOG() (using a single argument only) or LN().

```
mysql> SELECT EXP(2);
        -> 7.3890560989307
mysql> SELECT EXP(-2);
        -> 0.13533528323661
mysql> SELECT EXP(0);
        -> 1
```

- FLOOR(X)

Returns the largest integer value not greater than X.

```
mysql> SELECT FLOOR(1.23), FLOOR(-1.23);
        -> 1, -2
```

For exact-value numeric arguments, the return value has an exact-value numeric type. For string or floating-point arguments, the return value has a floating-point type.

- FORMAT(X,D)

Formats the number X to a format like `'#,###,###.##'`, rounded to D decimal places, and returns the result as a string. For details, see Section 12.5, "String Functions".

- `HEX(N_or_S)`

  This function can be used to obtain a hexadecimal representation of a decimal number or a string; the manner in which it does so varies according to the argument's type. See this function's description in Section 12.5, "String Functions", for details.

- `LN(X)`

  Returns the natural logarithm of X; that is, the base-e logarithm of X. If X is less than or equal to 0, then `NULL` is returned.

  ```
  mysql> SELECT LN(2);
          -> 0.69314718055995
  mysql> SELECT LN(-2);
          -> NULL
  ```

  This function is synonymous with `LOG(X)`. The inverse of this function is the `EXP()` function.

- `LOG(X)`, `LOG(B,X)`

  If called with one parameter, this function returns the natural logarithm of X. If X is less than or equal to 0, then `NULL` is returned.

  The inverse of this function (when called with a single argument) is the `EXP()` function.

  ```
  mysql> SELECT LOG(2);
          -> 0.69314718055995
  mysql> SELECT LOG(-2);
          -> NULL
  ```

  If called with two parameters, this function returns the logarithm of X to the base B. If X is less than or equal to 0, or if B is less than or equal to 1, then `NULL` is returned.

  ```
  mysql> SELECT LOG(2,65536);
          -> 16
  mysql> SELECT LOG(10,100);
          -> 2
  mysql> SELECT LOG(1,100);
          -> NULL
  ```

  `LOG(B,X)` is equivalent to `LOG(X) / LOG(B)`.

- `LOG2(X)`

  Returns the base-2 logarithm of X.

  ```
  mysql> SELECT LOG2(65536);
          -> 16
  mysql> SELECT LOG2(-100);
          -> NULL
  ```

  `LOG2()` is useful for finding out how many bits a number requires for storage. This function is equivalent to the expression `LOG(X) / LOG(2)`.

- `LOG10(X)`

  Returns the base-10 logarithm of X.

  ```
  mysql> SELECT LOG10(2);
          -> 0.30102999566398
  mysql> SELECT LOG10(100);
          -> 2
  mysql> SELECT LOG10(-100);
          -> NULL
  ```

  `LOG10(X)` is equivalent to `LOG(10,X)`.

- `MOD(N,M)`, `N % M`, `N MOD M`

  Modulo operation. Returns the remainder of N divided by M.

  ```
  mysql> SELECT MOD(234, 10);
          -> 4
  mysql> SELECT 253 % 7;
          -> 1
  mysql> SELECT MOD(29,9);
          -> 2
  mysql> SELECT 29 MOD 9;
          -> 2
  ```

  This function is safe to use with `BIGINT` values.

  `MOD()` also works on values that have a fractional part and returns the exact remainder after division:

  ```
  mysql> SELECT MOD(34.5,3);
          -> 1.5
  ```

  `MOD(N,0)` returns `NULL`.

- `PI()`

  Returns the value of π (pi). The default number of decimal places displayed is seven, but MySQL uses the full double-precision value internally.

  ```
  mysql> SELECT PI();
          -> 3.141593
  mysql> SELECT PI()+0.000000000000000000;
          -> 3.141592653589793116
  ```

- `POW(X,Y)`

  Returns the value of X raised to the power of Y.

  ```
  mysql> SELECT POW(2,2);
          -> 4
  mysql> SELECT POW(2,-2);
          -> 0.25
  ```

- `POWER(X,Y)`

  This is a synonym for `POW()`.

- `RADIANS(X)`

  Returns the argument X, converted from degrees to radians. (Note that π radians equals 180 degrees.)

  ```
  mysql> SELECT RADIANS(90);
          -> 1.5707963267949
  ```

- `RAND()`, `RAND(N)`

  Returns a random floating-point value v in the range `0 <= v < 1.0`. If a constant integer argument N is specified, it is used as the seed value, which produces a repeatable sequence of column values. In the following example, note that the sequences of values produced by `RAND(3)` is the same both places where it occurs.

  ```
  mysql> CREATE TABLE t (i INT);
  Query OK, 0 rows affected (0.42 sec)

  mysql> INSERT INTO t VALUES(1),(2),(3);
  Query OK, 3 rows affected (0.00 sec)
  Records: 3  Duplicates: 0  Warnings: 0

  mysql> SELECT i, RAND() FROM t;
  +------+------------------+
  | i    | RAND()           |
  +------+------------------+
  |    1 | 0.61914388706828 |
  |    2 | 0.93845168309142 |
  |    3 | 0.83482678498591 |
  +------+------------------+
  3 rows in set (0.00 sec)

  mysql> SELECT i, RAND(3) FROM t;
  +------+------------------+
  | i    | RAND(3)          |
  +------+------------------+
  |    1 | 0.90576975597606 |
  |    2 | 0.37307905813035 |
  |    3 | 0.14808605345719 |
  +------+------------------+
  3 rows in set (0.00 sec)

  mysql> SELECT i, RAND() FROM t;
  +------+------------------+
  | i    | RAND()           |
  +------+------------------+
  |    1 | 0.35877890638893 |
  |    2 | 0.28941420772058 |
  |    3 | 0.37073435016976 |
  +------+------------------+
  3 rows in set (0.00 sec)

  mysql> SELECT i, RAND(3) FROM t;
  +------+------------------+
  | i    | RAND(3)          |
  +------+------------------+
  |    1 | 0.90576975597606 |
  |    2 | 0.37307905813035 |
  |    3 | 0.14808605345719 |
  +------+------------------+
  3 rows in set (0.01 sec)
  ```

With a constant initializer, the seed is initialized once when the statement is compiled, prior to execution. As of MySQL 5.1.16, if a nonconstant initializer (such as a column name) is used as the argument, the seed is initialized with the value for each invocation of `RAND()`. (One implication of this is that for equal argument values, `RAND()` will return the same value each time.) From MySQL 5.1.3 to 5.1.15, nonconstant arguments are not permitted. Before that, the effect of using a nonconstant argument is undefined.

To obtain a random integer `R` in the range `i` <= `R` < `j`, use the expression `FLOOR(i + RAND() * (j - i))`. For example, to obtain a random integer in the range the range `7` <= `R` < `12`, you could use the following statement:

```
SELECT FLOOR(7 + (RAND() * 5));
```

`RAND()` in a `WHERE` clause is re-evaluated every time the `WHERE` is executed.

Use of a column with `RAND()` values in an `ORDER BY` or `GROUP BY` clause may yield unexpected results because for either clause a `RAND()` expression can be evaluated multiple times for the same row, each time returning a different result. However, you can retrieve rows in random order like this:

```
mysql> SELECT * FROM tbl_name ORDER BY RAND();
```

`ORDER BY RAND()` combined with `LIMIT` is useful for selecting a random sample from a set of rows:

```
mysql> SELECT * FROM table1, table2 WHERE a=b AND c<d ORDER BY RAND() LIMIT 1000;
```

`RAND()` is not meant to be a perfect random generator. It is a fast way to generate random numbers on demand that is portable between platforms for the same MySQL version.

Beginning with MySQL 5.1.43, this function is flagged as unsafe for statement-based replication; use of this function causes a warning when using statement-based replication, and the statement is logged using the binary format when `binlog_format` is `MIXED`. (Bug #49222)

- `ROUND(X)`, `ROUND(X,D)`

  Rounds the argument `X` to `D` decimal places. The rounding algorithm depends on the data type of `X`. `D` defaults to 0 if not specified. `D` can be negative to cause `D` digits left of the decimal point of the value `X` to become zero.

  ```
  mysql> SELECT ROUND(-1.23);
          -> -1
  mysql> SELECT ROUND(-1.58);
          -> -2
  mysql> SELECT ROUND(1.58);
          -> 2
  mysql> SELECT ROUND(1.298, 1);
          -> 1.3
  mysql> SELECT ROUND(1.298, 0);
          -> 1
  mysql> SELECT ROUND(23.298, -1);
          -> 20
  ```

  The return type is the same type as that of the first argument (assuming that it is integer, double, or decimal). This means that for an integer argument, the result is an integer (no decimal places):

```
mysql> SELECT ROUND(150.000,2), ROUND(150,2);
+------------------+--------------+
| ROUND(150.000,2) | ROUND(150,2) |
+------------------+--------------+
|           150.00 |          150 |
+------------------+--------------+
```

ROUND() uses the following rules depending on the type of the first argument:

- For exact-value numbers, ROUND() uses the "round half away from zero" or "round toward nearest" rule: A value with a fractional part of .5 or greater is rounded up to the next integer if positive or down to the next integer if negative. (In other words, it is rounded away from zero.) A value with a fractional part less than .5 is rounded down to the next integer if positive or up to the next integer if negative.

- For approximate-value numbers, the result depends on the C library. On many systems, this means that ROUND() uses the "round to nearest even" rule: A value with any fractional part is rounded to the nearest even integer.

The following example shows how rounding differs for exact and approximate values:

```
mysql> SELECT ROUND(2.5), ROUND(25E-1);
+------------+--------------+
| ROUND(2.5) | ROUND(25E-1) |
+------------+--------------+
| 3          |            2 |
+------------+--------------+
```

For more information, see Section 12.18, "Precision Math".

This function is unsafe for statement-based replication. Beginning with MySQL 5.1.43, a warning is logged if you use this function when binlog_format is set to STATEMENT. (Bug #49222)

- SIGN(X)

  Returns the sign of the argument as -1, 0, or 1, depending on whether X is negative, zero, or positive.

```
mysql> SELECT SIGN(-32);
        -> -1
mysql> SELECT SIGN(0);
        -> 0
mysql> SELECT SIGN(234);
        -> 1
```

- SIN(X)

  Returns the sine of X, where X is given in radians.

```
mysql> SELECT SIN(PI());
        -> 1.2246063538224e-16
mysql> SELECT ROUND(SIN(PI()));
        -> 0
```

- SQRT(X)

  Returns the square root of a nonnegative number X.

```
mysql> SELECT SQRT(4);
        -> 2
```

```
mysql> SELECT SQRT(20);
        -> 4.4721359549996
mysql> SELECT SQRT(-16);
        -> NULL
```

- TAN(*X*)

  Returns the tangent of *X*, where *X* is given in radians.

```
mysql> SELECT TAN(PI());
        -> -1.2246063538224e-16
mysql> SELECT TAN(PI()+1);
        -> 1.5574077246549
```

- TRUNCATE(*X*,*D*)

  Returns the number *X*, truncated to *D* decimal places. If *D* is 0, the result has no decimal point or fractional part. *D* can be negative to cause *D* digits left of the decimal point of the value *X* to become zero.

```
mysql> SELECT TRUNCATE(1.223,1);
        -> 1.2
mysql> SELECT TRUNCATE(1.999,1);
        -> 1.9
mysql> SELECT TRUNCATE(1.999,0);
        -> 1
mysql> SELECT TRUNCATE(-1.999,1);
        -> -1.9
mysql> SELECT TRUNCATE(122,-2);
        -> 100
mysql> SELECT TRUNCATE(10.28*100,0);
        -> 1028
```

  All numbers are rounded toward zero.

12.7 Date and Time Functions

This section describes the functions that can be used to manipulate temporal values. See Section 11.3, "Date and Time Types", for a description of the range of values each date and time type has and the valid formats in which values may be specified.

Table 12.13 Date/Time Functions

Name	Description
ADDDATE()	Add time values (intervals) to a date value
ADDTIME()	Add time
CONVERT_TZ()	Convert from one timezone to another
CURDATE()	Return the current date
CURRENT_DATE(), CURRENT_DATE	Synonyms for CURDATE()
CURRENT_TIME(), CURRENT_TIME	Synonyms for CURTIME()
CURRENT_TIMESTAMP(), CURRENT_TIMESTAMP	Synonyms for NOW()
CURTIME()	Return the current time
DATE()	Extract the date part of a date or datetime expression
DATE_ADD()	Add time values (intervals) to a date value

Name	Description
DATE_FORMAT()	Format date as specified
DATE_SUB()	Subtract a time value (interval) from a date
DATEDIFF()	Subtract two dates
DAY()	Synonym for DAYOFMONTH()
DAYNAME()	Return the name of the weekday
DAYOFMONTH()	Return the day of the month (0-31)
DAYOFWEEK()	Return the weekday index of the argument
DAYOFYEAR()	Return the day of the year (1-366)
EXTRACT()	Extract part of a date
FROM_DAYS()	Convert a day number to a date
FROM_UNIXTIME()	Format UNIX timestamp as a date
GET_FORMAT()	Return a date format string
HOUR()	Extract the hour
LAST_DAY	Return the last day of the month for the argument
LOCALTIME(), LOCALTIME	Synonym for NOW()
LOCALTIMESTAMP, LOCALTIMESTAMP()	Synonym for NOW()
MAKEDATE()	Create a date from the year and day of year
MAKETIME()	Create time from hour, minute, second
MICROSECOND()	Return the microseconds from argument
MINUTE()	Return the minute from the argument
MONTH()	Return the month from the date passed
MONTHNAME()	Return the name of the month
NOW()	Return the current date and time
PERIOD_ADD()	Add a period to a year-month
PERIOD_DIFF()	Return the number of months between periods
QUARTER()	Return the quarter from a date argument
SEC_TO_TIME()	Converts seconds to 'HH:MM:SS' format
SECOND()	Return the second (0-59)
STR_TO_DATE()	Convert a string to a date
SUBDATE()	Synonym for DATE_SUB() when invoked with three arguments
SUBTIME()	Subtract times
SYSDATE()	Return the time at which the function executes
TIME()	Extract the time portion of the expression passed
TIME_FORMAT()	Format as time
TIME_TO_SEC()	Return the argument converted to seconds
TIMEDIFF()	Subtract time

Name	Description
TIMESTAMP()	With a single argument, this function returns the date or datetime expression; with two arguments, the sum of the arguments
TIMESTAMPADD()	Add an interval to a datetime expression
TIMESTAMPDIFF()	Subtract an interval from a datetime expression
TO_DAYS()	Return the date argument converted to days
UNIX_TIMESTAMP()	Return a UNIX timestamp
UTC_DATE()	Return the current UTC date
UTC_TIME()	Return the current UTC time
UTC_TIMESTAMP()	Return the current UTC date and time
WEEK()	Return the week number
WEEKDAY()	Return the weekday index
WEEKOFYEAR()	Return the calendar week of the date (1-53)
YEAR()	Return the year
YEARWEEK()	Return the year and week

Here is an example that uses date functions. The following query selects all rows with a *date_col* value from within the last 30 days:

```
mysql> SELECT something FROM tbl_name
    -> WHERE DATE_SUB(CURDATE(),INTERVAL 30 DAY) <= date_col;
```

The query also selects rows with dates that lie in the future.

Functions that expect date values usually accept datetime values and ignore the time part. Functions that expect time values usually accept datetime values and ignore the date part.

Functions that return the current date or time each are evaluated only once per query at the start of query execution. This means that multiple references to a function such as NOW() within a single query always produce the same result. (For our purposes, a single query also includes a call to a stored program (stored routine, trigger, or event) and all subprograms called by that program.) This principle also applies to CURDATE(), CURTIME(), UTC_DATE(), UTC_TIME(), UTC_TIMESTAMP(), and to any of their synonyms.

The CURRENT_TIMESTAMP(), CURRENT_TIME(), CURRENT_DATE(), and FROM_UNIXTIME() functions return values in the connection's current time zone, which is available as the value of the time_zone system variable. In addition, UNIX_TIMESTAMP() assumes that its argument is a datetime value in the current time zone. See Section 10.6, "MySQL Server Time Zone Support".

Some date functions can be used with "zero" dates or incomplete dates such as '2001-11-00', whereas others cannot. Functions that extract parts of dates typically work with incomplete dates and thus can return 0 when you might otherwise expect a nonzero value. For example:

```
mysql> SELECT DAYOFMONTH('2001-11-00'), MONTH('2005-00-00');
        -> 0, 0
```

Other functions expect complete dates and return NULL for incomplete dates. These include functions that perform date arithmetic or that map parts of dates to names. For example:

```
mysql> SELECT DATE_ADD('2006-05-00',INTERVAL 1 DAY);
        -> NULL
mysql> SELECT DAYNAME('2006-05-00');
        -> NULL
```

> **Note**
>
> From MySQL 5.1.59 to 5.1.61, a change in handling of a date-related assertion caused several functions to become more strict when passed a `DATE()` function value as their argument and reject incomplete dates with a day part of zero. These functions are affected: `CONVERT_TZ()`, `DATE_ADD()`, `DATE_SUB()`, `DAYOFYEAR()`, `LAST_DAY()`, `TIMESTAMPDIFF()`, `TO_DAYS()`, `WEEK()`, `WEEKDAY()`, `WEEKOFYEAR()`, `YEARWEEK()`. Because this changes date-handling behavior in General Availability-status series MySQL 5.1, the change was reverted in 5.1.62.

- `ADDDATE(date,INTERVAL expr unit)`, `ADDDATE(expr,days)`

  When invoked with the `INTERVAL` form of the second argument, `ADDDATE()` is a synonym for `DATE_ADD()`. The related function `SUBDATE()` is a synonym for `DATE_SUB()`. For information on the `INTERVAL unit` argument, see the discussion for `DATE_ADD()`.

  ```
  mysql> SELECT DATE_ADD('2008-01-02', INTERVAL 31 DAY);
          -> '2008-02-02'
  mysql> SELECT ADDDATE('2008-01-02', INTERVAL 31 DAY);
          -> '2008-02-02'
  ```

  When invoked with the `days` form of the second argument, MySQL treats it as an integer number of days to be added to `expr`.

  ```
  mysql> SELECT ADDDATE('2008-01-02', 31);
          -> '2008-02-02'
  ```

- `ADDTIME(expr1,expr2)`

  `ADDTIME()` adds `expr2` to `expr1` and returns the result. `expr1` is a time or datetime expression, and `expr2` is a time expression.

  ```
  mysql> SELECT ADDTIME('2007-12-31 23:59:59.999999', '1 1:1:1.000002');
          -> '2008-01-02 01:01:01.000001'
  mysql> SELECT ADDTIME('01:00:00.999999', '02:00:00.999998');
          -> '03:00:01.999997'
  ```

- `CONVERT_TZ(dt,from_tz,to_tz)`

  `CONVERT_TZ()` converts a datetime value `dt` from the time zone given by `from_tz` to the time zone given by `to_tz` and returns the resulting value. Time zones are specified as described in Section 10.6, "MySQL Server Time Zone Support". This function returns `NULL` if the arguments are invalid.

  If the value falls out of the supported range of the `TIMESTAMP` type when converted from `from_tz` to UTC, no conversion occurs. The `TIMESTAMP` range is described in Section 11.1.2, "Date and Time Type Overview".

  ```
  mysql> SELECT CONVERT_TZ('2004-01-01 12:00:00','GMT','MET');
          -> '2004-01-01 13:00:00'
  mysql> SELECT CONVERT_TZ('2004-01-01 12:00:00','+00:00','+10:00');
          -> '2004-01-01 22:00:00'
  ```

Note

To use named time zones such as `'MET'` or `'Europe/Moscow'`, the time zone tables must be properly set up. See Section 10.6, "MySQL Server Time Zone Support", for instructions.

Before MySQL 5.1.17, if you intend to use `CONVERT_TZ()` while other tables are locked with `LOCK TABLES`, you must also lock the `mysql.time_zone_name` table. See Section 13.3.5, "LOCK TABLES and UNLOCK TABLES Syntax".

- `CURDATE()`

  Returns the current date as a value in `'YYYY-MM-DD'` or `YYYYMMDD` format, depending on whether the function is used in a string or numeric context.

  ```
  mysql> SELECT CURDATE();
          -> '2008-06-13'
  mysql> SELECT CURDATE() + 0;
          -> 20080613
  ```

- `CURRENT_DATE`, `CURRENT_DATE()`

  `CURRENT_DATE` and `CURRENT_DATE()` are synonyms for `CURDATE()`.

- `CURRENT_TIME`, `CURRENT_TIME()`

  `CURRENT_TIME` and `CURRENT_TIME()` are synonyms for `CURTIME()`.

- `CURRENT_TIMESTAMP`, `CURRENT_TIMESTAMP()`

  `CURRENT_TIMESTAMP` and `CURRENT_TIMESTAMP()` are synonyms for `NOW()`.

- `CURTIME()`

  Returns the current time as a value in `'HH:MM:SS'` or `HHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context. The value is expressed in the current time zone.

  ```
  mysql> SELECT CURTIME();
          -> '23:50:26'
  mysql> SELECT CURTIME() + 0;
          -> 235026.000000
  ```

- `DATE(expr)`

  Extracts the date part of the date or datetime expression `expr`.

  ```
  mysql> SELECT DATE('2003-12-31 01:02:03');
          -> '2003-12-31'
  ```

- `DATEDIFF(expr1,expr2)`

  `DATEDIFF()` returns `expr1` − `expr2` expressed as a value in days from one date to the other. `expr1` and `expr2` are date or date-and-time expressions. Only the date parts of the values are used in the calculation.

  ```
  mysql> SELECT DATEDIFF('2007-12-31 23:59:59','2007-12-30');
  ```

```
        -> 1
mysql> SELECT DATEDIFF('2010-11-30 23:59:59','2010-12-31');
        -> -31
```

- DATE_ADD(*date*,INTERVAL *expr unit*), DATE_SUB(*date*,INTERVAL *expr unit*)

  These functions perform date arithmetic. The *date* argument specifies the starting date or datetime value. *expr* is an expression specifying the interval value to be added or subtracted from the starting date. *expr* is a string; it may start with a "-" for negative intervals. *unit* is a keyword indicating the units in which the expression should be interpreted.

  The INTERVAL keyword and the *unit* specifier are not case sensitive.

  The following table shows the expected form of the *expr* argument for each *unit* value.

unit Value	Expected *expr* Format
MICROSECOND	MICROSECONDS
SECOND	SECONDS
MINUTE	MINUTES
HOUR	HOURS
DAY	DAYS
WEEK	WEEKS
MONTH	MONTHS
QUARTER	QUARTERS
YEAR	YEARS
SECOND_MICROSECOND	'SECONDS.MICROSECONDS'
MINUTE_MICROSECOND	'MINUTES:SECONDS.MICROSECONDS'
MINUTE_SECOND	'MINUTES:SECONDS'
HOUR_MICROSECOND	'HOURS:MINUTES:SECONDS.MICROSECONDS'
HOUR_SECOND	'HOURS:MINUTES:SECONDS'
HOUR_MINUTE	'HOURS:MINUTES'
DAY_MICROSECOND	'DAYS HOURS:MINUTES:SECONDS.MICROSECONDS'
DAY_SECOND	'DAYS HOURS:MINUTES:SECONDS'
DAY_MINUTE	'DAYS HOURS:MINUTES'
DAY_HOUR	'DAYS HOURS'
YEAR_MONTH	'YEARS-MONTHS'

  The return value depends on the arguments:

  - DATETIME if the first argument is a DATETIME (or TIMESTAMP) value, or if the first argument is a DATE and the *unit* value uses HOURS, MINUTES, or SECONDS.

  - String otherwise.

  To ensure that the result is DATETIME, you can use CAST() to convert the first argument to DATETIME.

MySQL permits any punctuation delimiter in the *expr* format. Those shown in the table are the suggested delimiters. If the *date* argument is a DATE value and your calculations involve only YEAR, MONTH, and DAY parts (that is, no time parts), the result is a DATE value. Otherwise, the result is a DATETIME value.

Date arithmetic also can be performed using INTERVAL together with the + or - operator:

```
date + INTERVAL expr unit
date - INTERVAL expr unit
```

INTERVAL *expr unit* is permitted on either side of the + operator if the expression on the other side is a date or datetime value. For the - operator, INTERVAL *expr unit* is permitted only on the right side, because it makes no sense to subtract a date or datetime value from an interval.

```
mysql> SELECT '2008-12-31 23:59:59' + INTERVAL 1 SECOND;
        -> '2009-01-01 00:00:00'
mysql> SELECT INTERVAL 1 DAY + '2008-12-31';
        -> '2009-01-01'
mysql> SELECT '2005-01-01' - INTERVAL 1 SECOND;
        -> '2004-12-31 23:59:59'
mysql> SELECT DATE_ADD('2000-12-31 23:59:59',
    ->                 INTERVAL 1 SECOND);
        -> '2001-01-01 00:00:00'
mysql> SELECT DATE_ADD('2010-12-31 23:59:59',
    ->                 INTERVAL 1 DAY);
        -> '2011-01-01 23:59:59'
mysql> SELECT DATE_ADD('2100-12-31 23:59:59',
    ->                 INTERVAL '1:1' MINUTE_SECOND);
        -> '2101-01-01 00:01:00'
mysql> SELECT DATE_SUB('2005-01-01 00:00:00',
    ->                 INTERVAL '1 1:1:1' DAY_SECOND);
        -> '2004-12-30 22:58:59'
mysql> SELECT DATE_ADD('1900-01-01 00:00:00',
    ->                 INTERVAL '-1 10' DAY_HOUR);
        -> '1899-12-30 14:00:00'
mysql> SELECT DATE_SUB('1998-01-02', INTERVAL 31 DAY);
        -> '1997-12-02'
mysql> SELECT DATE_ADD('1992-12-31 23:59:59.000002',
    ->             INTERVAL '1.999999' SECOND_MICROSECOND);
        -> '1993-01-01 00:00:01.000001'
```

If you specify an interval value that is too short (does not include all the interval parts that would be expected from the *unit* keyword), MySQL assumes that you have left out the leftmost parts of the interval value. For example, if you specify a *unit* of DAY_SECOND, the value of *expr* is expected to have days, hours, minutes, and seconds parts. If you specify a value like '1:10', MySQL assumes that the days and hours parts are missing and the value represents minutes and seconds. In other words, '1:10' DAY_SECOND is interpreted in such a way that it is equivalent to '1:10' MINUTE_SECOND. This is analogous to the way that MySQL interprets TIME values as representing elapsed time rather than as a time of day.

Because *expr* is treated as a string, be careful if you specify a nonstring value with INTERVAL. For example, with an interval specifier of HOUR_MINUTE, 6/4 evaluates to 1.5000 and is treated as 1 hour, 5000 minutes:

```
mysql> SELECT 6/4;
        -> 1.5000
mysql> SELECT DATE_ADD('2009-01-01', INTERVAL 6/4 HOUR_MINUTE);
        -> '2009-01-04 12:20:00'
```

To ensure interpretation of the interval value as you expect, a `CAST()` operation may be used. To treat `6/4` as 1 hour, 5 minutes, cast it to a `DECIMAL` value with a single fractional digit:

```
mysql> SELECT CAST(6/4 AS DECIMAL(3,1));
        -> 1.5
mysql> SELECT DATE_ADD('1970-01-01 12:00:00',
    ->                 INTERVAL CAST(6/4 AS DECIMAL(3,1)) HOUR_MINUTE);
        -> '1970-01-01 13:05:00'
```

If you add to or subtract from a date value something that contains a time part, the result is automatically converted to a datetime value:

```
mysql> SELECT DATE_ADD('2013-01-01', INTERVAL 1 DAY);
        -> '2013-01-02'
mysql> SELECT DATE_ADD('2013-01-01', INTERVAL 1 HOUR);
        -> '2013-01-01 01:00:00'
```

If you add `MONTH`, `YEAR_MONTH`, or `YEAR` and the resulting date has a day that is larger than the maximum day for the new month, the day is adjusted to the maximum days in the new month:

```
mysql> SELECT DATE_ADD('2009-01-30', INTERVAL 1 MONTH);
        -> '2009-02-28'
```

Date arithmetic operations require complete dates and do not work with incomplete dates such as `'2006-07-00'` or badly malformed dates:

```
mysql> SELECT DATE_ADD('2006-07-00', INTERVAL 1 DAY);
        -> NULL
mysql> SELECT '2005-03-32' + INTERVAL 1 MONTH;
        -> NULL
```

- `DATE_FORMAT(date,format)`

  Formats the `date` value according to the `format` string.

  The following specifiers may be used in the `format` string. The "`%`" character is required before format specifier characters.

Specifier	Description
`%a`	Abbreviated weekday name (`Sun`..`Sat`)
`%b`	Abbreviated month name (`Jan`..`Dec`)
`%c`	Month, numeric (`0`..`12`)
`%D`	Day of the month with English suffix (`0th`, `1st`, `2nd`, `3rd`, …)
`%d`	Day of the month, numeric (`00`..`31`)
`%e`	Day of the month, numeric (`0`..`31`)
`%f`	Microseconds (`000000`..`999999`)
`%H`	Hour (`00`..`23`)
`%h`	Hour (`01`..`12`)
`%I`	Hour (`01`..`12`)
`%i`	Minutes, numeric (`00`..`59`)

Specifier	Description
`%j`	Day of year (`001..366`)
`%k`	Hour (`0..23`)
`%l`	Hour (`1..12`)
`%M`	Month name (`January..December`)
`%m`	Month, numeric (`00..12`)
`%p`	`AM` or `PM`
`%r`	Time, 12-hour (`hh:mm:ss` followed by `AM` or `PM`)
`%S`	Seconds (`00..59`)
`%s`	Seconds (`00..59`)
`%T`	Time, 24-hour (`hh:mm:ss`)
`%U`	Week (`00..53`), where Sunday is the first day of the week; `WEEK()` mode 0
`%u`	Week (`00..53`), where Monday is the first day of the week; `WEEK()` mode 1
`%V`	Week (`01..53`), where Sunday is the first day of the week; `WEEK()` mode 2; used with `%X`
`%v`	Week (`01..53`), where Monday is the first day of the week; `WEEK()` mode 3; used with `%x`
`%W`	Weekday name (`Sunday..Saturday`)
`%w`	Day of the week (`0`=Sunday..`6`=Saturday)
`%X`	Year for the week where Sunday is the first day of the week, numeric, four digits; used with `%V`
`%x`	Year for the week, where Monday is the first day of the week, numeric, four digits; used with `%v`
`%Y`	Year, numeric, four digits
`%y`	Year, numeric (two digits)
`%%`	A literal "`%`" character
`%x`	*x*, for any "*x*" not listed above

Ranges for the month and day specifiers begin with zero due to the fact that MySQL permits the storing of incomplete dates such as `'2014-00-00'`.

As of MySQL 5.1.12, the language used for day and month names and abbreviations is controlled by the value of the `lc_time_names` system variable (Section 10.7, "MySQL Server Locale Support").

For the `%U`, `%u`, `%V`, and `%v` specifiers, see the description of the `WEEK()` function for information about the mode values. The mode affects how week numbering occurs.

As of MySQL 5.1.15, `DATE_FORMAT()` returns a string with a character set and collation given by `character_set_connection` and `collation_connection` so that it can return month and weekday names containing non-ASCII characters. Before 5.1.15, the return value is a binary string.

```
mysql> SELECT DATE_FORMAT('2009-10-04 22:23:00', '%W %M %Y');
        -> 'Sunday October 2009'
mysql> SELECT DATE_FORMAT('2007-10-04 22:23:00', '%H:%i:%s');
        -> '22:23:00'
mysql> SELECT DATE_FORMAT('1900-10-04 22:23:00',
```

```
    ->                 '%D %y %a %d %m %b %j');
        -> '4th 00 Thu 04 10 Oct 277'
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00',
    ->                 '%H %k %I %r %T %S %w');
        -> '22 22 10 10:23:00 PM 22:23:00 00 6'
mysql> SELECT DATE_FORMAT('1999-01-01', '%X %V');
        -> '1998 52'
mysql> SELECT DATE_FORMAT('2006-06-00', '%d');
        -> '00'
```

- DATE_SUB(date,INTERVAL expr unit)

  See the description for DATE_ADD().

- DAY(date)

  DAY() is a synonym for DAYOFMONTH().

- DAYNAME(date)

  Returns the name of the weekday for date. As of MySQL 5.1.12, the language used for the name is controlled by the value of the lc_time_names system variable (Section 10.7, "MySQL Server Locale Support").

```
mysql> SELECT DAYNAME('2007-02-03');
        -> 'Saturday'
```

- DAYOFMONTH(date)

  Returns the day of the month for date, in the range 1 to 31, or 0 for dates such as '0000-00-00' or '2008-00-00' that have a zero day part.

```
mysql> SELECT DAYOFMONTH('2007-02-03');
        -> 3
```

- DAYOFWEEK(date)

  Returns the weekday index for date (1 = Sunday, 2 = Monday, …, 7 = Saturday). These index values correspond to the ODBC standard.

```
mysql> SELECT DAYOFWEEK('2007-02-03');
        -> 7
```

- DAYOFYEAR(date)

  Returns the day of the year for date, in the range 1 to 366.

```
mysql> SELECT DAYOFYEAR('2007-02-03');
        -> 34
```

- EXTRACT(unit FROM date)

  The EXTRACT() function uses the same kinds of unit specifiers as DATE_ADD() or DATE_SUB(), but extracts parts from the date rather than performing date arithmetic.

```
mysql> SELECT EXTRACT(YEAR FROM '2009-07-02');
        -> 2009
mysql> SELECT EXTRACT(YEAR_MONTH FROM '2009-07-02 01:02:03');
```

```
        -> 200907
mysql> SELECT EXTRACT(DAY_MINUTE FROM '2009-07-02 01:02:03');
        -> 20102
mysql> SELECT EXTRACT(MICROSECOND
    ->                FROM '2003-01-02 10:30:00.000123');
        -> 123
```

- FROM_DAYS(*N*)

  Given a day number *N*, returns a DATE value.

  ```
  mysql> SELECT FROM_DAYS(730669);
          -> '2007-07-03'
  ```

  Use FROM_DAYS() with caution on old dates. It is not intended for use with values that precede the advent of the Gregorian calendar (1582). See Section 12.8, "What Calendar Is Used By MySQL?".

- FROM_UNIXTIME(*unix_timestamp*), FROM_UNIXTIME(*unix_timestamp,format*)

  Returns a representation of the *unix_timestamp* argument as a value in 'YYYY-MM-DD HH:MM:SS' or YYYYMMDDHHMMSS.uuuuuu format, depending on whether the function is used in a string or numeric context. The value is expressed in the current time zone. *unix_timestamp* is an internal timestamp value such as is produced by the UNIX_TIMESTAMP() function.

  If *format* is given, the result is formatted according to the *format* string, which is used the same way as listed in the entry for the DATE_FORMAT() function.

  ```
  mysql> SELECT FROM_UNIXTIME(1447430881);
          -> '2015-11-13 10:08:01'
  mysql> SELECT FROM_UNIXTIME(1447430881) + 0;
          -> 20151113100801
  mysql> SELECT FROM_UNIXTIME(UNIX_TIMESTAMP(),
      ->                      '%Y %D %M %h:%i:%s %x');
          -> '2015 13th November 10:08:01 2015'
  ```

  Note: If you use UNIX_TIMESTAMP() and FROM_UNIXTIME() to convert between TIMESTAMP values and Unix timestamp values, the conversion is lossy because the mapping is not one-to-one in both directions. For details, see the description of the UNIX_TIMESTAMP() function.

- GET_FORMAT({DATE|TIME|DATETIME}, {'EUR'|'USA'|'JIS'|'ISO'|'INTERNAL'})

  Returns a format string. This function is useful in combination with the DATE_FORMAT() and the STR_TO_DATE() functions.

  The possible values for the first and second arguments result in several possible format strings (for the specifiers used, see the table in the DATE_FORMAT() function description). ISO format refers to ISO 9075, not ISO 8601.

Function Call	Result
GET_FORMAT(DATE,'USA')	'%m.%d.%Y'
GET_FORMAT(DATE,'JIS')	'%Y-%m-%d'
GET_FORMAT(DATE,'ISO')	'%Y-%m-%d'
GET_FORMAT(DATE,'EUR')	'%d.%m.%Y'
GET_FORMAT(DATE,'INTERNAL')	'%Y%m%d'
GET_FORMAT(DATETIME,'USA')	'%Y-%m-%d %H.%i.%s'

Function Call	Result
GET_FORMAT(DATETIME,'JIS')	'%Y-%m-%d %H:%i:%s'
GET_FORMAT(DATETIME,'ISO')	'%Y-%m-%d %H:%i:%s'
GET_FORMAT(DATETIME,'EUR')	'%Y-%m-%d %H.%i.%s'
GET_FORMAT(DATETIME,'INTERNAL')	'%Y%m%d%H%i%s'
GET_FORMAT(TIME,'USA')	'%h:%i:%s %p'
GET_FORMAT(TIME,'JIS')	'%H:%i:%s'
GET_FORMAT(TIME,'ISO')	'%H:%i:%s'
GET_FORMAT(TIME,'EUR')	'%H.%i.%s'
GET_FORMAT(TIME,'INTERNAL')	'%H%i%s'

TIMESTAMP can also be used as the first argument to GET_FORMAT(), in which case the function returns the same values as for DATETIME.

```
mysql> SELECT DATE_FORMAT('2003-10-03',GET_FORMAT(DATE,'EUR'));
        -> '03.10.2003'
mysql> SELECT STR_TO_DATE('10.31.2003',GET_FORMAT(DATE,'USA'));
        -> '2003-10-31'
```

- HOUR(time)

  Returns the hour for time. The range of the return value is 0 to 23 for time-of-day values. However, the range of TIME values actually is much larger, so HOUR can return values greater than 23.

```
mysql> SELECT HOUR('10:05:03');
        -> 10
mysql> SELECT HOUR('272:59:59');
        -> 272
```

- LAST_DAY(date)

  Takes a date or datetime value and returns the corresponding value for the last day of the month. Returns NULL if the argument is invalid.

```
mysql> SELECT LAST_DAY('2003-02-05');
        -> '2003-02-28'
mysql> SELECT LAST_DAY('2004-02-05');
        -> '2004-02-29'
mysql> SELECT LAST_DAY('2004-01-01 01:01:01');
        -> '2004-01-31'
mysql> SELECT LAST_DAY('2003-03-32');
        -> NULL
```

- LOCALTIME, LOCALTIME()

  LOCALTIME and LOCALTIME() are synonyms for NOW().

- LOCALTIMESTAMP, LOCALTIMESTAMP()

  LOCALTIMESTAMP and LOCALTIMESTAMP() are synonyms for NOW().

- MAKEDATE(year,dayofyear)

Returns a date, given year and day-of-year values. `dayofyear` must be greater than 0 or the result is
NULL.

```
mysql> SELECT MAKEDATE(2011,31), MAKEDATE(2011,32);
        -> '2011-01-31', '2011-02-01'
mysql> SELECT MAKEDATE(2011,365), MAKEDATE(2014,365);
        -> '2011-12-31', '2014-12-31'
mysql> SELECT MAKEDATE(2011,0);
        -> NULL
```

- MAKETIME(`hour`,`minute`,`second`)

  Returns a time value calculated from the `hour`, `minute`, and `second` arguments.

```
mysql> SELECT MAKETIME(12,15,30);
        -> '12:15:30'
```

- MICROSECOND(`expr`)

  Returns the microseconds from the time or datetime expression `expr` as a number in the range from 0
  to 999999.

```
mysql> SELECT MICROSECOND('12:00:00.123456');
        -> 123456
mysql> SELECT MICROSECOND('2009-12-31 23:59:59.000010');
        -> 10
```

- MINUTE(`time`)

  Returns the minute for `time`, in the range 0 to 59.

```
mysql> SELECT MINUTE('2008-02-03 10:05:03');
        -> 5
```

- MONTH(`date`)

  Returns the month for `date`, in the range 1 to 12 for January to December, or 0 for dates such as
  '0000-00-00' or '2008-00-00' that have a zero month part.

```
mysql> SELECT MONTH('2008-02-03');
        -> 2
```

- MONTHNAME(`date`)

  Returns the full name of the month for `date`. As of MySQL 5.1.12, the language used for the name is
  controlled by the value of the `lc_time_names` system variable (Section 10.7, "MySQL Server Locale
  Support").

```
mysql> SELECT MONTHNAME('2008-02-03');
        -> 'February'
```

- NOW()

Returns the current date and time as a value in `'YYYY-MM-DD HH:MM:SS'` or `YYYYMMDDHHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context. The value is expressed in the current time zone.

```
mysql> SELECT NOW();
        -> '2007-12-15 23:50:26'
mysql> SELECT NOW() + 0;
        -> 20071215235026.000000
```

`NOW()` returns a constant time that indicates the time at which the statement began to execute. (Within a stored function or trigger, `NOW()` returns the time at which the function or triggering statement began to execute.) This differs from the behavior for `SYSDATE()`, which returns the exact time at which it executes.

```
mysql> SELECT NOW(), SLEEP(2), NOW();
+---------------------+----------+---------------------+
| NOW()               | SLEEP(2) | NOW()               |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:36 |        0 | 2006-04-12 13:47:36 |
+---------------------+----------+---------------------+

mysql> SELECT SYSDATE(), SLEEP(2), SYSDATE();
+---------------------+----------+---------------------+
| SYSDATE()           | SLEEP(2) | SYSDATE()           |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:44 |        0 | 2006-04-12 13:47:46 |
+---------------------+----------+---------------------+
```

In addition, the `SET TIMESTAMP` statement affects the value returned by `NOW()` but not by `SYSDATE()`. This means that timestamp settings in the binary log have no effect on invocations of `SYSDATE()`. Setting the timestamp to a nonzero value causes each subsequent invocation of `NOW()` to return that value. Setting the timestamp to zero cancels this effect so that `NOW()` once again returns the current date and time.

See the description for `SYSDATE()` for additional information about the differences between the two functions.

- `PERIOD_ADD(P,N)`

  Adds `N` months to period `P` (in the format `YYMM` or `YYYYMM`). Returns a value in the format `YYYYMM`. Note that the period argument `P` is *not* a date value.

  ```
  mysql> SELECT PERIOD_ADD(200801,2);
          -> 200803
  ```

- `PERIOD_DIFF(P1,P2)`

  Returns the number of months between periods `P1` and `P2`. `P1` and `P2` should be in the format `YYMM` or `YYYYMM`. Note that the period arguments `P1` and `P2` are *not* date values.

  ```
  mysql> SELECT PERIOD_DIFF(200802,200703);
          -> 11
  ```

- `QUARTER(date)`

  Returns the quarter of the year for `date`, in the range `1` to `4`.

```
mysql> SELECT QUARTER('2008-04-01');
        -> 2
```

- SECOND(*time*)

  Returns the second for *time*, in the range 0 to 59.

```
mysql> SELECT SECOND('10:05:03');
        -> 3
```

- SEC_TO_TIME(*seconds*)

  Returns the *seconds* argument, converted to hours, minutes, and seconds, as a TIME value. The range of the result is constrained to that of the TIME data type. A warning occurs if the argument corresponds to a value outside that range.

```
mysql> SELECT SEC_TO_TIME(2378);
        -> '00:39:38'
mysql> SELECT SEC_TO_TIME(2378) + 0;
        -> 3938
```

- STR_TO_DATE(*str*,*format*)

  This is the inverse of the DATE_FORMAT() function. It takes a string *str* and a format string *format*. STR_TO_DATE() returns a DATETIME value if the format string contains both date and time parts, or a DATE or TIME value if the string contains only date or time parts. If the date, time, or datetime value extracted from *str* is illegal, STR_TO_DATE() returns NULL and produces a warning.

  The server scans *str* attempting to match *format* to it. The format string can contain literal characters and format specifiers beginning with %. Literal characters in *format* must match literally in *str*. Format specifiers in *format* must match a date or time part in *str*. For the specifiers that can be used in *format*, see the DATE_FORMAT() function description.

```
mysql> SELECT STR_TO_DATE('01,5,2013','%d,%m,%Y');
        -> '2013-05-01'
mysql> SELECT STR_TO_DATE('May 1, 2013','%M %d,%Y');
        -> '2013-05-01'
```

  Scanning starts at the beginning of *str* and fails if *format* is found not to match. Extra characters at the end of *str* are ignored.

```
mysql> SELECT STR_TO_DATE('a09:30:17','a%h:%i:%s');
        -> '09:30:17'
mysql> SELECT STR_TO_DATE('a09:30:17','%h:%i:%s');
        -> NULL
mysql> SELECT STR_TO_DATE('09:30:17a','%h:%i:%s');
        -> '09:30:17'
```

  Unspecified date or time parts have a value of 0, so incompletely specified values in *str* produce a result with some or all parts set to 0:

```
mysql> SELECT STR_TO_DATE('abc','abc');
        -> '0000-00-00'
mysql> SELECT STR_TO_DATE('9','%m');
        -> '0000-09-00'
```

```
mysql> SELECT STR_TO_DATE('9','%s');
        -> '00:00:09'
```

Range checking on the parts of date values is as described in Section 11.3.1, "The DATE, DATETIME, and TIMESTAMP Types". This means, for example, that "zero" dates or dates with part values of 0 are permitted unless the SQL mode is set to disallow such values.

```
mysql> SELECT STR_TO_DATE('00/00/0000', '%m/%d/%Y');
        -> '0000-00-00'
mysql> SELECT STR_TO_DATE('04/31/2004', '%m/%d/%Y');
        -> '2004-04-31'
```

> **Note**
>
> You cannot use format `"%X%V"` to convert a year-week string to a date because the combination of a year and week does not uniquely identify a year and month if the week crosses a month boundary. To convert a year-week to a date, you should also specify the weekday:
>
> ```
> mysql> SELECT STR_TO_DATE('200442 Monday', '%X%V %W');
>         -> '2004-10-18'
> ```

- SUBDATE(*date*,INTERVAL *expr unit*), SUBDATE(*expr*,*days*)

  When invoked with the INTERVAL form of the second argument, SUBDATE() is a synonym for DATE_SUB(). For information on the INTERVAL *unit* argument, see the discussion for DATE_ADD().

  ```
  mysql> SELECT DATE_SUB('2008-01-02', INTERVAL 31 DAY);
          -> '2007-12-02'
  mysql> SELECT SUBDATE('2008-01-02', INTERVAL 31 DAY);
          -> '2007-12-02'
  ```

  The second form enables the use of an integer value for *days*. In such cases, it is interpreted as the number of days to be subtracted from the date or datetime expression *expr*.

  ```
  mysql> SELECT SUBDATE('2008-01-02 12:00:00', 31);
          -> '2007-12-02 12:00:00'
  ```

- SUBTIME(*expr1*,*expr2*)

  SUBTIME() returns *expr1* − *expr2* expressed as a value in the same format as *expr1*. *expr1* is a time or datetime expression, and *expr2* is a time expression.

  ```
  mysql> SELECT SUBTIME('2007-12-31 23:59:59.999999','1 1:1:1.000002');
          -> '2007-12-30 22:58:58.999997'
  mysql> SELECT SUBTIME('01:00:00.999999', '02:00:00.999998');
          -> '-00:59:59.999999'
  ```

- SYSDATE()

  Returns the current date and time as a value in `'YYYY-MM-DD HH:MM:SS'` or YYYYMMDDHHMMSS.uuuuuu format, depending on whether the function is used in a string or numeric context.

SYSDATE() returns the time at which it executes. This differs from the behavior for NOW(), which returns a constant time that indicates the time at which the statement began to execute. (Within a stored function or trigger, NOW() returns the time at which the function or triggering statement began to execute.)

```
mysql> SELECT NOW(), SLEEP(2), NOW();
+---------------------+----------+---------------------+
| NOW()               | SLEEP(2) | NOW()               |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:36 |        0 | 2006-04-12 13:47:36 |
+---------------------+----------+---------------------+

mysql> SELECT SYSDATE(), SLEEP(2), SYSDATE();
+---------------------+----------+---------------------+
| SYSDATE()           | SLEEP(2) | SYSDATE()           |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:44 |        0 | 2006-04-12 13:47:46 |
+---------------------+----------+---------------------+
```

In addition, the SET TIMESTAMP statement affects the value returned by NOW() but not by SYSDATE(). This means that timestamp settings in the binary log have no effect on invocations of SYSDATE().

Because SYSDATE() can return different values even within the same statement, and is not affected by SET TIMESTAMP, it is nondeterministic and therefore unsafe for replication if statement-based binary logging is used. If that is a problem, you can use row-based logging.

Alternatively, you can use the --sysdate-is-now option to cause SYSDATE() to be an alias for NOW(). This works if the option is used on both the master and the slave.

The nondeterministic nature of SYSDATE() also means that indexes cannot be used for evaluating expressions that refer to it.

Beginning with MySQL 5.1.42, a warning is logged if you use this function when binlog_format is set to STATEMENT. (Bug #47995)

- TIME(*expr*)

  Extracts the time part of the time or datetime expression *expr* and returns it as a string.

  This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when binlog_format is set to STATEMENT. (Bug #47995)

```
mysql> SELECT TIME('2003-12-31 01:02:03');
        -> '01:02:03'
mysql> SELECT TIME('2003-12-31 01:02:03.000123');
        -> '01:02:03.000123'
```

- TIMEDIFF(*expr1*,*expr2*)

  TIMEDIFF() returns *expr1* − *expr2* expressed as a time value. *expr1* and *expr2* are time or date-and-time expressions, but both must be of the same type.

  The result returned by TIMEDIFF() is limited to the range allowed for TIME values. Alternatively, you can use either of the functions TIMESTAMPDIFF() and UNIX_TIMESTAMP(), both of which return integers.

```
mysql> SELECT TIMEDIFF('2000:01:01 00:00:00',
    ->                 '2000:01:01 00:00:00.000001');
```

```
      -> '-00:00:00.000001'
mysql> SELECT TIMEDIFF('2008-12-31 23:59:59.000001',
    ->                 '2008-12-30 01:01:01.000002');
      -> '46:58:57.999999'
```

- TIMESTAMP(*expr*), TIMESTAMP(*expr1*,*expr2*)

  With a single argument, this function returns the date or datetime expression *expr* as a datetime value. With two arguments, it adds the time expression *expr2* to the date or datetime expression *expr1* and returns the result as a datetime value.

```
mysql> SELECT TIMESTAMP('2003-12-31');
      -> '2003-12-31 00:00:00'
mysql> SELECT TIMESTAMP('2003-12-31 12:00:00','12:00:00');
      -> '2004-01-01 00:00:00'
```

- TIMESTAMPADD(*unit*,*interval*,*datetime_expr*)

  Adds the integer expression *interval* to the date or datetime expression *datetime_expr*. The unit for *interval* is given by the *unit* argument, which should be one of the following values: FRAC_SECOND (microseconds), SECOND, MINUTE, HOUR, DAY, WEEK, MONTH, QUARTER, or YEAR.

  Beginning with MySQL 5.1.24, it is possible to use MICROSECOND in place of FRAC_SECOND with this function, and FRAC_SECOND is deprecated. FRAC_SECOND is removed in MySQL 5.5.

  The *unit* value may be specified using one of keywords as shown, or with a prefix of SQL_TSI_. For example, DAY and SQL_TSI_DAY both are legal.

```
mysql> SELECT TIMESTAMPADD(MINUTE,1,'2003-01-02');
      -> '2003-01-02 00:01:00'
mysql> SELECT TIMESTAMPADD(WEEK,1,'2003-01-02');
      -> '2003-01-09'
```

- TIMESTAMPDIFF(*unit*,*datetime_expr1*,*datetime_expr2*)

  Returns *datetime_expr2* − *datetime_expr1*, where *datetime_expr1* and *datetime_expr2* are date or datetime expressions. One expression may be a date and the other a datetime; a date value is treated as a datetime having the time part '00:00:00' where necessary. The unit for the result (an integer) is given by the *unit* argument. The legal values for *unit* are the same as those listed in the description of the TIMESTAMPADD() function.

```
mysql> SELECT TIMESTAMPDIFF(MONTH,'2003-02-01','2003-05-01');
      -> 3
mysql> SELECT TIMESTAMPDIFF(YEAR,'2002-05-01','2001-01-01');
      -> -1
mysql> SELECT TIMESTAMPDIFF(MINUTE,'2003-02-01','2003-05-01 12:05:55');
      -> 128885
```

> **Note**
>
> The order of the date or datetime arguments for this function is the opposite of that used with the TIMESTAMP() function when invoked with 2 arguments.

- TIME_FORMAT(*time*,*format*)

  This is used like the DATE_FORMAT() function, but the *format* string may contain format specifiers only for hours, minutes, seconds, and microseconds. Other specifiers produce a NULL value or 0.

If the `time` value contains an hour part that is greater than `23`, the `%H` and `%k` hour format specifiers produce a value larger than the usual range of `0..23`. The other hour format specifiers produce the hour value modulo 12.

```
mysql> SELECT TIME_FORMAT('100:00:00', '%H %k %h %I %l');
        -> '100 100 04 04 4'
```

- `TIME_TO_SEC(time)`

Returns the `time` argument, converted to seconds.

```
mysql> SELECT TIME_TO_SEC('22:23:00');
        -> 80580
mysql> SELECT TIME_TO_SEC('00:39:38');
        -> 2378
```

- `TO_DAYS(date)`

Given a date `date`, returns a day number (the number of days since year 0).

```
mysql> SELECT TO_DAYS(950501);
        -> 728779
mysql> SELECT TO_DAYS('2007-10-07');
        -> 733321
```

`TO_DAYS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable. See Section 12.8, "What Calendar Is Used By MySQL?", for details.

Remember that MySQL converts two-digit year values in dates to four-digit form using the rules in Section 11.3, "Date and Time Types". For example, `'2008-10-07'` and `'08-10-07'` are seen as identical dates:

```
mysql> SELECT TO_DAYS('2008-10-07'), TO_DAYS('08-10-07');
        -> 733687, 733687
```

In MySQL, the zero date is defined as `'0000-00-00'`, even though this date is itself considered invalid. This means that, for `'0000-00-00'` and `'0000-01-01'`, `TO_DAYS()` returns the values shown here:

```
mysql> SELECT TO_DAYS('0000-00-00');
+----------------------+
| to_days('0000-00-00') |
+----------------------+
|                 NULL |
+----------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+--------------------------------------+
| Level   | Code | Message                              |
+---------+------+--------------------------------------+
| Warning | 1292 | Incorrect datetime value: '0000-00-00' |
+---------+------+--------------------------------------+
1 row in set (0.00 sec)
```

```
mysql> SELECT TO_DAYS('0000-01-01');
+----------------------+
| to_days('0000-01-01') |
+----------------------+
|                    1 |
+----------------------+
1 row in set (0.00 sec)
```

This is true whether or not the `ALLOW_INVALID_DATES` SQL server mode is enabled.

- `UNIX_TIMESTAMP()`, `UNIX_TIMESTAMP(date)`

If called with no argument, returns a Unix timestamp (seconds since `'1970-01-01 00:00:00'` UTC) as an unsigned integer. If `UNIX_TIMESTAMP()` is called with a `date` argument, it returns the value of the argument as seconds since `'1970-01-01 00:00:00'` UTC. `date` may be a `DATE` string, a `DATETIME` string, a `TIMESTAMP`, or a number in the format `YYMMDD` or `YYYYMMDD`. The server interprets `date` as a value in the current time zone and converts it to an internal value in UTC. Clients can set their time zone as described in Section 10.6, "MySQL Server Time Zone Support".

```
mysql> SELECT UNIX_TIMESTAMP();
        -> 1447431666
mysql> SELECT UNIX_TIMESTAMP('2015-11-13 10:20:19');
        -> 1447431619
```

When `UNIX_TIMESTAMP()` is used on a `TIMESTAMP` column, the function returns the internal timestamp value directly, with no implicit "string-to-Unix-timestamp" conversion. If you pass an out-of-range date to `UNIX_TIMESTAMP()`, it returns `0`.

Note: If you use `UNIX_TIMESTAMP()` and `FROM_UNIXTIME()` to convert between `TIMESTAMP` values and Unix timestamp values, the conversion is lossy because the mapping is not one-to-one in both directions. For example, due to conventions for local time zone changes, it is possible for two `UNIX_TIMESTAMP()` to map two `TIMESTAMP` values to the same Unix timestamp value. `FROM_UNIXTIME()` will map that value back to only one of the original `TIMESTAMP` values. Here is an example, using `TIMESTAMP` values in the `CET` time zone:

```
mysql> SELECT UNIX_TIMESTAMP('2005-03-27 03:00:00');
+-------------------------------------+
| UNIX_TIMESTAMP('2005-03-27 03:00:00') |
+-------------------------------------+
|                          1111885200 |
+-------------------------------------+
mysql> SELECT UNIX_TIMESTAMP('2005-03-27 02:00:00');
+-------------------------------------+
| UNIX_TIMESTAMP('2005-03-27 02:00:00') |
+-------------------------------------+
|                          1111885200 |
+-------------------------------------+
mysql> SELECT FROM_UNIXTIME(1111885200);
+--------------------------+
| FROM_UNIXTIME(1111885200) |
+--------------------------+
| 2005-03-27 03:00:00      |
+--------------------------+
```

If you want to subtract `UNIX_TIMESTAMP()` columns, you might want to cast the result to signed integers. See Section 12.10, "Cast Functions and Operators".

- `UTC_DATE`, `UTC_DATE()`

Returns the current UTC date as a value in `'YYYY-MM-DD'` or `YYYYMMDD` format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT UTC_DATE(), UTC_DATE() + 0;
        -> '2003-08-14', 20030814
```

- `UTC_TIME`, `UTC_TIME()`

Returns the current UTC time as a value in `'HH:MM:SS'` or `HHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT UTC_TIME(), UTC_TIME() + 0;
        -> '18:07:53', 180753.000000
```

- `UTC_TIMESTAMP`, `UTC_TIMESTAMP()`

Returns the current UTC date and time as a value in `'YYYY-MM-DD HH:MM:SS'` or `YYYYMMDDHHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT UTC_TIMESTAMP(), UTC_TIMESTAMP() + 0;
        -> '2003-08-14 18:08:04', 20030814180804.000000
```

- `WEEK(date[,mode])`

This function returns the week number for `date`. The two-argument form of `WEEK()` enables you to specify whether the week starts on Sunday or Monday and whether the return value should be in the range from `0` to `53` or from `1` to `53`. If the `mode` argument is omitted, the value of the `default_week_format` system variable is used. See Section 5.1.4, "Server System Variables".

The following table describes how the `mode` argument works.

Mode	First day of week	Range	Week 1 is the first week …
0	Sunday	0-53	with a Sunday in this year
1	Monday	0-53	with 4 or more days this year
2	Sunday	1-53	with a Sunday in this year
3	Monday	1-53	with 4 or more days this year
4	Sunday	0-53	with 4 or more days this year
5	Monday	0-53	with a Monday in this year
6	Sunday	1-53	with 4 or more days this year
7	Monday	1-53	with a Monday in this year

For `mode` values with a meaning of "with 4 or more days this year," weeks are numbered according to ISO 8601:1988:

- If the week containing January 1 has 4 or more days in the new year, it is week 1.

- Otherwise, it is the last week of the previous year, and the next week is week 1.

```
mysql> SELECT WEEK('2008-02-20');
        -> 7
```

```
mysql> SELECT WEEK('2008-02-20',0);
        -> 7
mysql> SELECT WEEK('2008-02-20',1);
        -> 8
mysql> SELECT WEEK('2008-12-31',1);
        -> 53
```

Note that if a date falls in the last week of the previous year, MySQL returns 0 if you do not use 2, 3, 6, or 7 as the optional *mode* argument:

```
mysql> SELECT YEAR('2000-01-01'), WEEK('2000-01-01',0);
        -> 2000, 0
```

One might argue that WEEK() should return 52 because the given date actually occurs in the 52nd week of 1999. WEEK() returns 0 instead so that the return value is "the week number in the given year." This makes use of the WEEK() function reliable when combined with other functions that extract a date part from a date.

If you prefer a result evaluated with respect to the year that contains the first day of the week for the given date, use 0, 2, 5, or 7 as the optional *mode* argument.

```
mysql> SELECT WEEK('2000-01-01',2);
        -> 52
```

Alternatively, use the YEARWEEK() function:

```
mysql> SELECT YEARWEEK('2000-01-01');
        -> 199952
mysql> SELECT MID(YEARWEEK('2000-01-01'),5,2);
        -> '52'
```

- WEEKDAY(*date*)

  Returns the weekday index for *date* (0 = Monday, 1 = Tuesday, … 6 = Sunday).

  ```
  mysql> SELECT WEEKDAY('2008-02-03 22:23:00');
          -> 6
  mysql> SELECT WEEKDAY('2007-11-06');
          -> 1
  ```

- WEEKOFYEAR(*date*)

  Returns the calendar week of the date as a number in the range from 1 to 53. WEEKOFYEAR() is a compatibility function that is equivalent to WEEK(*date*,3).

  ```
  mysql> SELECT WEEKOFYEAR('2008-02-20');
          -> 8
  ```

- YEAR(*date*)

  Returns the year for *date*, in the range 1000 to 9999, or 0 for the "zero" date.

  ```
  mysql> SELECT YEAR('1987-01-01');
          -> 1987
  ```

- YEARWEEK(*date*), YEARWEEK(*date*,*mode*)

Returns year and week for a date. The year in the result may be different from the year in the date argument for the first and the last week of the year.

The *mode* argument works exactly like the *mode* argument to `WEEK()`. For the single-argument syntax, a *mode* value of 0 is used. Unlike `WEEK()`, the value of `default_week_format` does not influence `YEARWEEK()`.

```
mysql> SELECT YEARWEEK('1987-01-01');
        -> 198652
```

Note that the week number is different from what the `WEEK()` function would return (`0`) for optional arguments `0` or `1`, as `WEEK()` then returns the week in the context of the given year.

12.8 What Calendar Is Used By MySQL?

MySQL uses what is known as a *proleptic Gregorian calendar*.

Every country that has switched from the Julian to the Gregorian calendar has had to discard at least ten days during the switch. To see how this works, consider the month of October 1582, when the first Julian-to-Gregorian switch occurred.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

There are no dates between October 4 and October 15. This discontinuity is called the *cutover*. Any dates before the cutover are Julian, and any dates following the cutover are Gregorian. Dates during a cutover are nonexistent.

A calendar applied to dates when it was not actually in use is called *proleptic*. Thus, if we assume there was never a cutover and Gregorian rules always rule, we have a proleptic Gregorian calendar. This is what is used by MySQL, as is required by standard SQL. For this reason, dates prior to the cutover stored as MySQL `DATE` or `DATETIME` values must be adjusted to compensate for the difference. It is important to realize that the cutover did not occur at the same time in all countries, and that the later it happened, the more days were lost. For example, in Great Britain, it took place in 1752, when Wednesday September 2 was followed by Thursday September 14. Russia remained on the Julian calendar until 1918, losing 13 days in the process, and what is popularly referred to as its "October Revolution" occurred in November according to the Gregorian calendar.

12.9 Full-Text Search Functions

```
MATCH (col1,col2,...) AGAINST (expr [search_modifier])
```

```
search_modifier:
  {
      IN NATURAL LANGUAGE MODE
    | IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION
    | IN BOOLEAN MODE
    | WITH QUERY EXPANSION
  }
```

MySQL has support for full-text indexing and searching:

- A full-text index in MySQL is an index of type `FULLTEXT`.

- Full-text indexes can be used only with `MyISAM` tables. (In MySQL 5.6 and up, they can also be used with `InnoDB` tables.) Full-text indexes can be created only for `CHAR`, `VARCHAR`, or `TEXT` columns.

- A `FULLTEXT` index definition can be given in the `CREATE TABLE` statement when a table is created, or added later using `ALTER TABLE` or `CREATE INDEX`.

- For large data sets, it is much faster to load your data into a table that has no `FULLTEXT` index and then create the index after that, than to load data into a table that has an existing `FULLTEXT` index.

Full-text searching is performed using `MATCH() ... AGAINST` syntax. `MATCH()` takes a comma-separated list that names the columns to be searched. `AGAINST` takes a string to search for, and an optional modifier that indicates what type of search to perform. The search string must be a string value that is constant during query evaluation. This rules out, for example, a table column because that can differ for each row.

There are three types of full-text searches:

- A natural language search interprets the search string as a phrase in natural human language (a phrase in free text). There are no special operators. The stopword list applies. In addition, words that are present in 50% or more of the rows are considered common and do not match.

  Full-text searches are natural language searches if the `IN NATURAL LANGUAGE MODE` modifier is given or if no modifier is given. For more information, see Section 12.9.1, "Natural Language Full-Text Searches".

- A boolean search interprets the search string using the rules of a special query language. The string contains the words to search for. It can also contain operators that specify requirements such that a word must be present or absent in matching rows, or that it should be weighted higher or lower than usual. Common words such as "some" or "then" are stopwords and do not match if present in the search string. The `IN BOOLEAN MODE` modifier specifies a boolean search. For more information, see Section 12.9.2, "Boolean Full-Text Searches".

- A query expansion search is a modification of a natural language search. The search string is used to perform a natural language search. Then words from the most relevant rows returned by the search are added to the search string and the search is done again. The query returns the rows from the second search. The `IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION` or `WITH QUERY EXPANSION` modifier specifies a query expansion search. For more information, see Section 12.9.3, "Full-Text Searches with Query Expansion".

The `IN NATURAL LANGUAGE MODE` and `IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION` modifiers were added in MySQL 5.1.7.

Constraints on full-text searching are listed in Section 12.9.5, "Full-Text Restrictions".

The `myisam_ftdump` utility can be used to dump the contents of a full-text index. This may be helpful for debugging full-text queries. See Section 4.6.2, "`myisam_ftdump` — Display Full-Text Index information".

12.9.1 Natural Language Full-Text Searches

By default or with the `IN NATURAL LANGUAGE MODE` modifier, the `MATCH()` function performs a natural language search for a string against a *text collection*. A collection is a set of one or more columns included in a `FULLTEXT` index. The search string is given as the argument to `AGAINST()`. For each row in the table, `MATCH()` returns a relevance value; that is, a similarity measure between the search string and the text in that row in the columns named in the `MATCH()` list.

```
mysql> CREATE TABLE articles (
```

```
    ->   id INT UNSIGNED AUTO_INCREMENT NOT NULL PRIMARY KEY,
    ->   title VARCHAR(200),
    ->   body TEXT,
    ->   FULLTEXT (title,body)
    -> ) ENGINE=MyISAM;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO articles (title,body) VALUES
    -> ('MySQL Tutorial','DBMS stands for DataBase ...'),
    -> ('How To Use MySQL Well','After you went through a ...'),
    -> ('Optimizing MySQL','In this tutorial we will show ...'),
    -> ('1001 MySQL Tricks','1. Never run mysqld as root. 2. ...'),
    -> ('MySQL vs. YourSQL','In the following database comparison ...'),
    -> ('MySQL Security','When configured properly, MySQL ...');
Query OK, 6 rows affected (0.00 sec)
Records: 6  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' IN NATURAL LANGUAGE MODE);
+----+-------------------+-----------------------------------------+
| id | title             | body                                    |
+----+-------------------+-----------------------------------------+
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
|  1 | MySQL Tutorial    | DBMS stands for DataBase ...            |
+----+-------------------+-----------------------------------------+
2 rows in set (0.00 sec)
```

By default, the search is performed in case-insensitive fashion. However, you can perform a case-sensitive full-text search by using a binary collation for the indexed columns. For example, a column that uses the `latin1` character set of can be assigned a collation of `latin1_bin` to make it case sensitive for full-text searches.

When `MATCH()` is used in a `WHERE` clause, as in the example shown earlier, the rows returned are automatically sorted with the highest relevance first. Relevance values are nonnegative floating-point numbers. Zero relevance means no similarity. Relevance is computed based on the number of words in the row, the number of unique words in that row, the total number of words in the collection, and the number of documents (rows) that contain a particular word.

To simply count matches, you could use a query like this:

```
mysql> SELECT COUNT(*) FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' IN NATURAL LANGUAGE MODE);
+----------+
| COUNT(*) |
+----------+
|        2 |
+----------+
1 row in set (0.00 sec)
```

However, you might find it quicker to rewrite the query as follows:

```
mysql> SELECT
    -> COUNT(IF(MATCH (title,body) AGAINST ('database' IN NATURAL LANGUAGE MODE), 1, NULL))
    -> AS count
    -> FROM articles;
+-------+
| count |
+-------+
|     2 |
+-------+
1 row in set (0.03 sec)
```

The first query sorts the results by relevance whereas the second does not. However, the second query performs a full table scan and the first does not. The first may be faster if the search matches few rows; otherwise, the second may be faster because it would read many rows anyway.

For natural-language full-text searches, it is a requirement that the columns named in the `MATCH()` function be the same columns included in some `FULLTEXT` index in your table. For the preceding query, note that the columns named in the `MATCH()` function (`title` and `body`) are the same as those named in the definition of the `article` table's `FULLTEXT` index. If you wanted to search the `title` or `body` separately, you would need to create separate `FULLTEXT` indexes for each column.

It is also possible to perform a boolean search or a search with query expansion. These search types are described in Section 12.9.2, "Boolean Full-Text Searches", and Section 12.9.3, "Full-Text Searches with Query Expansion".

A full-text search that uses an index can name columns only from a single table in the `MATCH()` clause because an index cannot span multiple tables. A boolean search can be done in the absence of an index (albeit more slowly), in which case it is possible to name columns from multiple tables.

The preceding example is a basic illustration that shows how to use the `MATCH()` function where rows are returned in order of decreasing relevance. The next example shows how to retrieve the relevance values explicitly. Returned rows are not ordered because the `SELECT` statement includes neither `WHERE` nor `ORDER BY` clauses:

```
mysql> SELECT id, MATCH (title,body)
    -> AGAINST ('Tutorial' IN NATURAL LANGUAGE MODE) AS score
    -> FROM articles;
+----+------------------+
| id | score            |
+----+------------------+
|  1 | 0.65545833110809 |
|  2 |                0 |
|  3 | 0.66266459226608 |
|  4 |                0 |
|  5 |                0 |
|  6 |                0 |
+----+------------------+
6 rows in set (0.00 sec)
```

The following example is more complex. The query returns the relevance values and it also sorts the rows in order of decreasing relevance. To achieve this result, specify `MATCH()` twice: once in the `SELECT` list and once in the `WHERE` clause. This causes no additional overhead, because the MySQL optimizer notices that the two `MATCH()` calls are identical and invokes the full-text search code only once.

```
mysql> SELECT id, body, MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root'
    -> IN NATURAL LANGUAGE MODE) AS score
    -> FROM articles WHERE MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root'
    -> IN NATURAL LANGUAGE MODE);
+----+-------------------------------------+-----------------+
| id | body                                | score           |
+----+-------------------------------------+-----------------+
|  4 | 1. Never run mysqld as root. 2. ... | 1.5219271183014 |
|  6 | When configured properly, MySQL ... | 1.3114095926285 |
+----+-------------------------------------+-----------------+
2 rows in set (0.00 sec)
```

The MySQL `FULLTEXT` implementation regards any sequence of true word characters (letters, digits, and underscores) as a word. That sequence may also contain apostrophes ("`'`"), but not more than one

in a row. This means that `aaa'bbb` is regarded as one word, but `aaa''bbb` is regarded as two words. Apostrophes at the beginning or the end of a word are stripped by the `FULLTEXT` parser; `'aaa'bbb'` would be parsed as `aaa'bbb`.

The `FULLTEXT` parser determines where words start and end by looking for certain delimiter characters; for example, " " (space), "," (comma), and "." (period). If words are not separated by delimiters (as in, for example, Chinese), the `FULLTEXT` parser cannot determine where a word begins or ends. To be able to add words or other indexed terms in such languages to a `FULLTEXT` index, you must preprocess them so that they are separated by some arbitrary delimiter such as "`"`".

It is possible to write a plugin that replaces the built-in full-text parser. For details, see Section 22.2, "The MySQL Plugin API". For example parser plugin source code, see the `plugin/fulltext` directory of a MySQL source distribution.

Some words are ignored in full-text searches:

- Any word that is too short is ignored. The default minimum length of words that are found by full-text searches is four characters.

- Words in the stopword list are ignored. A stopword is a word such as "the" or "some" that is so common that it is considered to have zero semantic value. There is a built-in stopword list, but it can be overwritten by a user-defined list.

The default stopword list is given in Section 12.9.4, "Full-Text Stopwords". The default minimum word length and stopword list can be changed as described in Section 12.9.6, "Fine-Tuning MySQL Full-Text Search".

Every correct word in the collection and in the query is weighted according to its significance in the collection or query. Consequently, a word that is present in many documents has a lower weight (and may even have a zero weight), because it has lower semantic value in this particular collection. Conversely, if the word is rare, it receives a higher weight. The weights of the words are combined to compute the relevance of the row.

Such a technique works best with large collections (in fact, it was carefully tuned this way). For very small tables, word distribution does not adequately reflect their semantic value, and this model may sometimes produce bizarre results. For example, although the word "MySQL" is present in every row of the `articles` table shown earlier, a search for the word produces no results:

```
mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('MySQL' IN NATURAL LANGUAGE MODE);
Empty set (0.00 sec)
```

The search result is empty because the word "MySQL" is present in at least 50% of the rows. As such, it is effectively treated as a stopword. For large data sets, this is the most desirable behavior: A natural language query should not return every second row from a 1GB table. For small data sets, it may be less desirable.

A word that matches half of the rows in a table is less likely to locate relevant documents. In fact, it most likely finds plenty of irrelevant documents. We all know this happens far too often when we are trying to find something on the Internet with a search engine. It is with this reasoning that rows containing the word are assigned a low semantic value for *the particular data set in which they occur*. A given word may reach the 50% threshold in one data set but not another.

The 50% threshold has a significant implication when you first try full-text searching to see how it works: If you create a table and insert only one or two rows of text into it, every word in the text occurs in at least

50% of the rows. As a result, no search returns any results. Be sure to insert at least three rows, and preferably many more. Users who need to bypass the 50% limitation can use the boolean search mode; see Section 12.9.2, "Boolean Full-Text Searches".

12.9.2 Boolean Full-Text Searches

MySQL can perform boolean full-text searches using the `IN BOOLEAN MODE` modifier. With this modifier, certain characters have special meaning at the beginning or end of words in the search string. In the following query, the `+` and `-` operators indicate that a word is required to be present or absent, respectively, for a match to occur. Thus, the query retrieves all the rows that contain the word "MySQL" but that do *not* contain the word "YourSQL":

```
mysql> SELECT * FROM articles WHERE MATCH (title,body)
    -> AGAINST ('+MySQL -YourSQL' IN BOOLEAN MODE);
+----+-----------------------+-------------------------------------+
| id | title                 | body                                |
+----+-----------------------+-------------------------------------+
|  1 | MySQL Tutorial        | DBMS stands for DataBase ...        |
|  2 | How To Use MySQL Well | After you went through a ...        |
|  3 | Optimizing MySQL      | In this tutorial we will show ...   |
|  4 | 1001 MySQL Tricks     | 1. Never run mysqld as root. 2. ... |
|  6 | MySQL Security        | When configured properly, MySQL ... |
+----+-----------------------+-------------------------------------+
```

Note

In implementing this feature, MySQL uses what is sometimes referred to as *implied Boolean logic*, in which

- `+` stands for `AND`

- `-` stands for `NOT`

- [*no operator*] implies `OR`

Boolean full-text searches have these characteristics:

- They do not use the 50% threshold.

- They do not automatically sort rows in order of decreasing relevance. You can see this from the preceding query result: The row with the highest relevance is the one that contains "MySQL" twice, but it is listed last, not first.

- They can work even without a `FULLTEXT` index, although a search executed in this fashion would be quite slow.

- The minimum and maximum word length full-text parameters apply.

- The stopword list applies.

The boolean full-text search capability supports the following operators:

- `+`

  A leading plus sign indicates that this word *must* be present in each row that is returned.

- `-`

  A leading minus sign indicates that this word must *not* be present in any of the rows that are returned.

Note: The `-` operator acts only to exclude rows that are otherwise matched by other search terms. Thus, a boolean-mode search that contains only terms preceded by `-` returns an empty result. It does not return "all rows except those containing any of the excluded terms."

- (no operator)

  By default (when neither `+` nor `-` is specified) the word is optional, but the rows that contain it are rated higher. This mimics the behavior of `MATCH() ... AGAINST()` without the `IN BOOLEAN MODE` modifier.

- `>` `<`

  These two operators are used to change a word's contribution to the relevance value that is assigned to a row. The `>` operator increases the contribution and the `<` operator decreases it. See the example following this list.

- `(` `)`

  Parentheses group words into subexpressions. Parenthesized groups can be nested.

- `~`

  A leading tilde acts as a negation operator, causing the word's contribution to the row's relevance to be negative. This is useful for marking "noise" words. A row containing such a word is rated lower than others, but is not excluded altogether, as it would be with the `-` operator.

- `*`

  The asterisk serves as the truncation (or wildcard) operator. Unlike the other operators, it should be *appended* to the word to be affected. Words match if they begin with the word preceding the `*` operator.

  If a word is specified with the truncation operator, it is not stripped from a boolean query, even if it is too short (as determined from the `ft_min_word_len` setting) or a stopword. This occurs because the word is not seen as too short or a stopword, but as a prefix that must be present in the document in the form of a word that begins with the prefix. Suppose that `ft_min_word_len=4`. Then a search for `'+word +the*'` will likely return fewer rows than a search for `'+word +the'`:

  - The former query remains as is and requires both *word* and `the*` (a word starting with `the`) to be present in the document.

  - The latter query is transformed to `+word` (requiring only *word* to be present). `the` is both too short and a stopword, and either condition is enough to cause it to be ignored.

- `"`

  A phrase that is enclosed within double quote (""") characters matches only rows that contain the phrase *literally, as it was typed*. The full-text engine splits the phrase into words and performs a search in the `FULLTEXT` index for the words. Nonword characters need not be matched exactly: Phrase searching requires only that matches contain exactly the same words as the phrase and in the same order. For example, `"test phrase"` matches `"test, phrase"`.

  If the phrase contains no words that are in the index, the result is empty. For example, if all words are either stopwords or shorter than the minimum length of indexed words, the result is empty.

The following examples demonstrate some search strings that use boolean full-text operators:

- `'apple banana'`

Find rows that contain at least one of the two words.

- `'+apple +juice'`

Find rows that contain both words.

- `'+apple macintosh'`

Find rows that contain the word "apple", but rank rows higher if they also contain "macintosh".

- `'+apple -macintosh'`

Find rows that contain the word "apple" but not "macintosh".

- `'+apple ~macintosh'`

Find rows that contain the word "apple", but if the row also contains the word "macintosh", rate it lower than if row does not. This is "softer" than a search for `'+apple -macintosh'`, for which the presence of "macintosh" causes the row not to be returned at all.

- `'+apple +(>turnover <strudel)'`

Find rows that contain the words "apple" and "turnover", or "apple" and "strudel" (in any order), but rank "apple turnover" higher than "apple strudel".

- `'apple*'`

Find rows that contain words such as "apple", "apples", "applesauce", or "applet".

- `'"some words"'`

Find rows that contain the exact phrase "some words" (for example, rows that contain "some words of wisdom" but not "some noise words"). Note that the """ characters that enclose the phrase are operator characters that delimit the phrase. They are not the quotation marks that enclose the search string itself.

12.9.3 Full-Text Searches with Query Expansion

Full-text search supports query expansion (and in particular, its variant "blind query expansion"). This is generally useful when a search phrase is too short, which often means that the user is relying on implied knowledge that the full-text search engine lacks. For example, a user searching for "database" may really mean that "MySQL", "Oracle", "DB2", and "RDBMS" all are phrases that should match "databases" and should be returned, too. This is implied knowledge.

Blind query expansion (also known as automatic relevance feedback) is enabled by adding `WITH QUERY EXPANSION` or `IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION` following the search phrase. It works by performing the search twice, where the search phrase for the second search is the original search phrase concatenated with the few most highly relevant documents from the first search. Thus, if one of these documents contains the word "databases" and the word "MySQL", the second search finds the documents that contain the word "MySQL" even if they do not contain the word "database". The following example shows this difference:

```
mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' IN NATURAL LANGUAGE MODE);
+----+-------------------+------------------------------------------+
| id | title             | body                                     |
+----+-------------------+------------------------------------------+
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
```

```
|  1 | MySQL Tutorial   | DBMS stands for DataBase ...            |
+----+------------------+-----------------------------------------+
2 rows in set (0.00 sec)

mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' WITH QUERY EXPANSION);
+----+------------------+-----------------------------------------+
| id | title            | body                                    |
+----+------------------+-----------------------------------------+
|  1 | MySQL Tutorial   | DBMS stands for DataBase ...            |
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
|  3 | Optimizing MySQL | In this tutorial we will show ...       |
+----+------------------+-----------------------------------------+
3 rows in set (0.00 sec)
```

Another example could be searching for books by Georges Simenon about Maigret, when a user is not sure how to spell "Maigret". A search for "Megre and the reluctant witnesses" finds only "Maigret and the Reluctant Witnesses" without query expansion. A search with query expansion finds all books with the word "Maigret" on the second pass.

Note

Because blind query expansion tends to increase noise significantly by returning nonrelevant documents, it is meaningful to use only when a search phrase is rather short.

12.9.4 Full-Text Stopwords

The stopword list is loaded and searched for full-text queries using the server character set and collation (the values of the `character_set_server` and `collation_server` system variables). False hits or misses may occur for stopword lookups if the stopword file or columns used for full-text indexing or searches have a character set or collation different from `character_set_server` or `collation_server`.

Case sensitivity of stopword lookups depends on the server collation. For example, lookups are case insensitive if the collation is `latin1_swedish_ci`, whereas lookups are case sensitive if the collation is `latin1_general_cs` or `latin1_bin`.

The following table shows the default list of full-text stopwords. In a MySQL source distribution, you can find this list in the `storage/myisam/ft_static.c` file.

a's	able	about	above	according
accordingly	across	actually	after	afterwards
again	against	ain't	all	allow
allows	almost	alone	along	already
also	although	always	am	among
amongst	an	and	another	any
anybody	anyhow	anyone	anything	anyway
anyways	anywhere	apart	appear	appreciate
appropriate	are	aren't	around	as
aside	ask	asking	associated	at
available	away	awfully	be	became
because	become	becomes	becoming	been

before	beforehand	behind	being	believe
below	beside	besides	best	better
between	beyond	both	brief	but
by	c'mon	c's	came	can
can't	cannot	cant	cause	causes
certain	certainly	changes	clearly	co
com	come	comes	concerning	consequently
consider	considering	contain	containing	contains
corresponding	could	couldn't	course	currently
definitely	described	despite	did	didn't
different	do	does	doesn't	doing
don't	done	down	downwards	during
each	edu	eg	eight	either
else	elsewhere	enough	entirely	especially
et	etc	even	ever	every
everybody	everyone	everything	everywhere	ex
exactly	example	except	far	few
fifth	first	five	followed	following
follows	for	former	formerly	forth
four	from	further	furthermore	get
gets	getting	given	gives	go
goes	going	gone	got	gotten
greetings	had	hadn't	happens	hardly
has	hasn't	have	haven't	having
he	he's	hello	help	hence
her	here	here's	hereafter	hereby
herein	hereupon	hers	herself	hi
him	himself	his	hither	hopefully
how	howbeit	however	i'd	i'll
i'm	i've	ie	if	ignored
immediate	in	inasmuch	inc	indeed
indicate	indicated	indicates	inner	insofar
instead	into	inward	is	isn't
it	it'd	it'll	it's	its
itself	just	keep	keeps	kept
know	known	knows	last	lately
later	latter	latterly	least	less
lest	let	let's	like	liked
likely	little	look	looking	looks

ltd	mainly	many	may	maybe
me	mean	meanwhile	merely	might
more	moreover	most	mostly	much
must	my	myself	name	namely
nd	near	nearly	necessary	need
needs	neither	never	nevertheless	new
next	nine	no	nobody	non
none	noone	nor	normally	not
nothing	novel	now	nowhere	obviously
of	off	often	oh	ok
okay	old	on	once	one
ones	only	onto	or	other
others	otherwise	ought	our	ours
ourselves	out	outside	over	overall
own	particular	particularly	per	perhaps
placed	please	plus	possible	presumably
probably	provides	que	quite	qv
rather	rd	re	really	reasonably
regarding	regardless	regards	relatively	respectively
right	said	same	saw	say
saying	says	second	secondly	see
seeing	seem	seemed	seeming	seems
seen	self	selves	sensible	sent
serious	seriously	seven	several	shall
she	should	shouldn't	since	six
so	some	somebody	somehow	someone
something	sometime	sometimes	somewhat	somewhere
soon	sorry	specified	specify	specifying
still	sub	such	sup	sure
t's	take	taken	tell	tends
th	than	thank	thanks	thanx
that	that's	thats	the	their
theirs	them	themselves	then	thence
there	there's	thereafter	thereby	therefore
therein	theres	thereupon	these	they
they'd	they'll	they're	they've	think
third	this	thorough	thoroughly	those
though	three	through	throughout	thru
thus	to	together	too	took

toward	towards	tried	tries	truly
try	trying	twice	two	un
under	unfortunately	unless	unlikely	until
unto	up	upon	us	use
used	useful	uses	using	usually
value	various	very	via	viz
vs	want	wants	was	wasn't
way	we	we'd	we'll	we're
we've	welcome	well	went	were
weren't	what	what's	whatever	when
whence	whenever	where	where's	whereafter
whereas	whereby	wherein	whereupon	wherever
whether	which	while	whither	who
who's	whoever	whole	whom	whose
why	will	willing	wish	with
within	without	won't	wonder	would
wouldn't	yes	yet	you	you'd
you'll	you're	you've	your	yours
yourself	yourselves	zero		

12.9.5 Full-Text Restrictions

- Full-text searches are supported for `MyISAM` tables only. (In MySQL 5.6 and up, they can also be used with `InnoDB` tables.)

- Full-text searches are not supported for partitioned tables. See Section 18.5, "Restrictions and Limitations on Partitioning".

- Full-text searches can be used with most multibyte character sets. The exception is that for Unicode, the `utf8` character set can be used, but not the `ucs2` character set. However, although `FULLTEXT` indexes on `ucs2` columns cannot be used, you can perform `IN BOOLEAN MODE` searches on a `ucs2` column that has no such index.

- Ideographic languages such as Chinese and Japanese do not have word delimiters. Therefore, the `FULLTEXT` parser *cannot determine where words begin and end in these and other such languages*. The implications of this and some workarounds for the problem are described in Section 12.9, "Full-Text Search Functions".

- Although the use of multiple character sets within a single table is supported, all columns in a `FULLTEXT` index must use the same character set and collation.

- The `MATCH()` column list must match exactly the column list in some `FULLTEXT` index definition for the table, unless this `MATCH()` is `IN BOOLEAN MODE`. Boolean-mode searches can be done on nonindexed columns, although they are likely to be slow.

- The argument to `AGAINST()` must be a string value that is constant during query evaluation. This rules out, for example, a table column because that can differ for each row.

- Index hints are more limited for `FULLTEXT` searches than for non-`FULLTEXT` searches. See Section 8.9.3, "Index Hints".

- The '%' character is not a supported wildcard character for full-text searches.

12.9.6 Fine-Tuning MySQL Full-Text Search

MySQL's full-text search capability has few user-tunable parameters. You can exert more control over full-text searching behavior if you have a MySQL source distribution because some changes require source code modifications. See Section 2.11, "Installing MySQL from Source".

Full-text search is carefully tuned for the most effectiveness. Modifying the default behavior in most cases can actually decrease effectiveness. *Do not alter the MySQL sources unless you know what you are doing.*

Most full-text variables described in this section must be set at server startup time. A server restart is required to change them; they cannot be modified while the server is running.

Some variable changes require that you rebuild the `FULLTEXT` indexes in your tables. Instructions for doing so are given later in this section.

- The minimum and maximum lengths of words to be indexed are defined by the `ft_min_word_len` and `ft_max_word_len` system variables. (See Section 5.1.4, "Server System Variables".) The default minimum value is four characters; the default maximum is version dependent. If you change either value, you must rebuild your `FULLTEXT` indexes. For example, if you want three-character words to be searchable, you can set the `ft_min_word_len` variable by putting the following lines in an option file:

```
[mysqld]
ft_min_word_len=3
```

Then restart the server and rebuild your `FULLTEXT` indexes. Note particularly the remarks regarding `myisamchk` in the instructions following this list.

- To override the default stopword list, set the `ft_stopword_file` system variable. (See Section 5.1.4, "Server System Variables".) The variable value should be the path name of the file containing the stopword list, or the empty string to disable stopword filtering. The server looks for the file in the data directory unless an absolute path name is given to specify a different directory. After changing the value of this variable or the contents of the stopword file, restart the server and rebuild your `FULLTEXT` indexes.

The stopword list is free-form. That is, you may use any nonalphanumeric character such as newline, space, or comma to separate stopwords. Exceptions are the underscore character ("_") and a single apostrophe ("'") which are treated as part of a word. The character set of the stopword list is the server's default character set; see Section 10.1.3.1, "Server Character Set and Collation".

- The 50% threshold for natural language searches is determined by the particular weighting scheme chosen. To disable it, look for the following line in `storage/myisam/ftdefs.h`:

```
#define GWS_IN_USE GWS_PROB
```

Change that line to this:

```
#define GWS_IN_USE GWS_FREQ
```

Then recompile MySQL. There is no need to rebuild the indexes in this case.

> **Note**
>
> By making this change, you *severely* decrease MySQL's ability to provide adequate relevance values for the `MATCH()` function. If you really need to search for such common words, it would be better to search using `IN BOOLEAN MODE` instead, which does not observe the 50% threshold.

- To change the operators used for boolean full-text searches, set the `ft_boolean_syntax` system variable. This variable can be changed while the server is running, but you must have the `SUPER` privilege to do so. No rebuilding of indexes is necessary in this case. See Section 5.1.4, "Server System Variables", which describes the rules governing how to set this variable.

- If you want to change the set of characters that are considered word characters, you can do so in several ways, as described in the following list. After making the modification, you must rebuild the indexes for each table that contains any `FULLTEXT` indexes. Suppose that you want to treat the hyphen character ('-') as a word character. Use one of these methods:

  - Modify the MySQL source: In `storage/myisam/ftdefs.h`, see the `true_word_char()` and `misc_word_char()` macros. Add `'-'` to one of those macros and recompile MySQL.

  - Modify a character set file: This requires no recompilation. The `true_word_char()` macro uses a "character type" table to distinguish letters and numbers from other characters. . You can edit the contents of the `<ctype><map>` array in one of the character set XML files to specify that `'-'` is a "letter." Then use the given character set for your `FULLTEXT` indexes. For information about the `<ctype><map>` array format, see Section 10.3.1, "Character Definition Arrays".

  - Add a new collation for the character set used by the indexed columns, and alter the columns to use that collation. For general information about adding collations, see Section 10.4, "Adding a Collation to a Character Set". For an example specific to full-text indexing, see Section 12.9.7, "Adding a Collation for Full-Text Indexing".

If you modify full-text variables that affect indexing (`ft_min_word_len`, `ft_max_word_len`, or `ft_stopword_file`), or if you change the stopword file itself, you must rebuild your `FULLTEXT` indexes after making the changes and restarting the server. To rebuild the indexes in this case, it is sufficient to do a `QUICK` repair operation:

```
mysql> REPAIR TABLE tbl_name QUICK;
```

Alternatively, use `ALTER TABLE` with the `DROP INDEX` and `ADD INDEX` options to drop and re-create each `FULLTEXT` index. In some cases, this may be faster than a repair operation.

Each table that contains any `FULLTEXT` index must be repaired as just shown. Otherwise, queries for the table may yield incorrect results, and modifications to the table will cause the server to see the table as corrupt and in need of repair.

If you use `myisamchk` to perform an operation that modifies table indexes (such as repair or analyze), the `FULLTEXT` indexes are rebuilt using the *default* full-text parameter values for minimum word length, maximum word length, and stopword file unless you specify otherwise. This can result in queries failing.

The problem occurs because these parameters are known only by the server. They are not stored in `MyISAM` index files. To avoid the problem if you have modified the minimum or maximum word length or stopword file values used by the server, specify the same `ft_min_word_len`, `ft_max_word_len`, and `ft_stopword_file` values for `myisamchk` that you use for `mysqld`. For example, if you have set the minimum word length to 3, you can repair a table with `myisamchk` like this:

```
shell> myisamchk --recover --ft_min_word_len=3 tbl_name.MYI
```

To ensure that `myisamchk` and the server use the same values for full-text parameters, place each one in both the `[mysqld]` and `[myisamchk]` sections of an option file:

```
[mysqld]
ft_min_word_len=3

[myisamchk]
ft_min_word_len=3
```

An alternative to using `myisamchk` for index modification is to use the `REPAIR TABLE`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, or `ALTER TABLE` statements. These statements are performed by the server, which knows the proper full-text parameter values to use.

12.9.7 Adding a Collation for Full-Text Indexing

This section describes how to add a new collation for full-text searches. The sample collation is like `latin1_swedish_ci` but treats the `'-'` character as a letter rather than as a punctuation character so that it can be indexed as a word character. General information about adding collations is given in Section 10.4, "Adding a Collation to a Character Set"; it is assumed that you have read it and are familiar with the files involved.

To add a collation for full-text indexing, use this procedure:

1. Add a collation to the `Index.xml` file. The collation ID must be unused, so choose a value different from 62 if that ID is already taken on your system.

   ```
   <charset name="latin1">
   ...
   <collation name="latin1_fulltext_ci" id="62"/>
   </charset>
   ```

2. Declare the sort order for the collation in the `latin1.xml` file. In this case, the order can be copied from `latin1_swedish_ci`:

   ```
   <collation name="latin1_fulltext_ci">
   <map>
   00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
   10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
   20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
   30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F
   40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
   50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F
   60 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
   50 51 52 53 54 55 56 57 58 59 5A 7B 7C 7D 7E 7F
   80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
   90 91 92 93 94 95 96 97 98 99 9A 9B 9C 9D 9E 9F
   A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AA AB AC AD AE AF
   B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 BA BB BC BD BE BF
   41 41 41 41 5C 5B 5C 43 45 45 45 45 49 49 49 49
   44 4E 4F 4F 4F 4F 5D D7 D8 55 55 55 59 59 DE DF
   41 41 41 41 5C 5B 5C 43 45 45 45 45 49 49 49 49
   44 4E 4F 4F 4F 4F 5D F7 D8 55 55 55 59 59 DE FF
   </map>
   </collation>
   ```

3. Modify the `ctype` array in `latin1.xml`. Change the value corresponding to 0x2D (which is the code for the `'-'` character) from 10 (punctuation) to 01 (small letter). In the following array, this is the element in the fourth row down, third value from the end.

```
<ctype>
<map>
00
20 20 20 20 20 20 20 20 20 28 28 28 28 28 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
48 10 10 10 10 10 10 10 10 10 10 10 10 01 10 10
84 84 84 84 84 84 84 84 84 84 10 10 10 10 10 10
10 81 81 81 81 81 81 01 01 01 01 01 01 01 01 01
01 01 01 01 01 01 01 01 01 01 01 10 10 10 10 10
10 82 82 82 82 82 82 02 02 02 02 02 02 02 02 02
02 02 02 02 02 02 02 02 02 02 02 10 10 10 10 20
10 00 10 02 10 10 10 10 10 10 01 10 01 00 01 00
00 10 10 10 10 10 10 10 10 10 02 10 02 00 02 01
48 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
01 01 01 01 01 01 01 10 01 01 01 01 01 01 01 02
02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02
02 02 02 02 02 02 02 10 02 02 02 02 02 02 02 02
</map>
</ctype>
```

4. Restart the server.

5. To employ the new collation, include it in the definition of columns that are to use it:

```
mysql> DROP TABLE IF EXISTS t1;
Query OK, 0 rows affected (0.13 sec)

mysql> CREATE TABLE t1 (
    -> a TEXT CHARACTER SET latin1 COLLATE latin1_fulltext_ci,
    -> FULLTEXT INDEX(a)
    -> ) ENGINE=MyISAM;
Query OK, 0 rows affected (0.47 sec)
```

6. Test the collation to verify that hyphen is considered as a word character:

```
mysql> INSERT INTO t1 VALUEs ('----'),('....'),('abcd');
Query OK, 3 rows affected (0.22 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t1 WHERE MATCH a AGAINST ('----' IN BOOLEAN MODE);
+------+
| a    |
+------+
| ---- |
+------+
1 row in set (0.00 sec)
```

12.10 Cast Functions and Operators

Table 12.14 Cast Functions

Name	Description
BINARY	Cast a string to a binary string
CAST()	Cast a value as a certain type
CONVERT()	Cast a value as a certain type

- BINARY

The `BINARY` operator casts the string following it to a binary string. This is an easy way to force a column comparison to be done byte by byte rather than character by character. This causes the comparison to be case sensitive even if the column is not defined as `BINARY` or `BLOB`. `BINARY` also causes trailing spaces to be significant.

```
mysql> SELECT 'a' = 'A';
        -> 1
mysql> SELECT BINARY 'a' = 'A';
        -> 0
mysql> SELECT 'a' = 'a ';
        -> 1
mysql> SELECT BINARY 'a' = 'a ';
        -> 0
```

In a comparison, `BINARY` affects the entire operation; it can be given before either operand with the same result.

`BINARY str` is shorthand for `CAST(str AS BINARY)`.

Note that in some contexts, if you cast an indexed column to `BINARY`, MySQL is not able to use the index efficiently.

- `CAST(expr AS type)`

  The `CAST()` function takes an expression of any type and produces a result value of a specified type, similar to `CONVERT()`. See the description of `CONVERT()` for more information.

- `CONVERT(expr,type)`, `CONVERT(expr USING transcoding_name)`

  The `CONVERT()` and `CAST()` functions take an expression of any type and produce a result value of a specified type.

  `CAST()` and `CONVERT(... USING ...)` are standard SQL syntax. The non-`USING` form of `CONVERT()` is ODBC syntax.

  `CONVERT()` with `USING` converts data between different character sets. In MySQL, transcoding names are the same as the corresponding character set names. For example, this statement converts the string `'abc'` in the default character set to the corresponding string in the `utf8` character set:

```
SELECT CONVERT('abc' USING utf8);
```

  The `type` for the result can be one of the following values:

- `BINARY[(N)]`

- `CHAR[(N)]`

- `DATE`

- `DATETIME`

- `DECIMAL[(M[,D])]`

- `SIGNED [INTEGER]`

- `TIME`

- UNSIGNED [INTEGER]

BINARY produces a string with the BINARY data type. See Section 11.4.2, "The BINARY and VARBINARY Types" for a description of how this affects comparisons. If the optional length N is given, BINARY(N) causes the cast to use no more than N bytes of the argument. Values shorter than N bytes are padded with 0x00 bytes to a length of N.

CHAR(N) causes the cast to use no more than N characters of the argument.

Normally, you cannot compare a BLOB value or other binary string in case-insensitive fashion because binary strings have no character set, and thus no concept of lettercase. To perform a case-insensitive comparison, use the CONVERT() function to convert the value to a nonbinary string. Comparisons of the result use the string collation. For example, if the character set of the result has a case-insensitive collation, a LIKE operation is not case sensitive:

```
SELECT 'A' LIKE CONVERT(blob_col USING latin1) FROM tbl_name;
```

To use a different character set, substitute its name for latin1 in the preceding statement. To specify a particular collation for the converted string, use a COLLATE clause following the CONVERT() call, as described in Section 10.1.9.2, "CONVERT() and CAST()". For example, to use latin1_german1_ci:

```
SELECT 'A' LIKE CONVERT(blob_col USING latin1) COLLATE latin1_german1_ci
  FROM tbl_name;
```

CONVERT() can be used more generally for comparing strings that are represented in different character sets.

LOWER() (and UPPER()) are ineffective when applied to binary strings (BINARY, VARBINARY, BLOB). To perform lettercase conversion, convert the string to a nonbinary string:

```
mysql> SET @str = BINARY 'New York';
mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING latin1));
+-------------+-----------------------------------+
| LOWER(@str) | LOWER(CONVERT(@str USING latin1)) |
+-------------+-----------------------------------+
| New York    | new york                          |
+-------------+-----------------------------------+
```

The cast functions are useful when you want to create a column with a specific type in a CREATE TABLE ... SELECT statement:

```
CREATE TABLE new_table SELECT CAST('2000-01-01' AS DATE);
```

The functions also can be useful for sorting ENUM columns in lexical order. Normally, sorting of ENUM columns occurs using the internal numeric values. Casting the values to CHAR results in a lexical sort:

```
SELECT enum_col FROM tbl_name ORDER BY CAST(enum_col AS CHAR);
```

CAST(str AS BINARY) is the same thing as BINARY str. CAST(expr AS CHAR) treats the expression as a string with the default character set.

CAST() also changes the result if you use it as part of a more complex expression such as CONCAT('Date: ',CAST(NOW() AS DATE)).

You should not use `CAST()` to extract data in different formats but instead use string functions like `LEFT()` or `EXTRACT()`. See Section 12.7, "Date and Time Functions".

To cast a string to a numeric value in numeric context, you normally do not have to do anything other than to use the string value as though it were a number:

```
mysql> SELECT 1+'1';
        -> 2
```

If you use a string in an arithmetic operation, it is converted to a floating-point number during expression evaluation.

If you use a number in string context, the number automatically is converted to a string:

```
mysql> SELECT CONCAT('hello you ',2);
        -> 'hello you 2'
```

For information about implicit conversion of numbers to strings, see Section 12.2, "Type Conversion in Expression Evaluation".

When using an explicit `CAST()` on a `TIMESTAMP` value in a statement that does not select from any tables, the value is treated by MySQL as a string prior to performing any conversion. This results in the value being truncated when casting to a numeric type, as shown here:

```
mysql> SELECT CAST(TIMESTAMP '2014-09-08 18:07:54' AS SIGNED);
+-------------------------------------------------+
| CAST(TIMESTAMP '2014-09-08 18:07:54' AS SIGNED) |
+-------------------------------------------------+
|                                            2014 |
+-------------------------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+----------------------------------------------------------+
| Level   | Code | Message                                                  |
+---------+------+----------------------------------------------------------+
| Warning | 1292 | Truncated incorrect INTEGER value: '2014-09-08 18:07:54' |
+---------+------+----------------------------------------------------------+
1 row in set (0.00 sec)
```

This does not apply when selecting rows from a table, as shown here:

```
mysql> USE test;

Database changed
mysql> CREATE TABLE c_test (col TIMESTAMP);
Query OK, 0 rows affected (0.07 sec)

mysql> INSERT INTO c_test VALUES ('2014-09-08 18:07:54');
Query OK, 1 row affected (0.05 sec)

mysql> SELECT col, CAST(col AS UNSIGNED) AS c_col FROM c_test;
+---------------------+----------------+
| col                 | c_col          |
+---------------------+----------------+
| 2014-09-08 18:07:54 | 20140908180754 |
+---------------------+----------------+
1 row in set (0.00 sec)
```

This is a known issue which is resolved in MySQL 5.6.

MySQL supports arithmetic with both signed and unsigned 64-bit values. If you are using numeric operators (such as `+` or `-`) and one of the operands is an unsigned integer, the result is unsigned by default (see Section 12.6.1, "Arithmetic Operators"). You can override this by using the `SIGNED` or `UNSIGNED` cast operator to cast a value to a signed or unsigned 64-bit integer, respectively.

```
mysql> SELECT CAST(1-2 AS UNSIGNED);
        -> 18446744073709551615
mysql> SELECT CAST(CAST(1-2 AS UNSIGNED) AS SIGNED);
        -> -1
```

If either operand is a floating-point value, the result is a floating-point value and is not affected by the preceding rule. (In this context, `DECIMAL` column values are regarded as floating-point values.)

```
mysql> SELECT CAST(1 AS UNSIGNED) - 2.0;
        -> -1.0
```

The SQL mode affects the result of conversion operations. Examples:

- If you convert a "zero" date string to a date, `CONVERT()` and `CAST()` return `NULL` and produce a warning when the `NO_ZERO_DATE` SQL mode is enabled.

- For integer subtraction, if the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled, the subtraction result is signed even if any operand is unsigned.

For more information, see Section 5.1.7, "Server SQL Modes".

12.11 XML Functions

Table 12.15 XML Functions

Name	Description
ExtractValue()	Extracts a value from an XML string using XPath notation
UpdateXML()	Return replaced XML fragment

This section discusses XML and related functionality in MySQL.

Note

It is possible to obtain XML-formatted output from MySQL in the `mysql` and `mysqldump` clients by invoking them with the `--xml` option. See Section 4.5.1, "`mysql` — The MySQL Command-Line Tool", and Section 4.5.4, "`mysqldump` — A Database Backup Program".

Beginning with MySQL 5.1.5, two functions providing basic XPath 1.0 (XML Path Language, version 1.0) capabilities are available. Some basic information about XPath syntax and usage is provided later in this section; however, an in-depth discussion of these topics is beyond the scope of this Manual, and you should refer to the XML Path Language (XPath) 1.0 standard for definitive information. A useful resource for those new to XPath or who desire a refresher in the basics is the Zvon.org XPath Tutorial, which is available in several languages.

Note

These functions remain under development. We continue to improve these and other aspects of XML and XPath functionality in MySQL 5.1 and onwards. You may discuss these, ask questions about them, and obtain help from other users with them in the MySQL XML User Forum.

Beginning with MySQL 5.1.20, XPath expressions used with these functions support user variables and local stored program variables. User variables are weakly checked; variables local to stored programs are strongly checked (see also Bug #26518):

- **User variables (weak checking).** Variables using the syntax $@variable_name (that is, user variables) are not checked. No warnings or errors are issued by the server if a variable has the wrong type or has previously not been assigned a value. This also means the user is fully responsible for any typographical errors, since no warnings will be given if (for example) $@myvariable is used where $@myvariable was intended.

  Example:

```
mysql> SET @xml = '<a><b>X</b><b>Y</b></a>';
Query OK, 0 rows affected (0.00 sec)

mysql> SET @i =1, @j = 2;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @i, ExtractValue(@xml, '//b[$@i]');
+------+-------------------------------+
| @i   | ExtractValue(@xml, '//b[$@i]') |
+------+-------------------------------+
|    1 | X                             |
+------+-------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @j, ExtractValue(@xml, '//b[$@j]');
+------+-------------------------------+
| @j   | ExtractValue(@xml, '//b[$@j]') |
+------+-------------------------------+
|    2 | Y                             |
+------+-------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @k, ExtractValue(@xml, '//b[$@k]');
+------+-------------------------------+
| @k   | ExtractValue(@xml, '//b[$@k]') |
+------+-------------------------------+
| NULL |                               |
+------+-------------------------------+
1 row in set (0.00 sec)
```

- **Variables in stored programs (strong checking).** Variables using the syntax $variable_name can be declared and used with these functions when they are called inside stored programs. Such variables are local to the stored program in which they are defined, and are strongly checked for type and value.

  Example:

```
mysql> DELIMITER |

mysql> CREATE PROCEDURE myproc ()
    -> BEGIN
    ->   DECLARE i INT DEFAULT 1;
    ->   DECLARE xml VARCHAR(25) DEFAULT '<a>X</a><a>Y</a><a>Z</a>';
    ->
    ->   WHILE i < 4 DO
    ->     SELECT xml, i, ExtractValue(xml, '//a[$i]');
    ->     SET i = i+1;
    ->   END WHILE;
    -> END |
Query OK, 0 rows affected (0.01 sec)
```

```
mysql> DELIMITER ;

mysql> CALL myproc();
+--------------------------+---+----------------------------+
| xml                      | i | ExtractValue(xml, '//a[$i]') |
+--------------------------+---+----------------------------+
| <a>X</a><a>Y</a><a>Z</a> | 1 | X                          |
+--------------------------+---+----------------------------+
1 row in set (0.00 sec)


+--------------------------+---+----------------------------+
| xml                      | i | ExtractValue(xml, '//a[$i]') |
+--------------------------+---+----------------------------+
| <a>X</a><a>Y</a><a>Z</a> | 2 | Y                          |
+--------------------------+---+----------------------------+
1 row in set (0.01 sec)


+--------------------------+---+----------------------------+
| xml                      | i | ExtractValue(xml, '//a[$i]') |
+--------------------------+---+----------------------------+
| <a>X</a><a>Y</a><a>Z</a> | 3 | Z                          |
+--------------------------+---+----------------------------+
1 row in set (0.01 sec)
```

Parameters.   Variables used in XPath expressions inside stored routines that are passed in as parameters are also subject to strong checking.

Expressions containing user variables or variables local to stored programs must otherwise (except for notation) conform to the rules for XPath expressions containing variables as given in the XPath 1.0 specification.

> **Note**
>
> A user variable used to store an XPath expression is treated as an empty string. Because of this, it is not possible to store an XPath expression as a user variable. (Bug #32911)

- `ExtractValue(xml_frag, xpath_expr)`

  `ExtractValue()` takes two string arguments, a fragment of XML markup `xml_frag` and an XPath expression `xpath_expr` (also known as a *locator*); it returns the text (`CDATA`) of the first text node which is a child of the elements or elements matched by the XPath expression. In MySQL 5.1, the XPath expression can contain at most 127 characters. (This limitation is lifted in MySQL 5.6.)

  Using this function is the equivalent of performing a match using the `xpath_expr` after appending `/text()`. In other words, `ExtractValue('<a><b>Sakila</b></a>', '/a/b')` and `ExtractValue('<a><b>Sakila</b></a>', '/a/b/text()')` produce the same result.

  If multiple matches are found, the content of the first child text node of each matching element is returned (in the order matched) as a single, space-delimited string.

  If no matching text node is found for the expression (including the implicit `/text()`)—for whatever reason, as long as `xpath_expr` is valid, and `xml_frag` consists of elements which are properly nested and closed—an empty string is returned. No distinction is made between a match on an empty element and no match at all. This is by design.

  If you need to determine whether no matching element was found in `xml_frag` or such an element was found but contained no child text nodes, you should test the result of an expression that uses the XPath `count()` function. For example, both of these statements return an empty string, as shown here:

```
mysql> SELECT ExtractValue('<a><b/></a>', '/a/b');
+-----------------------------------+
| ExtractValue('<a><b/></a>', '/a/b') |
+-----------------------------------+
|                                   |
+-----------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a><c/></a>', '/a/b');
+-----------------------------------+
| ExtractValue('<a><c/></a>', '/a/b') |
+-----------------------------------+
|                                   |
+-----------------------------------+
1 row in set (0.00 sec)
```

However, you can determine whether there was actually a matching element using the following:

```
mysql> SELECT ExtractValue('<a><b/></a>', 'count(/a/b)');
+-----------------------------------+
| ExtractValue('<a><b/></a>', 'count(/a/b)') |
+-----------------------------------+
| 1                                 |
+-----------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a><c/></a>', 'count(/a/b)');
+-----------------------------------+
| ExtractValue('<a><c/></a>', 'count(/a/b)') |
+-----------------------------------+
| 0                                 |
+-----------------------------------+
1 row in set (0.01 sec)
```

> ⚠️ **Important**
>
> `ExtractValue()` returns only `CDATA`, and does not return any tags that might be contained within a matching tag, nor any of their content (see the result returned as `val1` in the following example).

```
mysql> SELECT
    ->    ExtractValue('<a>ccc<b>ddd</b></a>', '/a') AS val1,
    ->    ExtractValue('<a>ccc<b>ddd</b></a>', '/a/b') AS val2,
    ->    ExtractValue('<a>ccc<b>ddd</b></a>', '//b') AS val3,
    ->    ExtractValue('<a>ccc<b>ddd</b></a>', '/b') AS val4,
    ->    ExtractValue('<a>ccc<b>ddd</b><b>eee</b></a>', '//b') AS val5;

+------+------+------+------+---------+
| val1 | val2 | val3 | val4 | val5    |
+------+------+------+------+---------+
| ccc  | ddd  | ddd  |      | ddd eee |
+------+------+------+------+---------+
```

Beginning with MySQL 5.1.8, this function uses the current SQL collation for making comparisons with `contains()`, performing the same collation aggregation as other string functions (such as `CONCAT()`), in taking into account the collation coercibility of their arguments; see Section 10.1.7.5, "Collation of Expressions", for an explanation of the rules governing this behavior.

(Previously, binary—that is, case-sensitive—comparison was always used.)

Beginning with MySQL 5.1.12, `NULL` is returned if `xml_frag` contains elements which are not properly nested or closed, and a warning is generated, as shown in this example:

```
mysql> SELECT ExtractValue('<a>c</a><b', '//a');
+----------------------------------+
| ExtractValue('<a>c</a><b', '//a') |
+----------------------------------+
| NULL                             |
+----------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1525
Message: Incorrect XML value: 'parse error at line 1 pos 11:
         END-OF-INPUT unexpected ('>' wanted)'
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a>c</a><b/>', '//a');
+-----------------------------------+
| ExtractValue('<a>c</a><b/>', '//a') |
+-----------------------------------+
| c                                 |
+-----------------------------------+
1 row in set (0.00 sec)
```

Prior to MySQL 5.1.12, an empty string was returned in such cases. (Bug #18201)

- `UpdateXML(xml_target, xpath_expr, new_xml)`

  This function replaces a single portion of a given fragment of XML markup `xml_target` with a new XML fragment `new_xml`, and then returns the changed XML. The portion of `xml_target` that is replaced matches an XPath expression `xpath_expr` supplied by the user. In MySQL 5.1, the XPath expression can contain at most 127 characters. (This limitation is lifted in MySQL 5.6.)

  If no expression matching `xpath_expr` is found, or if multiple matches are found, the function returns the original `xml_target` XML fragment. All three arguments should be strings.

```
mysql> SELECT
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '/a', '<e>fff</e>') AS val1,
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '/b', '<e>fff</e>') AS val2,
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '//b', '<e>fff</e>') AS val3,
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '/a/d', '<e>fff</e>') AS val4,
    ->   UpdateXML('<a><d></d><b>ccc</b><d></d></a>', '/a/d', '<e>fff</e>') AS val5
    -> \G

*************************** 1. row ***************************
val1: <e>fff</e>
val2: <a><b>ccc</b><d></d></a>
val3: <a><e>fff</e><d></d></a>
val4: <a><b>ccc</b><e>fff</e></a>
val5: <a><d></d><b>ccc</b><d></d></a>
```

> **Note**
>
> A discussion in depth of XPath syntax and usage are beyond the scope of this Manual. Please see the XML Path Language (XPath) 1.0 specification for definitive information. A useful resource for those new to XPath or who are wishing a

> refresher in the basics is the Zvon.org XPath Tutorial, which is available in several languages.

Descriptions and examples of some basic XPath expressions follow:

- `/tag`

  Matches `<tag/>` if and only if `<tag/>` is the root element.

  Example: `/a` has a match in `<a><b/></a>` because it matches the outermost (root) tag. It does not match the inner *a* element in `<b><a/></b>` because in this instance it is the child of another element.

- `/tag1/tag2`

  Matches `<tag2/>` if and only if it is a child of `<tag1/>`, and `<tag1/>` is the root element.

  Example: `/a/b` matches the *b* element in the XML fragment `<a><b/></a>` because it is a child of the root element *a*. It does not have a match in `<b><a/></b>` because in this case, *b* is the root element (and hence the child of no other element). Nor does the XPath expression have a match in `<a><c><b/></c></a>`; here, *b* is a descendant of *a*, but not actually a child of *a*.

  This construct is extendable to three or more elements. For example, the XPath expression `/a/b/c` matches the *c* element in the fragment `<a><b><c/></b></a>`.

- `//tag`

  Matches any instance of `<tag>`.

  Example: `//a` matches the *a* element in any of the following: `<a><b><c/></b></a>`; `<c><a><b/></a></b>`; `<c><b><a/></b></c>`.

  `//` can be combined with `/`. For example, `//a/b` matches the *b* element in either of the fragments `<a><b/></a>` or `<a><b><c/></b></a>`

> **Note**
>
> `//tag` is the equivalent of `/descendant-or-self::*/tag`. A common error is to confuse this with `/descendant-or-self::tag`, although the latter expression can actually lead to very different results, as can be seen here:
>
> ```
> mysql> SET @xml = '<a><b><c>w</c><b>x</b><d>y</d>z</b></a>';
> Query OK, 0 rows affected (0.00 sec)
>
> mysql> SELECT @xml;
> +-----------------------------------------+
> | @xml                                    |
> +-----------------------------------------+
> | <a><b><c>w</c><b>x</b><d>y</d>z</b></a> |
> +-----------------------------------------+
> 1 row in set (0.00 sec)
>
> mysql> SELECT ExtractValue(@xml, '//b[1]');
> +-----------------------------+
> | ExtractValue(@xml, '//b[1]') |
> +-----------------------------+
> | x z                         |
> +-----------------------------+
> 1 row in set (0.00 sec)
>
> mysql> SELECT ExtractValue(@xml, '//b[2]');
> ```

```
+----------------------------+
| ExtractValue(@xml, '//b[2]') |
+----------------------------+
|                            |
+----------------------------+
1 row in set (0.01 sec)

mysql> SELECT ExtractValue(@xml, '/descendant-or-self::*/b[1]');
+--------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::*/b[1]') |
+--------------------------------------------------+
| x z                                              |
+--------------------------------------------------+
1 row in set (0.06 sec)

mysql> SELECT ExtractValue(@xml, '/descendant-or-self::*/b[2]');
+--------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::*/b[2]') |
+--------------------------------------------------+
|                                                  |
+--------------------------------------------------+
1 row in set (0.00 sec)


mysql> SELECT ExtractValue(@xml, '/descendant-or-self::b[1]');
+------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::b[1]') |
+------------------------------------------------+
| z                                              |
+------------------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue(@xml, '/descendant-or-self::b[2]');
+------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::b[2]') |
+------------------------------------------------+
| x                                              |
+------------------------------------------------+
1 row in set (0.00 sec)
```

- The `*` operator acts as a "wildcard" that matches any element. For example, the expression `/*/b` matches the *b* element in either of the XML fragments `<a><b/></a>` or `<c><b/></c>`. However, the expression does not produce a match in the fragment `<b><a/></b>` because *b* must be a child of some other element. The wildcard may be used in any position: The expression `/*/b/*` will match any child of a *b* element that is itself not the root element.

- You can match any of several locators using the `|` (`UNION`) operator. For example, the expression `//b|//c` matches all *b* and *c* elements in the XML target.

- It is also possible to match an element based on the value of one or more of its attributes. This done using the syntax `tag[@attribute="value"]`. For example, the expression `//b[@id="idB"]` matches the second *b* element in the fragment `<a><b id="idA"/><c/><b id="idB"/></a>`. To match against *any* element having `attribute="value"`, use the XPath expression `//*[attribute="value"]`.

  To filter multiple attribute values, simply use multiple attribute-comparison clauses in succession. For example, the expression `//b[@c="x"][@d="y"]` matches the element `<b c="x" d="y"/>` occurring anywhere in a given XML fragment.

  To find elements for which the same attribute matches any of several values, you can use multiple locators joined by the `|` operator. For example, to match all *b* elements whose *c* attributes have either of the values 23 or 17, use the expression `//b[@c="23"]|//b[@c="17"]`. You can also use the logical `or` operator for this purpose: `//b[@c="23" or @c="17"]`.

> **Note**
>
> The difference between `or` and `|` is that `or` joins conditions, while `|` joins result sets.

XPath Limitations.　　The XPath syntax supported by these functions is currently subject to the following limitations:

- Nodeset-to-nodeset comparison (such as `'/a/b[@c=@d]'`) is not supported.

- Prior to MySQL 5.1.14, equality and inequality (`=` and `!=`) were the only supported comparison operators. Beginning with MySQL 5.1.14, all of the standard XPath comparison operators are supported. (Bug #22823)

- Relative locator expressions are resolved in the context of the root node. For example, consider the following query and result:

```
mysql> SELECT ExtractValue(
    ->    '<a><b c="1">X</b><b c="2">Y</b></a>',
    ->     'a/b'
    -> ) AS result;
+--------+
| result |
+--------+
| X Y    |
+--------+
1 row in set (0.03 sec)
```

In this case, the locator `a/b` resolves to `/a/b`.

Relative locators are also supported within predicates. In the following example, `d[../@c="1"]` is resolved as `/a/b[@c="1"]/d`:

```
mysql> SELECT ExtractValue(
    ->        '<a>
    ->          <b c="1"><d>X</d></b>
    ->          <b c="2"><d>X</d></b>
    ->        </a>',
    ->        'a/b/d[../@c="1"]')
    -> AS result;
+--------+
| result |
+--------+
| X      |
+--------+
1 row in set (0.00 sec)
```

- Locators prefixed with expressions that evaluate as scalar values—including variable references, literals, numbers, and scalar function calls—are not supported. Beginning with MySQL 5.1.32, they are not permitted, and their use results in an error. (Bug #42495)

- The `::` operator is not supported in combination with node types such as the following:

  - `axis::comment()`

  - `axis::text()`

  - `axis::processing-instructions()`

- `axis::node()`

However, name tests (such as `axis::name` and `axis::*`) are supported, as shown in these examples:

```
mysql> SELECT ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::b');
+----------------------------------------------------+
| ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::b') |
+----------------------------------------------------+
| x                                                  |
+----------------------------------------------------+
1 row in set (0.02 sec)

mysql> SELECT ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::*');
+----------------------------------------------------+
| ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::*') |
+----------------------------------------------------+
| x y                                                |
+----------------------------------------------------+
1 row in set (0.01 sec)
```

- "Up-and-down" navigation is not supported in cases where the path would lead "above" the root element. That is, you cannot use expressions which match on descendants of ancestors of a given element, where one or more of the ancestors of the current element is also an ancestor of the root element (see Bug #16321).

- The following XPath functions are not supported, or have known issues as indicated:

  - Prior to MySQL 5.1.24, the `boolean()` function did not produce correct results for some string and nodeset values, including the `NULL` string (see Bug #26051).

  - `id()`

  - `lang()`

  - Prior to MySQL 5.1.8, the `last()` function was not supported (see Bug #16318).

  - `local-name()`

  - `name()`

  - `namespace-uri()`

  - `normalize-space()`

  - `starts-with()`

  - `string()`

  - `substring-after()`

  - `substring-before()`

  - `translate()`

- The following axes are not supported:

  - `following-sibling`

  - `following`

- preceding-sibling

- preceding

Beginning with MySQL 5.1.10, XPath expressions passed as arguments to `ExtractValue()` and `UpdateXML()` may contain the colon character ("`:`") in element selectors, which enables their use with markup employing XML namespaces notation. For example:

```
mysql> SET @xml = '<a>111<b:c>222<d>333</d><e:f>444</e:f></b:c></a>';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT ExtractValue(@xml, '//e:f');
+---------------------------+
| ExtractValue(@xml, '//e:f') |
+---------------------------+
| 444                       |
+---------------------------+
1 row in set (0.00 sec)

mysql> SELECT UpdateXML(@xml, '//b:c', '<g:h>555</g:h>');
+------------------------------------------+
| UpdateXML(@xml, '//b:c', '<g:h>555</g:h>') |
+------------------------------------------+
| <a>111<g:h>555</g:h></a>                 |
+------------------------------------------+
1 row in set (0.00 sec)
```

This is similar in some respects to what is permitted by Apache Xalan and some other parsers, and is much simpler than requiring namespace declarations or the use of the `namespace-uri()` and `local-name()` functions.

Error handling.   For both `ExtractValue()` and `UpdateXML()`, the XPath locator used must be valid and the XML to be searched must consist of elements which are properly nested and closed. If the locator is invalid, an error is generated:

```
mysql> SELECT ExtractValue('<a>c</a><b/>', '/&a');
ERROR 1105 (HY000): XPATH syntax error: '&a'
```

If `xml_frag` does not consist of elements which are properly nested and closed, `NULL` is returned and a warning is generated, as shown in this example:

```
mysql> SELECT ExtractValue('<a>c</a><b', '//a');
+---------------------------------+
| ExtractValue('<a>c</a><b', '//a') |
+---------------------------------+
| NULL                            |
+---------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1525
Message: Incorrect XML value: 'parse error at line 1 pos 11:
        END-OF-INPUT unexpected ('>' wanted)'
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a>c</a><b/>', '//a');
+-----------------------------------+
```

```
| ExtractValue('<a>c</a><b/>', '//a') |
+-------------------------------------+
| c                                   |
+-------------------------------------+
1 row in set (0.00 sec)
```

Prior to MySQL 5.1.12, an empty string was returned in such cases. (Bug #18201)

> ⚠️ **Important**
>
> The replacement XML used as the third argument to `UpdateXML()` is *not* checked to determine whether it consists solely of elements which are properly nested and closed.

XPath Injection.   *code injection* occurs when malicious code is introduced into the system to gain unauthorized access to privileges and data. It is based on exploiting assumptions made by developers about the type and content of data input from users. XPath is no exception in this regard.

A common scenario in which this can happen is the case of application which handles authorization by matching the combination of a login name and password with those found in an XML file, using an XPath expression like this one:

```
//user[login/text()='neapolitan' and password/text()='1c3cr34m']/attribute::id
```

This is the XPath equivalent of an SQL statement like this one:

```
SELECT id FROM users WHERE login='neapolitan' AND password='1c3cr34m';
```

A PHP application employing XPath might handle the login process like this:

```php
<?php

  $file     =   "users.xml";

  $login    =   $POST["login"];
  $password =   $POST["password"];

  $xpath = "//user[login/text()=$login and password/text()=$password]/attribute::id";

  if( file_exists($file) )
  {
    $xml = simplexml_load_file($file);

    if($result = $xml->xpath($xpath))
      echo "You are now logged in as user $result[0].";
    else
      echo "Invalid login name or password.";
  }
  else
    exit("Failed to open $file.");

?>
```

No checks are performed on the input. This means that a malevolent user can "short-circuit" the test by entering ` ' or 1=1` for both the login name and password, resulting in `$xpath` being evaluated as shown here:

```
//user[login/text()='' or 1=1 and password/text()='' or 1=1]/attribute::id
```

Since the expression inside the square brackets always evaluates as `true`, it is effectively the same as this one, which matches the `id` attribute of every `user` element in the XML document:

```
//user/attribute::id
```

One way in which this particular attack can be circumvented is simply by quoting the variable names to be interpolated in the definition of `$xpath`, forcing the values passed from a Web form to be converted to strings:

```
$xpath = "//user[login/text()='$login' and password/text()='$password']/attribute::id";
```

This is the same strategy that is often recommended for preventing SQL injection attacks. In general, the practices you should follow for preventing XPath injection attacks are the same as for preventing SQL injection:

- Never accepted untested data from users in your application.

- Check all user-submitted data for type; reject or convert data that is of the wrong type

- Test numeric data for out of range values; truncate, round, or reject values that are out of range. Test strings for illegal characters and either strip them out or reject input containing them.

- Do not output explicit error messages that might provide an unauthorized user with clues that could be used to compromise the system; log these to a file or database table instead.

Just as SQL injection attacks can be used to obtain information about database schemas, so can XPath injection be used to traverse XML files to uncover their structure, as discussed in Amit Klein's paper Blind XPath Injection (PDF file, 46KB).

It is also important to check the output being sent back to the client. Consider what can happen when we use the MySQL `ExtractValue()` function:

```
mysql> SELECT ExtractValue(
    ->     LOAD_FILE('users.xml'),
    ->     '//user[login/text()="" or 1=1 and password/text()="" or 1=1]/attribute::id'
    -> ) AS id;
+-------------------------------+
| id                            |
+-------------------------------+
| 00327 13579 02403 42354 28570 |
+-------------------------------+
1 row in set (0.01 sec)
```

Because `ExtractValue()` returns multiple matches as a single space-delimited string, this injection attack provides every valid ID contained within `users.xml` to the user as a single row of output. As an extra safeguard, you should also test output before returning it to the user. Here is a simple example:

```
mysql> SELECT @id = ExtractValue(
    ->     LOAD_FILE('users.xml'),
    ->     '//user[login/text()="" or 1=1 and password/text()="" or 1=1]/attribute::id'
    -> );
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT IF(
```

```
    ->     INSTR(@id, ' ') = 0,
    ->     @id,
    ->     'Unable to retrieve user ID')
    -> AS singleID;
+---------------------------+
| singleID                  |
+---------------------------+
| Unable to retrieve user ID |
+---------------------------+
1 row in set (0.00 sec)
```

In general, the guidelines for returning data to users securely are the same as for accepting user input. These can be summed up as:

- Always test outgoing data for type and permissible values.

- Never permit unauthorized users to view error messages that might provide information about the application that could be used to exploit it.

12.12 Bit Functions and Operators

Table 12.16 Bit Functions and Operators

Name	Description
BIT_COUNT()	Return the number of bits that are set
&	Bitwise AND
~	Bitwise inversion
|	Bitwise OR
^	Bitwise XOR
<<	Left shift
>>	Right shift

Bit functions and operators comprise BIT_COUNT(), BIT_AND(), BIT_OR(), BIT_XOR(), &, |, ^, ~, <<, and >>. (BIT_AND(), BIT_OR(), and BIT_XOR() are aggregate functions described at Section 12.17.1, "Aggregate (GROUP BY) Function Descriptions".) Bit functions and operators require BIGINT (64-bit integer) arguments and return BIGINT values, so they have a maximum range of 64 bits. Arguments of other types (such as the BINARY and VARBINARY binary string types) are converted to BIGINT and truncation might occur.

The following list describes available bit functions and operators:

- |

  Bitwise OR:

  ```
  mysql> SELECT 29 | 15;
          -> 31
  ```

  The result is an unsigned 64-bit integer.

- &

  Bitwise AND:

```
mysql> SELECT 29 & 15;
        -> 13
```

The result is an unsigned 64-bit integer.

- **^**

  Bitwise XOR:

  ```
  mysql> SELECT 1 ^ 1;
          -> 0
  mysql> SELECT 1 ^ 0;
          -> 1
  mysql> SELECT 11 ^ 3;
          -> 8
  ```

  The result is an unsigned 64-bit integer.

- **<<**

  Shifts a longlong (`BIGINT`) number to the left.

  ```
  mysql> SELECT 1 << 2;
          -> 4
  ```

  The result is an unsigned 64-bit integer. The value is truncated to 64 bits. In particular, if the shift count is greater or equal to the width of an unsigned 64-bit number, the result is zero.

- **>>**

  Shifts a longlong (`BIGINT`) number to the right.

  ```
  mysql> SELECT 4 >> 2;
          -> 1
  ```

  The result is an unsigned 64-bit integer. The value is truncated to 64 bits. In particular, if the shift count is greater or equal to the width of an unsigned 64-bit number, the result is zero.

- **~**

  Invert all bits.

  ```
  mysql> SELECT 5 & ~1;
          -> 4
  ```

  The result is an unsigned 64-bit integer.

- **BIT_COUNT(*N*)**

  Returns the number of bits that are set in the argument *N*.

  ```
  mysql> SELECT BIT_COUNT(29), BIT_COUNT(b'101010');
          -> 4, 3
  ```

12.13 Encryption and Compression Functions

Table 12.17 Encryption Functions

Name	Description
AES_DECRYPT()	Decrypt using AES
AES_ENCRYPT()	Encrypt using AES
COMPRESS()	Return result as a binary string
DECODE()	Decodes a string encrypted using ENCODE()
DES_DECRYPT()	Decrypt a string
DES_ENCRYPT()	Encrypt a string
ENCODE()	Encode a string
ENCRYPT()	Encrypt a string
MD5()	Calculate MD5 checksum
OLD_PASSWORD()	Return the value of the pre-4.1 implementation of PASSWORD
PASSWORD()	Calculate and return a password string
SHA1(), SHA()	Calculate an SHA-1 160-bit checksum
UNCOMPRESS()	Uncompress a string compressed
UNCOMPRESSED_LENGTH()	Return the length of a string before compression

Many encryption and compression functions return strings for which the result might contain arbitrary byte values. If you want to store these results, use a column with a `VARBINARY` or `BLOB` binary string data type. This will avoid potential problems with trailing space removal or character set conversion that would change data values, such as may occur if you use a nonbinary string data type (`CHAR`, `VARCHAR`, `TEXT`).

For functions such as `MD5()` or `SHA1()` that return a string of hex digits, the return value cannot be converted to uppercase or compared in case-insensitive fashion as is. You must convert the value to a nonbinary string. See the discussion of binary string conversion in Section 12.10, "Cast Functions and Operators".

If an application stores values from a function such as `MD5()` or `SHA1()` that returns a string of hex digits, more efficient storage and comparisons can be obtained by converting the hex representation to binary using `UNHEX()` and storing the result in a `BINARY(N)` column. Each pair of hex digits requires one byte in binary form, so the value of N depends on the length of the hex string. N is 16 for an `MD5()` value and 20 for a `SHA1()` value.

The size penalty for storing the hex string in a `CHAR` column is at least two times, up to six times if the value is stored in a column that uses the `utf8` character set (where each character uses 3 bytes). Storing the string also results in slower comparisons because of the larger values and the need to take character set collation rules into account.

Suppose that an application stores `MD5()` string values in a `CHAR(32)` column:

```
CREATE TABLE md5_tbl (md5_val CHAR(32), ...);
INSERT INTO md5_tbl (md5_val, ...) VALUES(MD5('abcdef'), ...);
```

To convert hex strings to more compact form, modify the application to use `UNHEX()` and `BINARY(16)` instead as follows:

```
CREATE TABLE md5_tbl (md5_val BINARY(16), ...);
```

```
INSERT INTO md5_tbl (md5_val, ...) VALUES(UNHEX(MD5('abcdef')), ...);
```

Applications should be prepared to handle the very rare case that a hashing function produces the same value for two different input values. One way to make collisions detectable is to make the hash column a primary key.

Note

Exploits for the MD5 and SHA-1 algorithms have become known. You may wish to consider using one of the other encryption functions described in this section instead.

Caution

Passwords or other sensitive values supplied as arguments to encryption functions are sent in cleartext to the MySQL server unless an SSL connection is used. Also, such values will appear in any MySQL logs to which they are written. To avoid these types of exposure, applications can encrypt sensitive values on the client side before sending them to the server. The same considerations apply to encryption keys. To avoid exposing these, applications can use stored procedures to encrypt and decrypt values on the server side.

- `AES_DECRYPT(crypt_str,key_str)`

  This function decrypts data using the official AES (Advanced Encryption Standard) algorithm. For more information, see the description of `AES_ENCRYPT()`.

- `AES_ENCRYPT(str,key_str)`

  `AES_ENCRYPT()` and `AES_DECRYPT()` implement encryption and decryption of data using the official AES (Advanced Encryption Standard) algorithm, previously known as "Rijndael." The AES standard permits various key lengths. These functions implement AES with a 128-bit key length, but you can extend them to 256 bits by modifying the source. The key length is a trade off between performance and security.

  `AES_ENCRYPT()` encrypts the string `str` using the key string `key_str` and returns a binary string containing the encrypted output. `AES_DECRYPT()` decrypts the encrypted string `crypt_str` using the key string `key_str` and returns the original cleartext string. If either function argument is `NULL`, the function returns `NULL`.

  The `str` and `crypt_str` arguments can be any length, and padding is automatically added to `str` so it is a multiple of a block as required by block-based algorithms such as AES. This padding is automatically removed by the `AES_DECRYPT()` function. The length of `crypt_str` can be calculated using this formula:

  ```
  16 * (trunc(string_length / 16) + 1)
  ```

  For a key length of 128 bits, the most secure way to pass a key to the `key_str` argument is to create a truly random 128-bit value and pass it as a binary value. For example:

  ```
  INSERT INTO t
  VALUES (1,AES_ENCRYPT('text',UNHEX('F3229A0B371ED2D9441B830D21A390C3')));
  ```

  A passphrase can be used to generate an AES key by hashing the passphrase. For example:

```
INSERT INTO t VALUES (1,AES_ENCRYPT('text', SHA1('My secret passphrase')));
```

Do not pass a password or passphrase directly to `crypt_str`, hash it first. Previous versions of this documentation suggested the former approach, but it is no longer recommended as the examples shown here are more secure.

If `AES_DECRYPT()` detects invalid data or incorrect padding, it returns `NULL`. However, it is possible for `AES_DECRYPT()` to return a non-`NULL` value (possibly garbage) if the input data or the key is invalid.

- `COMPRESS(string_to_compress)`

  Compresses a string and returns the result as a binary string. This function requires MySQL to have been compiled with a compression library such as `zlib`. Otherwise, the return value is always `NULL`. The compressed string can be uncompressed with `UNCOMPRESS()`.

  ```
  mysql> SELECT LENGTH(COMPRESS(REPEAT('a',1000)));
          -> 21
  mysql> SELECT LENGTH(COMPRESS(''));
          -> 0
  mysql> SELECT LENGTH(COMPRESS('a'));
          -> 13
  mysql> SELECT LENGTH(COMPRESS(REPEAT('a',16)));
          -> 15
  ```

  The compressed string contents are stored the following way:

  - Empty strings are stored as empty strings.

  - Nonempty strings are stored as a 4-byte length of the uncompressed string (low byte first), followed by the compressed string. If the string ends with space, an extra "." character is added to avoid problems with endspace trimming should the result be stored in a `CHAR` or `VARCHAR` column. (However, use of nonbinary string data types such as `CHAR` or `VARCHAR` to store compressed strings is not recommended anyway because character set conversion may occur. Use a `VARBINARY` or `BLOB` binary string column instead.)

- `DECODE(crypt_str,pass_str)`

  Decrypts the encrypted string `crypt_str` using `pass_str` as the password. `crypt_str` should be a string returned from `ENCODE()`.

- `DES_DECRYPT(crypt_str[,key_str])`

  Decrypts a string encrypted with `DES_ENCRYPT()`. If an error occurs, this function returns `NULL`.

  This function works only if MySQL has been configured with SSL support. See Section 6.4, "Using Secure Connections".

  If no `key_str` argument is given, `DES_DECRYPT()` examines the first byte of the encrypted string to determine the DES key number that was used to encrypt the original string, and then reads the key from the DES key file to decrypt the message. For this to work, the user must have the `SUPER` privilege. The key file can be specified with the `--des-key-file` server option.

  If you pass this function a `key_str` argument, that string is used as the key for decrypting the message.

  If the `crypt_str` argument does not appear to be an encrypted string, MySQL returns the given `crypt_str`.

- `DES_ENCRYPT(str[,{key_num|key_str}])`

Encrypts the string with the given key using the Triple-DES algorithm.

This function works only if MySQL has been configured with SSL support. See Section 6.4, "Using Secure Connections".

The encryption key to use is chosen based on the second argument to `DES_ENCRYPT()`, if one was given. With no argument, the first key from the DES key file is used. With a `key_num` argument, the given key number (0 to 9) from the DES key file is used. With a `key_str` argument, the given key string is used to encrypt `str`.

The key file can be specified with the `--des-key-file` server option.

The return string is a binary string where the first character is `CHAR(128 | key_num)`. If an error occurs, `DES_ENCRYPT()` returns `NULL`.

The 128 is added to make it easier to recognize an encrypted key. If you use a string key, `key_num` is 127.

The string length for the result is given by this formula:

```
new_len = orig_len + (8 - (orig_len % 8)) + 1
```

Each line in the DES key file has the following format:

```
key_num des_key_str
```

Each `key_num` value must be a number in the range from 0 to 9. Lines in the file may be in any order. `des_key_str` is the string that is used to encrypt the message. There should be at least one space between the number and the key. The first key is the default key that is used if you do not specify any key argument to `DES_ENCRYPT()`.

You can tell MySQL to read new key values from the key file with the `FLUSH DES_KEY_FILE` statement. This requires the `RELOAD` privilege.

One benefit of having a set of default keys is that it gives applications a way to check for the existence of encrypted column values, without giving the end user the right to decrypt those values.

```
mysql> SELECT customer_address FROM customer_table
    > WHERE crypted_credit_card = DES_ENCRYPT('credit_card_number');
```

- `ENCODE(str,pass_str)`

Encrypt `str` using `pass_str` as the password. The result is a binary string of the same length as `str`. To decrypt the result, use `DECODE()`.

The `ENCODE()` function should no longer be used. If you still need to use `ENCODE()`, a salt value must be used with it to reduce risk. For example:

```
ENCODE('cleartext', CONCAT('my_random_salt','my_secret_password'))
```

A new random salt value must be used whenever a password is updated.

- `ENCRYPT(str[,salt])`

Encrypts *str* using the Unix `crypt()` system call and returns a binary string. The *salt* argument must be a string with at least two characters or the result will be `NULL`. If no *salt* argument is given, a random value is used.

```
mysql> SELECT ENCRYPT('hello');
        -> 'VxuFAJXVARROc'
```

`ENCRYPT()` ignores all but the first eight characters of *str*, at least on some systems. This behavior is determined by the implementation of the underlying `crypt()` system call.

The use of `ENCRYPT()` with the `ucs2` multibyte character set is not recommended because the system call expects a string terminated by a zero byte.

If `crypt()` is not available on your system (as is the case with Windows), `ENCRYPT()` always returns `NULL`.

- `MD5(`*str*`)`

  Calculates an MD5 128-bit checksum for the string. The value is returned as a binary string of 32 hex digits, or `NULL` if the argument was `NULL`. The return value can, for example, be used as a hash key. See the notes at the beginning of this section about storing hash values efficiently.

```
mysql> SELECT MD5('testing');
        -> 'ae2b1fca515949e5d54fb22b8ed95575'
```

  This is the "RSA Data Security, Inc. MD5 Message-Digest Algorithm."

  See the note regarding the MD5 algorithm at the beginning this section.

- `OLD_PASSWORD(`*str*`)`

  `OLD_PASSWORD()` was added when the implementation of `PASSWORD()` was changed in MySQL 4.1 to improve security. `OLD_PASSWORD()` returns the value of the pre-4.1 implementation of `PASSWORD()` as a binary string, and is intended to permit you to reset passwords for any pre-4.1 clients that need to connect to your version MySQL 5.1 server without locking them out. See Section 6.1.2.4, "Password Hashing in MySQL".

- `PASSWORD(`*str*`)`

  Returns a hashed password string calculated from the cleartext password *str*. The return value is a binary string, or `NULL` if the argument is `NULL`. This function is the SQL interface to the algorithm used by the server to encrypt MySQL passwords for storage in the `mysql.user` grant table.

  The `old_passwords` system variable controls the password hashing method used by the `PASSWORD()` function. It also influences password hashing performed by `CREATE USER` and `GRANT` statements that specify a password using an `IDENTIFIED BY` clause.

  The value determines whether or not to use "old" native MySQL password hashing. A value of 0 (or `OFF`) causes passwords to be encrypted using the format available from MySQL 4.1 on. A value of 1 (or `ON`) causes password encryption to use the older pre-4.1 format.

  If `old_passwords=1`, `PASSWORD(`*str*`)` returns the same value as `OLD_PASSWORD(`*str*`)`. The latter function is not affected by the value of `old_passwords`.

```
mysql> SET old_passwords = 0;
```

```
mysql> SELECT PASSWORD('mypass'), OLD_PASSWORD('mypass');
+-------------------------------------------+------------------------+
| PASSWORD('mypass')                        | OLD_PASSWORD('mypass') |
+-------------------------------------------+------------------------+
| *6C8989366EAF75BB670AD8EA7A7FC1176A95CEF4 | 6f8c114b58f2ce9e       |
+-------------------------------------------+------------------------+

mysql> SET old_passwords = 1;
mysql> SELECT PASSWORD('mypass'), OLD_PASSWORD('mypass');
+--------------------+------------------------+
| PASSWORD('mypass') | OLD_PASSWORD('mypass') |
+--------------------+------------------------+
| 6f8c114b58f2ce9e   | 6f8c114b58f2ce9e       |
+--------------------+------------------------+
```

Encryption performed by `PASSWORD()` is one-way (not reversible). It is not the same type of encryption as used for Unix passwords; for that, use `ENCRYPT()`.

Note

`PASSWORD()` is used by the authentication system in MySQL Server; you should *not* use it in your own applications. For that purpose, consider `MD5()` or `SHA1()` instead. Also see RFC 2195, section 2 (Challenge-Response Authentication Mechanism (CRAM)), for more information about handling passwords and authentication securely in your applications.

Caution

Statements that invoke `PASSWORD()` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, "Passwords and Logging". For similar information about client-side logging, see Section 4.5.1.3, "mysql Logging".

- `SHA1(str)`, `SHA(str)`

Calculates an SHA-1 160-bit checksum for the string, as described in RFC 3174 (Secure Hash Algorithm). The value is returned as a binary string of 40 hex digits, or `NULL` if the argument was `NULL`. One of the possible uses for this function is as a hash key. See the notes at the beginning of this section about storing hash values efficiently. You can also use `SHA1()` as a cryptographic function for storing passwords. `SHA()` is synonymous with `SHA1()`.

```
mysql> SELECT SHA1('abc');
        -> 'a9993e364706816aba3e25717850c26c9cd0d89d'
```

`SHA1()` can be considered a cryptographically more secure equivalent of `MD5()`. However, see the note regarding the MD5 and SHA-1 algorithms at the beginning this section.

- `UNCOMPRESS(string_to_uncompress)`

Uncompresses a string compressed by the `COMPRESS()` function. If the argument is not a compressed value, the result is `NULL`. This function requires MySQL to have been compiled with a compression library such as `zlib`. Otherwise, the return value is always `NULL`.

```
mysql> SELECT UNCOMPRESS(COMPRESS('any string'));
        -> 'any string'
mysql> SELECT UNCOMPRESS('any string');
```

```
        -> NULL
```

- UNCOMPRESSED_LENGTH(*compressed_string*)

Returns the length that the compressed string had before being compressed.

```
mysql> SELECT UNCOMPRESSED_LENGTH(COMPRESS(REPEAT('a',30)));
        -> 30
```

12.14 Information Functions

Table 12.18 Information Functions

Name	Description
BENCHMARK()	Repeatedly execute an expression
CHARSET()	Return the character set of the argument
COERCIBILITY()	Return the collation coercibility value of the string argument
COLLATION()	Return the collation of the string argument
CONNECTION_ID()	Return the connection ID (thread ID) for the connection
CURRENT_USER(), CURRENT_USER	The authenticated user name and host name
DATABASE()	Return the default (current) database name
FOUND_ROWS()	For a SELECT with a LIMIT clause, the number of rows that would be returned were there no LIMIT clause
LAST_INSERT_ID()	Value of the AUTOINCREMENT column for the last INSERT
ROW_COUNT()	The number of rows updated
SCHEMA()	Synonym for DATABASE()
SESSION_USER()	Synonym for USER()
SYSTEM_USER()	Synonym for USER()
USER()	The user name and host name provided by the client
VERSION()	Return a string that indicates the MySQL server version

- BENCHMARK(*count,expr*)

The BENCHMARK() function executes the expression *expr* repeatedly *count* times. It may be used to time how quickly MySQL processes the expression. The result value is always 0. The intended use is from within the mysql client, which reports query execution times:

```
mysql> SELECT BENCHMARK(1000000,ENCODE('hello','goodbye'));
+----------------------------------------------+
| BENCHMARK(1000000,ENCODE('hello','goodbye')) |
+----------------------------------------------+
|                                            0 |
+----------------------------------------------+
1 row in set (4.74 sec)
```

The time reported is elapsed time on the client end, not CPU time on the server end. It is advisable to execute BENCHMARK() several times, and to interpret the result with regard to how heavily loaded the server machine is.

`BENCHMARK()` is intended for measuring the runtime performance of scalar expressions, which has some significant implications for the way that you use it and interpret the results:

- Only scalar expressions can be used. Although the expression can be a subquery, it must return a single column and at most a single row. For example, `BENCHMARK(10, (SELECT * FROM t))` will fail if the table `t` has more than one column or more than one row.

- Executing a `SELECT expr` statement `N` times differs from executing `SELECT BENCHMARK(N, expr)` in terms of the amount of overhead involved. The two have very different execution profiles and you should not expect them to take the same amount of time. The former involves the parser, optimizer, table locking, and runtime evaluation `N` times each. The latter involves only runtime evaluation `N` times, and all the other components just once. Memory structures already allocated are reused, and runtime optimizations such as local caching of results already evaluated for aggregate functions can alter the results. Use of `BENCHMARK()` thus measures performance of the runtime component by giving more weight to that component and removing the "noise" introduced by the network, parser, optimizer, and so forth.

- `CHARSET(str)`

  Returns the character set of the string argument.

```
mysql> SELECT CHARSET('abc');
        -> 'latin1'
mysql> SELECT CHARSET(CONVERT('abc' USING utf8));
        -> 'utf8'
mysql> SELECT CHARSET(USER());
        -> 'utf8'
```

- `COERCIBILITY(str)`

  Returns the collation coercibility value of the string argument.

```
mysql> SELECT COERCIBILITY('abc' COLLATE latin1_swedish_ci);
        -> 0
mysql> SELECT COERCIBILITY(USER());
        -> 3
mysql> SELECT COERCIBILITY('abc');
        -> 4
```

  The return values have the meanings shown in the following table. Lower values have higher precedence.

Coercibility	Meaning	Example
0	Explicit collation	Value with `COLLATE` clause
1	No collation	Concatenation of strings with different collations
2	Implicit collation	Column value, stored routine parameter or local variable
3	System constant	`USER()` return value
4	Coercible	Literal string
5	Ignorable	`NULL` or an expression derived from `NULL`

- COLLATION(*str*)

  Returns the collation of the string argument.

  ```
  mysql> SELECT COLLATION('abc');
          -> 'latin1_swedish_ci'
  mysql> SELECT COLLATION(_utf8'abc');
          -> 'utf8_general_ci'
  ```

- CONNECTION_ID()

  Returns the connection ID (thread ID) for the connection. Every connection has an ID that is unique among the set of currently connected clients.

  The value returned by CONNECTION_ID() is the same type of value as displayed in the ID column of the INFORMATION_SCHEMA.PROCESSLIST table and the Id column of SHOW PROCESSLIST output.

  ```
  mysql> SELECT CONNECTION_ID();
          -> 23786
  ```

- CURRENT_USER, CURRENT_USER()

  Returns the user name and host name combination for the MySQL account that the server used to authenticate the current client. This account determines your access privileges. The return value is a string in the utf8 character set.

  The value of CURRENT_USER() can differ from the value of USER().

  ```
  mysql> SELECT USER();
          -> 'davida@localhost'
  mysql> SELECT * FROM mysql.user;
  ERROR 1044: Access denied for user ''@'localhost' to
  database 'mysql'
  mysql> SELECT CURRENT_USER();
          -> '@localhost'
  ```

  The example illustrates that although the client specified a user name of davida (as indicated by the value of the USER() function), the server authenticated the client using an anonymous user account (as seen by the empty user name part of the CURRENT_USER() value). One way this might occur is that there is no account listed in the grant tables for davida.

  Within a stored program or view, CURRENT_USER() returns the account for the user who defined the object (as given by its DEFINER value) unless defined with the SQL SECURITY INVOKER characteristic. In the latter case, CURRENT_USER() returns the object's invoker.

  Triggers and events have no option to define the SQL SECURITY characteristic, so for these objects, CURRENT_USER() returns the account for the user who defined the object. To return the invoker, use USER() or SESSION_USER().

  The following statements support use of the CURRENT_USER() function to take the place of the name of (and, possibly, a host for) an affected user or a definer; in such cases, CURRENT_USER() is expanded where and as needed:

  - DROP USER

  - RENAME USER

- GRANT

- REVOKE

- CREATE FUNCTION

- CREATE PROCEDURE

- CREATE TRIGGER

- CREATE EVENT

- CREATE VIEW

- ALTER EVENT

- ALTER VIEW

- SET PASSWORD

For information about the implications that this expansion of CURRENT_USER() has for replication in different releases of MySQL 5.1, see Section 16.4.1.7, "Replication of CURRENT_USER()".

- DATABASE()

Returns the default (current) database name as a string in the utf8 character set. If there is no default database, DATABASE() returns NULL. Within a stored routine, the default database is the database that the routine is associated with, which is not necessarily the same as the database that is the default in the calling context.

```
mysql> SELECT DATABASE();
        -> 'test'
```

If there is no default database, DATABASE() returns NULL.

- FOUND_ROWS()

A SELECT statement may include a LIMIT clause to restrict the number of rows the server returns to the client. In some cases, it is desirable to know how many rows the statement would have returned without the LIMIT, but without running the statement again. To obtain this row count, include a SQL_CALC_FOUND_ROWS option in the SELECT statement, and then invoke FOUND_ROWS() afterward:

```
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM tbl_name
    -> WHERE id > 100 LIMIT 10;
mysql> SELECT FOUND_ROWS();
```

The second SELECT returns a number indicating how many rows the first SELECT would have returned had it been written without the LIMIT clause.

In the absence of the SQL_CALC_FOUND_ROWS option in the most recent successful SELECT statement, FOUND_ROWS() returns the number of rows in the result set returned by that statement. If the statement includes a LIMIT clause, FOUND_ROWS() returns the number of rows up to the limit. For example, FOUND_ROWS() returns 10 or 60, respectively, if the statement includes LIMIT 10 or LIMIT 50, 10.

The row count available through `FOUND_ROWS()` is transient and not intended to be available past the statement following the `SELECT SQL_CALC_FOUND_ROWS` statement. If you need to refer to the value later, save it:

```
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM ... ;
mysql> SET @rows = FOUND_ROWS();
```

If you are using `SELECT SQL_CALC_FOUND_ROWS`, MySQL must calculate how many rows are in the full result set. However, this is faster than running the query again without `LIMIT`, because the result set need not be sent to the client.

`SQL_CALC_FOUND_ROWS` and `FOUND_ROWS()` can be useful in situations when you want to restrict the number of rows that a query returns, but also determine the number of rows in the full result set without running the query again. An example is a Web script that presents a paged display containing links to the pages that show other sections of a search result. Using `FOUND_ROWS()` enables you to determine how many other pages are needed for the rest of the result.

The use of `SQL_CALC_FOUND_ROWS` and `FOUND_ROWS()` is more complex for `UNION` statements than for simple `SELECT` statements, because `LIMIT` may occur at multiple places in a `UNION`. It may be applied to individual `SELECT` statements in the `UNION`, or global to the `UNION` result as a whole.

The intent of `SQL_CALC_FOUND_ROWS` for `UNION` is that it should return the row count that would be returned without a global `LIMIT`. The conditions for use of `SQL_CALC_FOUND_ROWS` with `UNION` are:

- The `SQL_CALC_FOUND_ROWS` keyword must appear in the first `SELECT` of the `UNION`.

- The value of `FOUND_ROWS()` is exact only if `UNION ALL` is used. If `UNION` without `ALL` is used, duplicate removal occurs and the value of `FOUND_ROWS()` is only approximate.

- If no `LIMIT` is present in the `UNION`, `SQL_CALC_FOUND_ROWS` is ignored and returns the number of rows in the temporary table that is created to process the `UNION`.

Beyond the cases described here, the behavior of `FOUND_ROWS()` is undefined (for example, its value following a `SELECT` statement that fails with an error).

> ⚠️ **Important**
>
> `FOUND_ROWS()` is not replicated reliably using statement-based replication. Starting with MySQL 5.1.23, this function is automatically replicated using row-based replication.

- `LAST_INSERT_ID()`, `LAST_INSERT_ID(expr)`

  For MySQL 5.1.12 and later, with no argument, `LAST_INSERT_ID()` returns a 64-bit value representing the first automatically generated value successfully inserted for an `AUTO_INCREMENT` column as a result of the most recently executed `INSERT` statement. The value has a type of `BIGINT UNSIGNED` as of MySQL 5.1.67, `BIGINT` (signed) before that. The value of `LAST_INSERT_ID()` remains unchanged if no rows are successfully inserted.

  With an argument, `LAST_INSERT_ID()` returns an unsigned integer as of MySQL 5.1.67, a signed integer before that.

  For example, after inserting a row that generates an `AUTO_INCREMENT` value, you can get the value like this:

```
mysql> SELECT LAST_INSERT_ID();
        -> 195
```

In MySQL 5.1.11 and earlier, `LAST_INSERT_ID()` (with no argument) returns the first automatically generated value if any rows were successfully inserted or updated. This means that the returned value could be a value that was not successfully inserted into the table. If no rows were successfully inserted, `LAST_INSERT_ID()` returns 0.

The value of `LAST_INSERT_ID()` will be consistent across all MySQL versions if all rows in the `INSERT` or `UPDATE` statement were successful.

if a table contains an `AUTO_INCREMENT` column and `INSERT ... ON DUPLICATE KEY UPDATE` updates (rather than inserts) a row, the value of `LAST_INSERT_ID()` is not meaningful prior to MySQL 5.1.12. For a workaround, see Section 13.2.5.3, "INSERT ... ON DUPLICATE KEY UPDATE Syntax".

The currently executing statement does not affect the value of `LAST_INSERT_ID()`. Suppose that you generate an `AUTO_INCREMENT` value with one statement, and then refer to `LAST_INSERT_ID()` in a multiple-row `INSERT` statement that inserts rows into a table with its own `AUTO_INCREMENT` column. The value of `LAST_INSERT_ID()` will remain stable in the second statement; its value for the second and later rows is not affected by the earlier row insertions. (However, if you mix references to `LAST_INSERT_ID()` and `LAST_INSERT_ID(expr)`, the effect is undefined.)

If the previous statement returned an error, the value of `LAST_INSERT_ID()` is undefined. For transactional tables, if the statement is rolled back due to an error, the value of `LAST_INSERT_ID()` is left undefined. For manual `ROLLBACK`, the value of `LAST_INSERT_ID()` is not restored to that before the transaction; it remains as it was at the point of the `ROLLBACK`.

Prior to MySQL 5.1.73, this function was not replicated correctly if replication filtering rules were in use. (Bug #17234370, Bug #69861)

Within the body of a stored routine (procedure or function) or a trigger, the value of `LAST_INSERT_ID()` changes the same way as for statements executed outside the body of these kinds of objects. The effect of a stored routine or trigger upon the value of `LAST_INSERT_ID()` that is seen by following statements depends on the kind of routine:

- If a stored procedure executes statements that change the value of `LAST_INSERT_ID()`, the changed value is seen by statements that follow the procedure call.

- For stored functions and triggers that change the value, the value is restored when the function or trigger ends, so following statements will not see a changed value.

The ID that was generated is maintained in the server on a *per-connection basis*. This means that the value returned by the function to a given client is the first `AUTO_INCREMENT` value generated for most recent statement affecting an `AUTO_INCREMENT` column *by that client*. This value cannot be affected by other clients, even if they generate `AUTO_INCREMENT` values of their own. This behavior ensures that each client can retrieve its own ID without concern for the activity of other clients, and without the need for locks or transactions.

The value of `LAST_INSERT_ID()` is not changed if you set the `AUTO_INCREMENT` column of a row to a non-"magic" value (that is, a value that is not `NULL` and not `0`).

> ⚠️ **Important**
>
> If you insert multiple rows using a single `INSERT` statement,
> `LAST_INSERT_ID()` returns the value generated for the *first* inserted row *only*.
> The reason for this is to make it possible to reproduce easily the same `INSERT`
> statement against some other server.

For example:

```
mysql> USE test;
Database changed
mysql> CREATE TABLE t (
    ->    id INT AUTO_INCREMENT NOT NULL PRIMARY KEY,
    ->    name VARCHAR(10) NOT NULL
    -> );
Query OK, 0 rows affected (0.09 sec)

mysql> INSERT INTO t VALUES (NULL, 'Bob');
Query OK, 1 row affected (0.01 sec)

mysql> SELECT * FROM t;
+----+------+
| id | name |
+----+------+
|  1 | Bob  |
+----+------+
1 row in set (0.01 sec)

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |
+------------------+
1 row in set (0.00 sec)

mysql> INSERT INTO t VALUES
    -> (NULL, 'Mary'), (NULL, 'Jane'), (NULL, 'Lisa');
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t;
+----+------+
| id | name |
+----+------+
|  1 | Bob  |
|  2 | Mary |
|  3 | Jane |
|  4 | Lisa |
+----+------+
4 rows in set (0.01 sec)

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                2 |
+------------------+
1 row in set (0.00 sec)
```

Although the second `INSERT` statement inserted three new rows into `t`, the ID generated for the first of
these rows was `2`, and it is this value that is returned by `LAST_INSERT_ID()` for the following `SELECT`
statement.

If you use INSERT IGNORE and the row is ignored, the LAST_INSERT_ID() remains unchanged from the current value (or 0 is returned if the connection has not yet performed a successful INSERT) and, for non-transactional tables, the AUTO_INCREMENT counter is not incremented. For InnoDB tables, the AUTO_INCREMENT counter is incremented if innodb_autoinc_lock_mode is set to 1 or 2, as demonstrated in the following example:

```
mysql> USE test;
Database changed

mysql> SELECT @@innodb_autoinc_lock_mode;
+----------------------------+
| @@innodb_autoinc_lock_mode |
+----------------------------+
|                          1 |
+----------------------------+
1 row in set (0.00 sec)

mysql> CREATE TABLE `t` (
`id` INT(11) NOT NULL AUTO_INCREMENT,
`val` INT(11) DEFAULT NULL,
PRIMARY KEY (`id`),
UNIQUE KEY `i1` (`val`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1;
Query OK, 0 rows affected (0.02 sec)


-- Insert two rows

mysql> INSERT INTO t (val) VALUES (1),(2);
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0


-- With auto_increment_offset=1, the inserted rows
-- result in an AUTO_INCREMENT value of 3

mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
       Table: t
Create Table: CREATE TABLE `t` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `val` int(11) DEFAULT NULL,
  PRIMARY KEY (`id`),
  UNIQUE KEY `i1` (`val`)
) ENGINE=MyISAM AUTO_INCREMENT=3 DEFAULT CHARSET=latin1
1 row in set (0.00 sec)


-- LAST_INSERT_ID() returns the first automatically generated
-- value that is successfully inserted for the AUTO_INCREMENT column

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |
+------------------+
1 row in set (0.00 sec)


-- The attempted insertion of duplicate rows fail but errors are ignored

mysql> INSERT IGNORE INTO t (val) VALUES (1),(2);
Query OK, 0 rows affected (0.00 sec)
Records: 2  Duplicates: 2  Warnings: 0


-- With innodb_autoinc_lock_mode=1, the AUTO_INCREMENT counter
-- is incremented for the ignored rows
```

```
mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
       Table: t
Create Table: CREATE TABLE `t` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `val` int(11) DEFAULT NULL,
  PRIMARY KEY (`id`),
  UNIQUE KEY `i1` (`val`)
) ENGINE=MyISAM AUTO_INCREMENT=5 DEFAULT CHARSET=latin1
1 row in set (0.00 sec)

-- The LAST_INSERT_ID is unchanged becuase the previous insert was unsuccessful

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |
+------------------+
1 row in set (0.00 sec)
```

See Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB" for more information.

If `expr` is given as an argument to `LAST_INSERT_ID()`, the value of the argument is returned by the function and is remembered as the next value to be returned by `LAST_INSERT_ID()`. This can be used to simulate sequences:

1. Create a table to hold the sequence counter and initialize it:

    ```
    mysql> CREATE TABLE sequence (id INT NOT NULL);
    mysql> INSERT INTO sequence VALUES (0);
    ```

2. Use the table to generate sequence numbers like this:

    ```
    mysql> UPDATE sequence SET id=LAST_INSERT_ID(id+1);
    mysql> SELECT LAST_INSERT_ID();
    ```

    The `UPDATE` statement increments the sequence counter and causes the next call to `LAST_INSERT_ID()` to return the updated value. The `SELECT` statement retrieves that value. The `mysql_insert_id()` C API function can also be used to get the value. See Section 21.8.7.37, "mysql_insert_id()".

You can generate sequences without calling `LAST_INSERT_ID()`, but the utility of using the function this way is that the ID value is maintained in the server as the last automatically generated value. It is multi-user safe because multiple clients can issue the `UPDATE` statement and get their own sequence value with the `SELECT` statement (or `mysql_insert_id()`), without affecting or being affected by other clients that generate their own sequence values.

Note that `mysql_insert_id()` is only updated after `INSERT` and `UPDATE` statements, so you cannot use the C API function to retrieve the value for `LAST_INSERT_ID(expr)` after executing other SQL statements like `SELECT` or `SET`.

-   `ROW_COUNT()`

    `ROW_COUNT()` returns the number of rows changed, deleted, or inserted by the last statement if it was an `UPDATE`, `DELETE`, or `INSERT`. For other statements, the value may not be meaningful.

For `UPDATE` statements, the affected-rows value by default is the number of rows actually changed. If you specify the `CLIENT_FOUND_ROWS` flag to `mysql_real_connect()` when connecting to `mysqld`, the affected-rows value is the number of rows "found"; that is, matched by the `WHERE` clause.

For `REPLACE` statements, the affected-rows value is 2 if the new row replaced an old row, because in this case, one row was inserted after the duplicate was deleted.

For `INSERT ... ON DUPLICATE KEY UPDATE` statements, the affected-rows value is 1 if the row is inserted as a new row and 2 if an existing row is updated.

The `ROW_COUNT()` value is similar to the value from the `mysql_affected_rows()` C API function and the row count that the `mysql` client displays following statement execution.

```
mysql> INSERT INTO t VALUES(1),(2),(3);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT ROW_COUNT();
+-------------+
| ROW_COUNT() |
+-------------+
|           3 |
+-------------+
1 row in set (0.00 sec)

mysql> DELETE FROM t WHERE i IN(1,2);
Query OK, 2 rows affected (0.00 sec)

mysql> SELECT ROW_COUNT();
+-------------+
| ROW_COUNT() |
+-------------+
|           2 |
+-------------+
1 row in set (0.00 sec)
```

> **Important**
>
> `ROW_COUNT()` is not replicated reliably using statement-based replication. Beginning with MySQL 5.1.23, this function is automatically replicated using row-based replication. (Bug #30244)

- `SCHEMA()`

  This function is a synonym for `DATABASE()`.

- `SESSION_USER()`

  `SESSION_USER()` is a synonym for `USER()`.

- `SYSTEM_USER()`

  `SYSTEM_USER()` is a synonym for `USER()`.

- `USER()`

  Returns the current MySQL user name and host name as a string in the `utf8` character set.

```
mysql> SELECT USER();
```

```
        -> 'davida@localhost'
```

The value indicates the user name you specified when connecting to the server, and the client host from which you connected. The value can be different from that of `CURRENT_USER()`.

- `VERSION()`

  Returns a string that indicates the MySQL server version. The string uses the `utf8` character set. The value might have a suffix in addition to the version number. See the description of the `version` system variable in Section 5.1.4, "Server System Variables".

  This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

```
mysql> SELECT VERSION();
        -> '5.1.73-standard'
```

12.15 Spatial Analysis Functions

MySQL provides functions to perform various operations on spatial data. These functions can be grouped into several major categories according to the type of operation they perform:

- Functions that create geometries in various formats (WKT, WKB, internal)
- Functions that convert geometries between formats
- Functions that access qualitative or quantitative properties of a geometry
- Functions that describe relations between two geometries
- Functions that create new geometries from existing ones

For general background about MySQL support for using spatial data, see Section 11.5, "Extensions for Spatial Data".

12.15.1 Spatial Function Reference

The following table lists each spatial function and provides a short description of each one.

Table 12.19 Spatial Functions

Name	Description
Area()	Return Polygon or MultiPolygon area
AsBinary(), AsWKB()	Convert from internal geometry format to WKB
AsText(), AsWKT()	Convert from internal geometry format to WKT
Centroid()	Return centroid as a point
Contains()	Whether MBR of one geometry contains MBR of another
Crosses()	Whether one geometry crosses another
Dimension()	Dimension of geometry
Disjoint()	Whether MBRs of two geometries are disjoint
EndPoint()	End Point of LineString
Envelope()	Return MBR of geometry
Equals()	Whether MBRs of two geometries are equal

Name	Description
`ExteriorRing()`	Return exterior ring of Polygon
`GeomCollFromText()`, `GeometryCollectionFromText()`	Return geometry collection from WKT
`GeomCollFromWKB()`, `GeometryCollectionFromWKB()`	Return geometry collection from WKB
`GeometryCollection()`	Construct geometry collection from geometries
`GeometryN()`	Return N-th geometry from geometry collection
`GeometryType()`	Return name of geometry type
`GeomFromText()`, `GeometryFromText()`	Return geometry from WKT
`GeomFromWKB()`, `GeometryFromWKB()`	Return geometry from WKB
`GLength()`	Return length of LineString
`InteriorRingN()`	Return N-th interior ring of Polygon
`Intersects()`	Whether MBRs of two geometries intersect
`IsClosed()`	Whether a geometry is closed and simple
`IsEmpty()`	Placeholder function
`IsSimple()`	Whether a geometry is simple
`LineFromText()`, `LineStringFromText()`	Construct LineString from WKT
`LineFromWKB()`, `LineStringFromWKB()`	Construct LineString from WKB
`LineString()`	Construct LineString from Point values
`MBRContains()`	Whether MBR of one geometry contains MBR of another
`MBRDisjoint()`	Whether MBRs of two geometries are disjoint
`MBREqual()`	Whether MBRs of two geometries are equal
`MBRIntersects()`	Whether MBRs of two geometries intersect
`MBROverlaps()`	Whether MBRs of two geometries overlap
`MBRTouches()`	Whether MBRs of two geometries touch
`MBRWithin()`	Whether MBR of one geometry is within MBR of another
`MLineFromText()`, `MultiLineStringFromText()`	Construct MultiLineString from WKT
`MLineFromWKB()`, `MultiLineStringFromWKB()`	Construct MultiLineString from WKB
`MPointFromText()`, `MultiPointFromText()`	Construct MultiPoint from WKT
`MPointFromWKB()`, `MultiPointFromWKB()`	Construct MultiPoint from WKB
`MPolyFromText()`, `MultiPolygonFromText()`	Construct MultiPolygon from WKT

Name	Description
MPolyFromWKB(), MultiPolygonFromWKB()	Construct MultiPolygon from WKB
MultiLineString()	Contruct MultiLineString from LineString values
MultiPoint()	Construct MultiPoint from Point values
MultiPolygon()	Construct MultiPolygon from Polygon values
NumGeometries()	Return number of geometries in geometry collection
NumInteriorRings()	Return number of interior rings in Polygon
NumPoints()	Return number of points in LineString
Overlaps()	Whether MBRs of two geometries overlap
Point()	Construct Point from coordinates
PointFromText()	Construct Point from WKT
PointFromWKB()	Construct Point from WKB
PointN()	Return N-th point from LineString
PolyFromText(), PolygonFromText()	Construct Polygon from WKT
PolyFromWKB(), PolygonFromWKB()	Construct Polygon from WKB
Polygon()	Construct Polygon from LineString arguments
SRID()	Return spatial reference system ID for geometry
StartPoint()	Start Point of LineString
Touches()	Whether one geometry touches another
Within()	Whether MBR of one geometry is within MBR of another
X()	Return X coordinate of Point
Y()	Return Y coordinate of Point

12.15.2 Argument Handling by Spatial Functions

Spatial values, or geometries, have the properties described at Section 11.5.2.2, "Geometry Class". The following discussion lists general spatial function argument-handling characteristics. Specific functions or groups of functions may have additional argument-handling characteristics, as discussed in the sections where those function descriptions occur.

Spatial functions are defined only for valid geometry values. If an invalid geometry is passed to a spatial function, the result is undefined.

The Spatial Reference Identifier (SRID) of a geometry identifies the coordinate space in which the geometry is defined. In MySQL, the SRID value is an integer associated with the geometry value. However, all calculations are done assuming SRID 0, representing cartesian (planar) coordinates, regardless of the actual SRID value. In the future, calculations may use the specified SRID values. To ensure SRID 0 behavior, create geometries using SRID 0. SRID 0 is the default for new geometries if no SRID is specified.

The maximum usable SRID value is $2^{32}-1$. If a larger value is given, only the lower 32 bits are used.

Geometry values produced by any spatial function inherit the SRID of the geometry arguments.

12.15.3 Functions That Create Geometry Values from WKT Values

These functions take as arguments a Well-Known Text (WKT) representation and, optionally, a spatial reference system identifier (SRID). They return the corresponding geometry.

`GeomFromText()` accepts a WKT value of any geometry type as its first argument. Other functions provide type-specific construction functions for construction of geometry values of each geometry type.

For a description of WKT format, see Well-Known Text (WKT) Format.

- `GeomCollFromText(wkt[,srid])`, `GeometryCollectionFromText(wkt[,srid])`

  Constructs a `GeometryCollection` value using its WKT representation and SRID.

- `GeomFromText(wkt[,srid])`, `GeometryFromText(wkt[,srid])`

  Constructs a geometry value of any type using its WKT representation and SRID.

- `LineFromText(wkt[,srid])`, `LineStringFromText(wkt[,srid])`

  Constructs a `LineString` value using its WKT representation and SRID.

- `MLineFromText(wkt[,srid])`, `MultiLineStringFromText(wkt[,srid])`

  Constructs a `MultiLineString` value using its WKT representation and SRID.

- `MPointFromText(wkt[,srid])`, `MultiPointFromText(wkt[,srid])`

  Constructs a `MultiPoint` value using its WKT representation and SRID.

- `MPolyFromText(wkt[,srid])`, `MultiPolygonFromText(wkt[,srid])`

  Constructs a `MultiPolygon` value using its WKT representation and SRID.

- `PointFromText(wkt[,srid])`

  Constructs a `Point` value using its WKT representation and SRID.

- `PolyFromText(wkt[,srid])`, `PolygonFromText(wkt[,srid])`

  Constructs a `Polygon` value using its WKT representation and SRID.

12.15.4 Functions That Create Geometry Values from WKB Values

These functions take as arguments a `BLOB` containing a Well-Known Binary (WKB) representation and, optionally, a spatial reference system identifier (SRID). They return the corresponding geometry.

As of MySQL 5.1.35, these functions also accept geometry objects for compatibility with the changes made in MySQL 5.1.35 to the return value of the functions in Section 12.15.5, "MySQL-Specific Functions That Create Geometry Values". Thus, those functions may continue to be used to provide the first argument to the functions in this section.

`GeomFromWKB()` accepts a WKB value of any geometry type as its first argument. Other functions provide type-specific construction functions for construction of geometry values of each geometry type.

For a description of WKB format, see Well-Known Binary (WKB) Format.

- `GeomCollFromWKB(wkb[,srid])`, `GeometryCollectionFromWKB(wkb[,srid])`

  Constructs a `GeometryCollection` value using its WKB representation and SRID.

- `GeomFromWKB(wkb[,srid])`, `GeometryFromWKB(wkb[,srid])`

  Constructs a geometry value of any type using its WKB representation and SRID.

- `LineFromWKB(wkb[,srid])`, `LineStringFromWKB(wkb[,srid])`

  Constructs a `LineString` value using its WKB representation and SRID.

- `MLineFromWKB(wkb[,srid])`, `MultiLineStringFromWKB(wkb[,srid])`

  Constructs a `MultiLineString` value using its WKB representation and SRID.

- `MPointFromWKB(wkb[,srid])`, `MultiPointFromWKB(wkb[,srid])`

  Constructs a `MultiPoint` value using its WKB representation and SRID.

- `MPolyFromWKB(wkb[,srid])`, `MultiPolygonFromWKB(wkb[,srid])`

  Constructs a `MultiPolygon` value using its WKB representation and SRID.

- `PointFromWKB(wkb[,srid])`

  Constructs a `Point` value using its WKB representation and SRID.

- `PolyFromWKB(wkb[,srid])`, `PolygonFromWKB(wkb[,srid])`

  Constructs a `Polygon` value using its WKB representation and SRID.

12.15.5 MySQL-Specific Functions That Create Geometry Values

MySQL provides a set of useful nonstandard functions for creating geometry values. The functions described in this section are MySQL extensions to the OpenGIS specification.

As of MySQL 5.1.35, these functions produce geometry objects from either WKB values or geometry objects as arguments. If any argument is not a proper WKB or geometry representation of the proper object type, the return value is `NULL`.

Before MySQL 5.1.35, these functions produce `BLOB` values containing WKB representations of geometry values with no SRID from WKB arguments. The WKB value returned from these functions can be converted to geometry arguments by using them as the first argument to functions in the `GeomFromWKB()` function family.

For example, as of MySQL 5.1.35, you can insert the geometry return value from `Point()` directly into a `POINT` column:

```
INSERT INTO t1 (pt_col) VALUES(Point(1,2));
```

Prior to MySQL 5.1.35, convert the WKB return value to a `Point` before inserting it:

```
INSERT INTO t1 (pt_col) VALUES(GeomFromWKB(Point(1,2)));
```

- `GeometryCollection(g1,g2,...)`

Constructs a `GeometryCollection`.

If the argument contains a nonsupported geometry, the return value is `NULL`.

- `LineString(pt1,pt2,...)`

Constructs a `LineString` value from a number of `Point` or WKB `Point` arguments. If the number of arguments is less than two, the return value is `NULL`.

- `MultiLineString(ls1,ls2,...)`

Constructs a `MultiLineString` value using `LineString` or WKB `LineString` arguments.

- `MultiPoint(pt1,pt2,...)`

Constructs a `MultiPoint` value using `Point` or WKB `Point` arguments.

- `MultiPolygon(poly1,poly2,...)`

Constructs a `MultiPolygon` value from a set of `Polygon` or WKB `Polygon` arguments.

- `Point(x,y)`

Constructs a `Point` using its coordinates.

- `Polygon(ls1,ls2,...)`

Constructs a `Polygon` value from a number of `LineString` or WKB `LineString` arguments. If any argument does not represent a `LinearRing` (that is, not a closed and simple `LineString`), the return value is `NULL`.

12.15.6 Geometry Format Conversion Functions

MySQL supports the functions listed in this section for converting geometry values from internal geometry format to WKT or WKB format.

In addition, there are functions to convert a string from WKT or WKB format to internal geometry format. See Section 12.15.3, "Functions That Create Geometry Values from WKT Values", and Section 12.15.4, "Functions That Create Geometry Values from WKB Values".

- `AsBinary(g)`, `AsWKB(g)`

Converts a value in internal geometry format to its WKB representation and returns the binary result.

```
SELECT AsBinary(g) FROM geom;
```

- `AsText(g)`, `AsWKT(g)`

Converts a value in internal geometry format to its WKT representation and returns the string result.

```
mysql> SET @g = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(GeomFromText(@g));
+-------------------------+
| AsText(GeomFromText(@g)) |
+-------------------------+
| LINESTRING(1 1,2 2,3 3) |
+-------------------------+
```

12.15.7 Geometry Property Functions

Each function that belongs to this group takes a geometry value as its argument and returns some quantitative or qualitative property of the geometry. Some functions restrict their argument type. Such functions return NULL if the argument is of an incorrect geometry type. For example, the Area() polygon function returns NULL if the object type is neither Polygon nor MultiPolygon.

12.15.7.1 General Geometry Property Functions

The functions listed in this section do not restrict their argument and accept a geometry value of any type.

- Dimension(*g*)

  Returns the inherent dimension of the geometry value *g*. The result can be −1, 0, 1, or 2. The meaning of these values is given in Section 11.5.2.2, "Geometry Class".

  ```
  mysql> SELECT Dimension(GeomFromText('LineString(1 1,2 2)'));
  +------------------------------------------------+
  | Dimension(GeomFromText('LineString(1 1,2 2)')) |
  +------------------------------------------------+
  |                                              1 |
  +------------------------------------------------+
  ```

- Envelope(*g*)

  Returns the minimum bounding rectangle (MBR) for the geometry value *g*. The result is returned as a Polygon value that is defined by the corner points of the bounding box:

  ```
  POLYGON((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
  ```

  ```
  mysql> SELECT AsText(Envelope(GeomFromText('LineString(1 1,2 2)')));
  +-------------------------------------------------------+
  | AsText(Envelope(GeomFromText('LineString(1 1,2 2)'))) |
  +-------------------------------------------------------+
  | POLYGON((1 1,2 1,2 2,1 2,1 1))                        |
  +-------------------------------------------------------+
  ```

- GeometryType(*g*)

  Returns a binary string indicating the name of the geometry type of which the geometry instance *g* is a member. The name corresponds to one of the instantiable Geometry subclasses.

  ```
  mysql> SELECT GeometryType(GeomFromText('POINT(1 1)'));
  +-----------------------------------------+
  | GeometryType(GeomFromText('POINT(1 1)')) |
  +-----------------------------------------+
  | POINT                                   |
  +-----------------------------------------+
  ```

- IsEmpty(*g*)

  This function is a placeholder that returns 0 for any valid geometry value, 1 for any invalid geometry value or NULL.

  MySQL does not support GIS EMPTY values such as POINT EMPTY.

- IsSimple(*g*)

In MySQL 5.1, this function is a placeholder that always returns 0.

The description of each instantiable geometric class given earlier in the chapter includes the specific conditions that cause an instance of that class to be classified as not simple. (See Section 11.5.2.1, "The Geometry Class Hierarchy".)

- `SRID(g)`

Returns an integer indicating the Spatial Reference System ID for the geometry value `g`.

In MySQL, the SRID value is just an integer associated with the geometry value. All calculations are done assuming Euclidean (planar) geometry.

```
mysql> SELECT SRID(GeomFromText('LineString(1 1,2 2)',101));
+----------------------------------------------+
| SRID(GeomFromText('LineString(1 1,2 2)',101)) |
+----------------------------------------------+
|                                          101 |
+----------------------------------------------+
```

12.15.7.2 Point Property Functions

A `Point` consists of X and Y coordinates, which may be obtained using the following functions:

- `X(p)`

Returns the X-coordinate value for the `Point` object `p` as a double-precision number.

```
mysql> SELECT X(POINT(56.7, 53.34));
+----------------------+
| X(POINT(56.7, 53.34)) |
+----------------------+
|                 56.7 |
+----------------------+
```

- `Y(p)`

Returns the Y-coordinate value for the `Point` object `p` as a double-precision number.

```
mysql> SELECT Y(POINT(56.7, 53.34));
+----------------------+
| Y(POINT(56.7, 53.34)) |
+----------------------+
|                53.34 |
+----------------------+
```

12.15.7.3 LineString and MultiLineString Property Functions

A `LineString` consists of `Point` values. You can extract particular points of a `LineString`, count the number of points that it contains, or obtain its length.

Some functions in this section also work for `MultiLineString` values.

- `EndPoint(ls)`

Returns the `Point` that is the endpoint of the `LineString` value `ls`.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
```

```
mysql> SELECT AsText(EndPoint(GeomFromText(@ls)));
+-----------------------------------+
| AsText(EndPoint(GeomFromText(@ls))) |
+-----------------------------------+
| POINT(3 3)                        |
+-----------------------------------+
```

- GLength(*ls*)

  Returns a double-precision number indicating the length of the LineString or MultiLineString value *ls* in its associated spatial reference. The length of a MultiLineString value is equal to the sum of the lengths of its elements.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT GLength(GeomFromText(@ls));
+--------------------------+
| GLength(GeomFromText(@ls)) |
+--------------------------+
|        2.8284271247461903 |
+--------------------------+

mysql> SET @mls = 'MultiLineString((1 1,2 2,3 3),(4 4,5 5))';
mysql> SELECT GLength(GeomFromText(@mls));
+---------------------------+
| GLength(GeomFromText(@mls)) |
+---------------------------+
|         4.242640687119286 |
+---------------------------+
```

  GLength() is a nonstandard name. It corresponds to the OpenGIS Length() function. (There is an existing SQL function Length() that calculates the length of string values.)

- IsClosed(*ls*)

  For a LineString value *ls*, IsClosed() returns 1 if *ls* is closed (that is, its StartPoint() and EndPoint() values are the same).

  For a MultiLineString value *ls*, IsClosed() returns 1 if *ls* is closed (that is, the StartPoint() and EndPoint() values are the same for each LineString in *ls*).

  IsClosed() returns 0 if *ls* is not closed, and NULL if *ls* is NULL.

```
mysql> SET @ls1 = 'LineString(1 1,2 2,3 3,2 2)';
mysql> SET @ls2 = 'LineString(1 1,2 2,3 3,1 1)';

mysql> SELECT IsClosed(GeomFromText(@ls1));
+----------------------------+
| IsClosed(GeomFromText(@ls1)) |
+----------------------------+
|                          0 |
+----------------------------+

mysql> SELECT IsClosed(GeomFromText(@ls2));
+----------------------------+
| IsClosed(GeomFromText(@ls2)) |
+----------------------------+
|                          1 |
+----------------------------+

mysql> SET @ls3 = 'MultiLineString((1 1,2 2,3 3),(4 4,5 5))';

mysql> SELECT IsClosed(GeomFromText(@ls3));
```

```
+-----------------------------+
| IsClosed(GeomFromText(@ls3)) |
+-----------------------------+
|                           0 |
+-----------------------------+
```

- NumPoints(*ls*)

  Returns the number of Point objects in the LineString value *ls*.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT NumPoints(GeomFromText(@ls));
+-----------------------------+
| NumPoints(GeomFromText(@ls)) |
+-----------------------------+
|                           3 |
+-----------------------------+
```

- PointN(*ls*,*N*)

  Returns the *N*-th Point in the Linestring value *ls*. Points are numbered beginning with 1.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(PointN(GeomFromText(@ls),2));
+-----------------------------------+
| AsText(PointN(GeomFromText(@ls),2)) |
+-----------------------------------+
| POINT(2 2)                        |
+-----------------------------------+
```

- StartPoint(*ls*)

  Returns the Point that is the start point of the LineString value *ls*.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(StartPoint(GeomFromText(@ls)));
+-------------------------------------+
| AsText(StartPoint(GeomFromText(@ls))) |
+-------------------------------------+
| POINT(1 1)                          |
+-------------------------------------+
```

12.15.7.4 Polygon and MultiPolygon Property Functions

These functions return properties of Polygon or MultiPolygon values.

- Area(*poly*)

  Returns a double-precision number indicating the area of the argument, as measured in its spatial reference system. For arguments of dimension 0 or 1, the result is 0.

```
mysql> SET @poly = 'Polygon((0 0,0 3,3 0,0 0),(1 1,1 2,2 1,1 1))';
mysql> SELECT Area(GeomFromText(@poly));
+--------------------------+
| Area(GeomFromText(@poly)) |
+--------------------------+
|                        4 |
+--------------------------+

mysql> SET @mpoly =
```

```
    -> 'MultiPolygon(((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1)))';
mysql> SELECT Area(GeomFromText(@mpoly));
+---------------------------+
| Area(GeomFromText(@mpoly)) |
+---------------------------+
|                         8 |
+---------------------------+
```

- Centroid(*mpoly*)

  Returns the mathematical centroid for the `MultiPolygon` value *mpoly* as a `Point`. The result is not guaranteed to be on the `MultiPolygon`.

```
mysql> SET @poly =
    -> GeomFromText('POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7,5 5))');
mysql> SELECT GeometryType(@poly),AsText(Centroid(@poly));
+--------------------+-------------------------------------------+
| GeometryType(@poly) | AsText(Centroid(@poly))                   |
+--------------------+-------------------------------------------+
| POLYGON             | POINT(4.958333333333333 4.958333333333333) |
+--------------------+-------------------------------------------+
```

- ExteriorRing(*poly*)

  Returns the exterior ring of the `Polygon` value *poly* as a `LineString`.

```
mysql> SET @poly =
    -> 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))';
mysql> SELECT AsText(ExteriorRing(GeomFromText(@poly)));
+-------------------------------------------+
| AsText(ExteriorRing(GeomFromText(@poly))) |
+-------------------------------------------+
| LINESTRING(0 0,0 3,3 3,3 0,0 0)           |
+-------------------------------------------+
```

- InteriorRingN(*poly*,*N*)

  Returns the *N*-th interior ring for the `Polygon` value *poly* as a `LineString`. Rings are numbered beginning with 1.

```
mysql> SET @poly =
    -> 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))';
mysql> SELECT AsText(InteriorRingN(GeomFromText(@poly),1));
+----------------------------------------------+
| AsText(InteriorRingN(GeomFromText(@poly),1)) |
+----------------------------------------------+
| LINESTRING(1 1,1 2,2 2,2 1,1 1)              |
+----------------------------------------------+
```

- NumInteriorRings(*poly*)

  Returns the number of interior rings in the `Polygon` value *poly*.

```
mysql> SET @poly =
    -> 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))';
mysql> SELECT NumInteriorRings(GeomFromText(@poly));
+---------------------------------------+
| NumInteriorRings(GeomFromText(@poly)) |
+---------------------------------------+
|                                     1 |
+---------------------------------------+
```

12.15.7.5 GeometryCollection Property Functions

These functions return properties of `GeometryCollection` values.

- `GeometryN(gc,N)`

  Returns the N-th geometry in the `GeometryCollection` value gc. Geometries are numbered beginning with 1.

  ```
  mysql> SET @gc = 'GeometryCollection(Point(1 1),LineString(2 2, 3 3))';
  mysql> SELECT AsText(GeometryN(GeomFromText(@gc),1));
  +--------------------------------------+
  | AsText(GeometryN(GeomFromText(@gc),1)) |
  +--------------------------------------+
  | POINT(1 1)                           |
  +--------------------------------------+
  ```

- `NumGeometries(gc)`

  Returns the number of geometries in the `GeometryCollection` value gc.

  ```
  mysql> SET @gc = 'GeometryCollection(Point(1 1),LineString(2 2, 3 3))';
  mysql> SELECT NumGeometries(GeomFromText(@gc));
  +--------------------------------+
  | NumGeometries(GeomFromText(@gc)) |
  +--------------------------------+
  |                              2 |
  +--------------------------------+
  ```

12.15.8 Spatial Operator Functions

Section 12.15.7, "Geometry Property Functions", discusses several functions that construct new geometries from existing ones. See that section for descriptions of these functions:

- `Envelope(g)`

- `StartPoint(ls)`

- `EndPoint(ls)`

- `PointN(ls,N)`

- `ExteriorRing(poly)`

- `InteriorRingN(poly,N)`

- `GeometryN(gc,N)`

12.15.9 Functions That Test Spatial Relations Between Geometry Objects

The functions described in this section take two geometries as arguments and return a qualitative or quantitative relation between them.

MySQL implements two sets of functions using function names defined by the OpenGIS specification. One set tests the relationship between two geometry values using precise object shapes, the other set uses object minimum bounding rectangles (MBRs).

There is also a MySQL-specific set of MBR-based functions available to test the relationship between two geometry values.

12.15.9.1 Spatial Relation Functions That Use Object Shapes

The OpenGIS specification defines the following functions. They test the relationship between two geometry values `g1` and `g2`, using precise object shapes. The return values 1 and 0 indicate true and false, respectively.

- `Crosses(g1,g2)`

  Returns 1 if `g1` spatially crosses `g2`. Returns `NULL` if g1 is a `Polygon` or a `MultiPolygon`, or if `g2` is a `Point` or a `MultiPoint`. Otherwise, returns 0.

  The term *spatially crosses* denotes a spatial relation between two given geometries that has the following properties:

  - The two geometries intersect

  - Their intersection results in a geometry that has a dimension that is one less than the maximum dimension of the two given geometries

  - Their intersection is not equal to either of the two given geometries

- `Touches(g1,g2)`

  Returns 1 or 0 to indicate whether `g1` spatially touches `g2`. Two geometries *spatially touch* if the interiors of the geometries do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

12.15.9.2 Spatial Relation Functions That Use Minimum Bounding Rectangles (MBRs)

The OpenGIS specification defines the following functions that test the relationship between two geometry values `g1` and `g2`. The MySQL implementation uses minimum bounding rectangles, so these functions return the same result as the corresponding MBR-based functions. The return values 1 and 0 indicate true and false, respectively.

- `Contains(g1,g2)`

  Returns 1 or 0 to indicate whether `g1` completely contains `g2`. This tests the opposite relationship as `Within()`.

- `Disjoint(g1,g2)`

  Returns 1 or 0 to indicate whether `g1` is spatially disjoint from (does not intersect) `g2`.

- `Equals(g1,g2)`

  Returns 1 or 0 to indicate whether `g1` is spatially equal to `g2`.

- `Intersects(g1,g2)`

  Returns 1 or 0 to indicate whether `g1` spatially intersects `g2`.

- `Overlaps(g1,g2)`

  Returns 1 or 0 to indicate whether `g1` spatially overlaps `g2`. The term *spatially overlaps* is used if two geometries intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

- `Within(g1,g2)`

Returns 1 or 0 to indicate whether `g1` is spatially within `g2`. This tests the opposite relationship as `Contains()`.

12.15.9.3 MySQL-Specific Spatial Relation Functions That Use Minimum Bounding Rectangles (MBRs)

MySQL provides several MySQL-specific functions that test relations between minimum bounding rectangles of two geometries `g1` and `g2`. The return values 1 and 0 indicate true and false, respectively.

- `MBRContains(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangle of `g1` contains the minimum bounding rectangle of `g2`. This tests the opposite relationship as `MBRWithin()`.

  ```
  mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
  mysql> SET @g2 = GeomFromText('Point(1 1)');
  mysql> SELECT MBRContains(@g1,@g2), MBRWithin(@g2,@g1);
  +----------------------+--------------------+
  | MBRContains(@g1,@g2) | MBRWithin(@g2,@g1) |
  +----------------------+--------------------+
  |                    1 |                  1 |
  +----------------------+--------------------+
  ```

- `MBRDisjoint(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries `g1` and `g2` are disjoint (do not intersect).

- `MBREqual(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries `g1` and `g2` are the same.

- `MBRIntersects(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries `g1` and `g2` intersect.

- `MBROverlaps(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries `g1` and `g2` overlap. The term *spatially overlaps* is used if two geometries intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

- `MBRTouches(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries `g1` and `g2` touch. Two geometries *spatially touch* if the interiors of the geometries do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

- `MBRWithin(g1,g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangle of `g1` is within the minimum bounding rectangle of `g2`. This tests the opposite relationship as `MBRContains()`.

  ```
  mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
  mysql> SET @g2 = GeomFromText('Polygon((0 0,0 5,5 5,5 0,0 0))');
  ```

```
mysql> SELECT MBRWithin(@g1,@g2), MBRWithin(@g2,@g1);
+--------------------+--------------------+
| MBRWithin(@g1,@g2) | MBRWithin(@g2,@g1) |
+--------------------+--------------------+
|                  1 |                  0 |
+--------------------+--------------------+
```

12.16 Miscellaneous Functions

Table 12.20 Miscellaneous Functions

Name	Description
DEFAULT()	Return the default value for a table column
GET_LOCK()	Get a named lock
INET_ATON()	Return the numeric value of an IP address
INET_NTOA()	Return the IP address from a numeric value
IS_FREE_LOCK()	Whether the named lock is free
IS_USED_LOCK()	Whether the named lock is in use; return connection identifier if true
MASTER_POS_WAIT()	Block until the slave has read and applied all updates up to the specified position
NAME_CONST()	Causes the column to have the given name
RAND()	Return a random floating-point value
RELEASE_LOCK()	Releases the named lock
SLEEP()	Sleep for a number of seconds
UUID()	Return a Universal Unique Identifier (UUID)
UUID_SHORT()	Return an integer-valued universal identifier
VALUES()	Defines the values to be used during an INSERT

- DEFAULT(*col_name*)

  Returns the default value for a table column. An error results if the column has no default value.

  ```
  mysql> UPDATE t SET i = DEFAULT(i)+1 WHERE id < 100;
  ```

- FORMAT(*X*,*D*)

  Formats the number *X* to a format like `'#,###,###.##'`, rounded to *D* decimal places, and returns the result as a string. For details, see Section 12.5, "String Functions".

- GET_LOCK(*str*,*timeout*)

  Tries to obtain a lock with a name given by the string *str*, using a timeout of *timeout* seconds. Returns 1 if the lock was obtained successfully, 0 if the attempt timed out (for example, because another client has previously locked the name), or NULL if an error occurred (such as running out of memory or the thread was killed with mysqladmin kill).

  A lock obtained with GET_LOCK() is released explicitly by executing RELEASE_LOCK() or a new GET_LOCK(), or implicitly when your session terminates (either normally or abnormally).

  Locks obtained with GET_LOCK() are not released when transactions commit or roll back.

`GET_LOCK()` can be used to implement application locks or to simulate record locks. Names are locked on a server-wide basis. If a name has been locked within one session, `GET_LOCK()` blocks any request by another session for a lock with the same name. This enables clients that agree on a given lock name to use the name to perform cooperative advisory locking. But be aware that it also enables a client that is not among the set of cooperating clients to lock a name, either inadvertently or deliberately, and thus prevent any of the cooperating clients from locking that name. One way to reduce the likelihood of this is to use lock names that are database-specific or application-specific. For example, use lock names of the form *db_name.str* or *app_name.str*.

```
mysql> SELECT GET_LOCK('lock1',10);
        -> 1
mysql> SELECT IS_FREE_LOCK('lock2');
        -> 1
mysql> SELECT GET_LOCK('lock2',10);
        -> 1
mysql> SELECT RELEASE_LOCK('lock2');
        -> 1
mysql> SELECT RELEASE_LOCK('lock1');
        -> NULL
```

The second `RELEASE_LOCK()` call returns `NULL` because the lock `'lock1'` was automatically released by the second `GET_LOCK()` call.

If multiple clients are waiting for a lock, the order in which they will acquire it is undefined. Applications should not assume that clients will acquire the lock in the same order that they issued the lock requests.

> **Note**
>
> If a client attempts to acquire a lock that is already held by another client, it blocks according to the *timeout* argument. If the blocked client terminates, its thread does not die until the lock request times out. This is a known bug (fixed in MySQL 5.5).

This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `INET_ATON(expr)`

Given the dotted-quad representation of an IPv4 network address as a string, returns an integer that represents the numeric value of the address in network byte order (big endian). `INET_ATON()` returns `NULL` if it does not understand its argument.

```
mysql> SELECT INET_ATON('10.0.5.9');
        -> 167773449
```

For this example, the return value is calculated as $10 \times 256^3 + 0 \times 256^2 + 5 \times 256 + 9$.

`INET_ATON()` may or may not return a non-`NULL` result for short-form IP addresses (such as `'127.1'` as a representation of `'127.0.0.1'`). Because of this, `INET_ATON()`a should not be used for such addresses.

> **Note**
>
> To store values generated by `INET_ATON()`, use an `INT UNSIGNED` column rather than `INT`, which is signed. If you use a signed column, values

> corresponding to IP addresses for which the first octet is greater than 127 cannot be stored correctly. See Section 11.2.6, "Out-of-Range and Overflow Handling".

- `INET_NTOA(expr)`

  Given a numeric IPv4 network address in network byte order, returns the dotted-quad representation of the address as a binary string. `INET_NTOA()` returns `NULL` if it does not understand its argument.

  ```
  mysql> SELECT INET_NTOA(167773449);
          -> '10.0.5.9'
  ```

- `IS_FREE_LOCK(str)`

  Checks whether the lock named `str` is free to use (that is, not locked). Returns `1` if the lock is free (no one is using the lock), `0` if the lock is in use, and `NULL` if an error occurs (such as an incorrect argument).

  This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `IS_USED_LOCK(str)`

  Checks whether the lock named `str` is in use (that is, locked). If so, it returns the connection identifier of the client session that holds the lock. Otherwise, it returns `NULL`.

  This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `MASTER_POS_WAIT(log_name,log_pos[,timeout])`

  This function is useful for control of master/slave synchronization. It blocks until the slave has read and applied all updates up to the specified position in the master log. The return value is the number of log events the slave had to wait for to advance to the specified position. The function returns `NULL` if the slave SQL thread is not started, the slave's master information is not initialized, the arguments are incorrect, or an error occurs. It returns `-1` if the timeout has been exceeded. If the slave SQL thread stops while `MASTER_POS_WAIT()` is waiting, the function returns `NULL`. If the slave is past the specified position, the function returns immediately.

  If a `timeout` value is specified, `MASTER_POS_WAIT()` stops waiting when `timeout` seconds have elapsed. `timeout` must be greater than 0; a zero or negative `timeout` means no timeout. The lock is exclusive. While held by one session, other sessions cannot obtain a lock of the same name.

  This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `NAME_CONST(name,value)`

  Returns the given value. When used to produce a result set column, `NAME_CONST()` causes the column to have the given name. The arguments should be constants.

  ```
  mysql> SELECT NAME_CONST('myname', 14);
  +--------+
  | myname |
  +--------+
  |     14 |
  +--------+
  ```

This function is for internal use only. The server uses it when writing statements from stored programs that contain references to local program variables, as described in Section 19.7, "Binary Logging of Stored Programs", You might see this function in the output from `mysqlbinlog`.

For your applications, you can obtain exactly the same result as in the example just shown by using simple aliasing, like this:

```
mysql> SELECT 14 AS myname;
+--------+
| myname |
+--------+
|     14 |
+--------+
1 row in set (0.00 sec)
```

See Section 13.2.8, "SELECT Syntax", for more information about column aliases.

- `RELEASE_LOCK(str)`

Releases the lock named by the string `str` that was obtained with `GET_LOCK()`. Returns `1` if the lock was released, `0` if the lock was not established by this thread (in which case the lock is not released), and `NULL` if the named lock did not exist. The lock does not exist if it was never obtained by a call to `GET_LOCK()` or if it has previously been released.

The `DO` statement is convenient to use with `RELEASE_LOCK()`. See Section 13.2.3, "DO Syntax".

This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `SLEEP(duration)`

Sleeps (pauses) for the number of seconds given by the `duration` argument, then returns 0. If `SLEEP()` is interrupted, it returns 1. The duration may have a fractional part.

When sleep returns normally (without interruption), it returns 0:

```
mysql> SELECT SLEEP(1000);
+-------------+
| SLEEP(1000) |
+-------------+
|           0 |
+-------------+
```

When `SLEEP()` is the only thing invoked by a query that is interrupted, it returns 1 and the query itself returns no error. This statement is interrupted using `KILL QUERY` from another session:

```
mysql> SELECT SLEEP(1000);
+-------------+
| SLEEP(1000) |
+-------------+
|           1 |
+-------------+
```

When `SLEEP()` is only part of a query that is interrupted, the query returns an error. This statement is interrupted using `KILL QUERY` from another session:

```
mysql> SELECT 1 FROM t1 WHERE SLEEP(1000);
ERROR 1317 (70100): Query execution was interrupted
```

This function is unsafe for statement-based replication. Beginning with MySQL 5.1.42, a warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `UUID()`

Returns a Universal Unique Identifier (UUID) generated according to RFC 4122, "A Universally Unique IDentifier (UUID) URN Namespace" (http://www.ietf.org/rfc/rfc4122.txt).

A UUID is designed as a number that is globally unique in space and time. Two calls to `UUID()` are expected to generate two different values, even if these calls are performed on two separate devices not connected to each other.

> **Warning**
>
> Although `UUID()` values are intended to be unique, they are not necessarily unguessable or unpredictable. If unpredictability is required, UUID values should be generated some other way.

`UUID()` returns a value that conforms to UUID version 1 as described in RFC 4122. The value is a 128-bit number represented as a `utf8` string of five hexadecimal numbers in `aaaaaaaa-bbbb-cccc-dddd-eeeeeeeeeeee` format:

- The first three numbers are generated from the low, middle, and high parts of a timestamp. The high part also includes the UUID version number.

- The fourth number preserves temporal uniqueness in case the timestamp value loses monotonicity (for example, due to daylight saving time).

- The fifth number is an IEEE 802 node number that provides spatial uniqueness. A random number is substituted if the latter is not available (for example, because the host device has no Ethernet card, or it is unknown how to find the hardware address of an interface on the host operating system). In this case, spatial uniqueness cannot be guaranteed. Nevertheless, a collision should have *very* low probability.

  The MAC address of an interface is taken into account only on FreeBSD and Linux. On other operating systems, MySQL uses a randomly generated 48-bit number.

```
mysql> SELECT UUID();
        -> '6ccd780c-baba-1026-9564-0040f4311e29'
```

> **Note**
>
> `UUID()` does not work with statement-based replication.

- `UUID_SHORT()`

Returns a "short" universal identifier as a 64-bit unsigned integer. Values returned by `UUID_SHORT()` differ from the string-format 128-bit identifiers returned by the `UUID()` function and have different uniqueness properties. The value of `UUID_SHORT()` is guaranteed to be unique if the following conditions hold:

- The `server_id` value of the current server is between 0 and 255 and is unique among your set of master and slave servers

- You do not set back the system time for your server host between `mysqld` restarts

- You invoke `UUID_SHORT()` on average fewer than 16 million times per second between `mysqld` restarts

The `UUID_SHORT()` return value is constructed this way:

```
  (server_id & 255) << 56
+ (server_startup_time_in_seconds << 24)
+ incremented_variable++;
```

```
mysql> SELECT UUID_SHORT();
        -> 92395783831158784
```

Note

> `UUID_SHORT()` does not work with statement-based replication.

This function was added in MySQL 5.1.20.

- `VALUES(col_name)`

In an `INSERT ... ON DUPLICATE KEY UPDATE` statement, you can use the `VALUES(col_name)` function in the `UPDATE` clause to refer to column values from the `INSERT` portion of the statement. In other words, `VALUES(col_name)` in the `UPDATE` clause refers to the value of `col_name` that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The `VALUES()` function is meaningful only in the `ON DUPLICATE KEY UPDATE` clause of `INSERT` statements and returns `NULL` otherwise. See Section 13.2.5.3, "INSERT ... ON DUPLICATE KEY UPDATE Syntax".

```
mysql> INSERT INTO table (a,b,c) VALUES (1,2,3),(4,5,6)
    -> ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
```

12.17 Aggregate (GROUP BY) Functions

12.17.1 Aggregate (GROUP BY) Function Descriptions

Table 12.21 Aggregate (`GROUP BY`) Functions

Name	Description
`AVG()`	Return the average value of the argument
`BIT_AND()`	Return bitwise AND
`BIT_OR()`	Return bitwise OR
`BIT_XOR()`	Return bitwise XOR
`COUNT()`	Return a count of the number of rows returned
`COUNT(DISTINCT)`	Return the count of a number of different values
`GROUP_CONCAT()`	Return a concatenated string
`MAX()`	Return the maximum value
`MIN()`	Return the minimum value
`STD()`	Return the population standard deviation

Name	Description
STDDEV()	Return the population standard deviation
STDDEV_POP()	Return the population standard deviation
STDDEV_SAMP()	Return the sample standard deviation
SUM()	Return the sum
VAR_POP()	Return the population standard variance
VAR_SAMP()	Return the sample variance
VARIANCE()	Return the population standard variance

This section describes group (aggregate) functions that operate on sets of values. Unless otherwise stated, group functions ignore NULL values.

If you use a group function in a statement containing no GROUP BY clause, it is equivalent to grouping on all rows. For more information, see Section 12.17.3, "MySQL Handling of GROUP BY".

For numeric arguments, the variance and standard deviation functions return a DOUBLE value. The SUM() and AVG() functions return a DECIMAL value for exact-value arguments (integer or DECIMAL), and a DOUBLE value for approximate-value arguments (FLOAT or DOUBLE).

The SUM() and AVG() aggregate functions do not work with temporal values. (They convert the values to numbers, losing everything after the first nonnumeric character.) To work around this problem, convert to numeric units, perform the aggregate operation, and convert back to a temporal value. Examples:

```
SELECT SEC_TO_TIME(SUM(TIME_TO_SEC(time_col))) FROM tbl_name;
SELECT FROM_DAYS(SUM(TO_DAYS(date_col))) FROM tbl_name;
```

Functions such as SUM() or AVG() that expect a numeric argument cast the argument to a number if necessary. For SET or ENUM values, the cast operation causes the underlying numeric value to be used.

The BIT_AND(), BIT_OR(), and BIT_XOR() aggregate functions perform bit operations. They require BIGINT (64-bit integer) arguments and return BIGINT values. Arguments of other types are converted to BIGINT and truncation might occur.

- AVG([DISTINCT] expr)

  Returns the average value of expr. The DISTINCT option can be used to return the average of the distinct values of expr.

  AVG() returns NULL if there were no matching rows.

  ```
  mysql> SELECT student_name, AVG(test_score)
      ->        FROM student
      ->        GROUP BY student_name;
  ```

- BIT_AND(expr)

  Returns the bitwise AND of all bits in expr. The calculation is performed with 64-bit (BIGINT) precision.

  BIT_AND() returns 18446744073709551615 if there were no matching rows. (This is the value of an unsigned BIGINT value with all bits set to 1.)

- BIT_OR(expr)

  Returns the bitwise OR of all bits in expr. The calculation is performed with 64-bit (BIGINT) precision.

BIT_OR() returns 0 if there were no matching rows.

- BIT_XOR(*expr*)

Returns the bitwise XOR of all bits in *expr*. The calculation is performed with 64-bit (BIGINT) precision.

BIT_XOR() returns 0 if there were no matching rows.

- COUNT(*expr*)

Returns a count of the number of non-NULL values of *expr* in the rows retrieved by a SELECT statement. The result is a BIGINT value.

COUNT() returns 0 if there were no matching rows.

```
mysql> SELECT student.student_name,COUNT(*)
    ->        FROM student,course
    ->        WHERE student.student_id=course.student_id
    ->        GROUP BY student_name;
```

COUNT(*) is somewhat different in that it returns a count of the number of rows retrieved, whether or not they contain NULL values.

COUNT(*) is optimized to return very quickly if the SELECT retrieves from one table, no other columns are retrieved, and there is no WHERE clause. For example:

```
mysql> SELECT COUNT(*) FROM student;
```

This optimization applies only to MyISAM tables only, because an exact row count is stored for this storage engine and can be accessed very quickly. For transactional storage engines such as InnoDB, storing an exact row count is more problematic because multiple transactions may be occurring, each of which may affect the count.

- COUNT(DISTINCT *expr*,[*expr*...])

Returns a count of the number of rows with different non-NULL *expr* values.

COUNT(DISTINCT) returns 0 if there were no matching rows.

```
mysql> SELECT COUNT(DISTINCT results) FROM student;
```

In MySQL, you can obtain the number of distinct expression combinations that do not contain NULL by giving a list of expressions. In standard SQL, you would have to do a concatenation of all expressions inside COUNT(DISTINCT ...).

- GROUP_CONCAT(*expr*)

This function returns a string result with the concatenated non-NULL values from a group. It returns NULL if there are no non-NULL values. The full syntax is as follows:

```
GROUP_CONCAT([DISTINCT] expr [,expr ...]
             [ORDER BY {unsigned_integer | col_name | expr}
                 [ASC | DESC] [,col_name ...]]
             [SEPARATOR str_val])
```

```
mysql> SELECT student_name,
    ->        GROUP_CONCAT(test_score)
    ->        FROM student
    ->        GROUP BY student_name;
```

Or:

```
mysql> SELECT student_name,
    ->        GROUP_CONCAT(DISTINCT test_score
    ->              ORDER BY test_score DESC SEPARATOR ' ')
    ->        FROM student
    ->        GROUP BY student_name;
```

In MySQL, you can get the concatenated values of expression combinations. To eliminate duplicate values, use the `DISTINCT` clause. To sort values in the result, use the `ORDER BY` clause. To sort in reverse order, add the `DESC` (descending) keyword to the name of the column you are sorting by in the `ORDER BY` clause. The default is ascending order; this may be specified explicitly using the `ASC` keyword. The default separator between values in a group is comma (","). To specify a separator explicitly, use `SEPARATOR` followed by the string literal value that should be inserted between group values. To eliminate the separator altogether, specify `SEPARATOR ''`.

The result is truncated to the maximum length that is given by the `group_concat_max_len` system variable, which has a default value of 1024. The value can be set higher, although the effective maximum length of the return value is constrained by the value of `max_allowed_packet`. The syntax to change the value of `group_concat_max_len` at runtime is as follows, where `val` is an unsigned integer:

```
SET [GLOBAL | SESSION] group_concat_max_len = val;
```

The return value is a nonbinary or binary string, depending on whether the arguments are nonbinary or binary strings. The result type is `TEXT` or `BLOB` unless `group_concat_max_len` is less than or equal to 512, in which case the result type is `VARCHAR` or `VARBINARY`.

See also `CONCAT()` and `CONCAT_WS()`: Section 12.5, "String Functions".

- `MAX([DISTINCT] expr)`

Returns the maximum value of `expr`. `MAX()` may take a string argument; in such cases, it returns the maximum string value. See Section 8.3.1, "How MySQL Uses Indexes". The `DISTINCT` keyword can be used to find the maximum of the distinct values of `expr`, however, this produces the same result as omitting `DISTINCT`.

`MAX()` returns `NULL` if there were no matching rows.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
    ->         FROM student
    ->         GROUP BY student_name;
```

For `MAX()`, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This differs from how `ORDER BY` compares them. This is expected to be rectified in a future MySQL release.

- `MIN([DISTINCT] expr)`

Returns the minimum value of `expr`. `MIN()` may take a string argument; in such cases, it returns the minimum string value. See Section 8.3.1, "How MySQL Uses Indexes". The `DISTINCT` keyword can

be used to find the minimum of the distinct values of `expr`, however, this produces the same result as omitting `DISTINCT`.

`MIN()` returns `NULL` if there were no matching rows.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
    ->        FROM student
    ->        GROUP BY student_name;
```

For `MIN()`, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This differs from how `ORDER BY` compares them. This is expected to be rectified in a future MySQL release.

- `STD(expr)`

  Returns the population standard deviation of `expr`. This is an extension to standard SQL. The standard SQL function `STDDEV_POP()` can be used instead.

  `STD()` returns `NULL` if there were no matching rows.

- `STDDEV(expr)`

  Returns the population standard deviation of `expr`. This function is provided for compatibility with Oracle. The standard SQL function `STDDEV_POP()` can be used instead.

  `STDDEV()` returns `NULL` if there were no matching rows.

- `STDDEV_POP(expr)`

  Returns the population standard deviation of `expr` (the square root of `VAR_POP()`). You can also use `STD()` or `STDDEV()`, which are equivalent but not standard SQL.

  `STDDEV_POP()` returns `NULL` if there were no matching rows.

- `STDDEV_SAMP(expr)`

  Returns the sample standard deviation of `expr` (the square root of `VAR_SAMP()`.

  `STDDEV_SAMP()` returns `NULL` if there were no matching rows.

- `SUM([DISTINCT] expr)`

  Returns the sum of `expr`. If the return set has no rows, `SUM()` returns `NULL`. The `DISTINCT` keyword can be used to sum only the distinct values of `expr`.

  `SUM()` returns `NULL` if there were no matching rows.

- `VAR_POP(expr)`

  Returns the population standard variance of `expr`. It considers rows as the whole population, not as a sample, so it has the number of rows as the denominator. You can also use `VARIANCE()`, which is equivalent but is not standard SQL.

  `VAR_POP()` returns `NULL` if there were no matching rows.

- `VAR_SAMP(expr)`

  Returns the sample variance of `expr`. That is, the denominator is the number of rows minus one.

`VAR_SAMP()` returns `NULL` if there were no matching rows.

- `VARIANCE(expr)`

  Returns the population standard variance of `expr`. This is an extension to standard SQL. The standard SQL function `VAR_POP()` can be used instead.

  `VARIANCE()` returns `NULL` if there were no matching rows.

12.17.2 GROUP BY Modifiers

The `GROUP BY` clause permits a `WITH ROLLUP` modifier that causes extra rows to be added to the summary output. These rows represent higher-level (or super-aggregate) summary operations. `ROLLUP` thus enables you to answer questions at multiple levels of analysis with a single query. It can be used, for example, to provide support for OLAP (Online Analytical Processing) operations.

Suppose that a table named `sales` has `year`, `country`, `product`, and `profit` columns for recording sales profitability:

```
CREATE TABLE sales
(
    year    INT NOT NULL,
    country VARCHAR(20) NOT NULL,
    product VARCHAR(32) NOT NULL,
    profit  INT
);
```

The table's contents can be summarized per year with a simple `GROUP BY` like this:

```
mysql> SELECT year, SUM(profit) FROM sales GROUP BY year;
+------+-------------+
| year | SUM(profit) |
+------+-------------+
| 2000 |        4525 |
| 2001 |        3010 |
+------+-------------+
```

This output shows the total profit for each year, but if you also want to determine the total profit summed over all years, you must add up the individual values yourself or run an additional query.

Or you can use `ROLLUP`, which provides both levels of analysis with a single query. Adding a `WITH ROLLUP` modifier to the `GROUP BY` clause causes the query to produce another row that shows the grand total over all year values:

```
mysql> SELECT year, SUM(profit) FROM sales GROUP BY year WITH ROLLUP;
+------+-------------+
| year | SUM(profit) |
+------+-------------+
| 2000 |        4525 |
| 2001 |        3010 |
| NULL |        7535 |
+------+-------------+
```

The grand total super-aggregate line is identified by the value `NULL` in the `year` column.

`ROLLUP` has a more complex effect when there are multiple `GROUP BY` columns. In this case, each time there is a "break" (change in value) in any but the last grouping column, the query produces an extra super-aggregate summary row.

For example, without `ROLLUP`, a summary on the `sales` table based on `year`, `country`, and `product` might look like this:

```
mysql> SELECT year, country, product, SUM(profit)
    -> FROM sales
    -> GROUP BY year, country, product;
+------+---------+------------+-------------+
| year | country | product    | SUM(profit) |
+------+---------+------------+-------------+
| 2000 | Finland | Computer   |        1500 |
| 2000 | Finland | Phone      |         100 |
| 2000 | India   | Calculator |         150 |
| 2000 | India   | Computer   |        1200 |
| 2000 | USA     | Calculator |          75 |
| 2000 | USA     | Computer   |        1500 |
| 2001 | Finland | Phone      |          10 |
| 2001 | USA     | Calculator |          50 |
| 2001 | USA     | Computer   |        2700 |
| 2001 | USA     | TV         |         250 |
+------+---------+------------+-------------+
```

The output indicates summary values only at the year/country/product level of analysis. When `ROLLUP` is added, the query produces several extra rows:

```
mysql> SELECT year, country, product, SUM(profit)
    -> FROM sales
    -> GROUP BY year, country, product WITH ROLLUP;
+------+---------+------------+-------------+
| year | country | product    | SUM(profit) |
+------+---------+------------+-------------+
| 2000 | Finland | Computer   |        1500 |
| 2000 | Finland | Phone      |         100 |
| 2000 | Finland | NULL       |        1600 |
| 2000 | India   | Calculator |         150 |
| 2000 | India   | Computer   |        1200 |
| 2000 | India   | NULL       |        1350 |
| 2000 | USA     | Calculator |          75 |
| 2000 | USA     | Computer   |        1500 |
| 2000 | USA     | NULL       |        1575 |
| 2000 | NULL    | NULL       |        4525 |
| 2001 | Finland | Phone      |          10 |
| 2001 | Finland | NULL       |          10 |
| 2001 | USA     | Calculator |          50 |
| 2001 | USA     | Computer   |        2700 |
| 2001 | USA     | TV         |         250 |
| 2001 | USA     | NULL       |        3000 |
| 2001 | NULL    | NULL       |        3010 |
| NULL | NULL    | NULL       |        7535 |
+------+---------+------------+-------------+
```

For this query, adding `ROLLUP` causes the output to include summary information at four levels of analysis, not just one. Here is how to interpret the `ROLLUP` output:

- Following each set of product rows for a given year and country, an extra summary row is produced showing the total for all products. These rows have the `product` column set to `NULL`.

- Following each set of rows for a given year, an extra summary row is produced showing the total for all countries and products. These rows have the `country` and `products` columns set to `NULL`.

- Finally, following all other rows, an extra summary row is produced showing the grand total for all years, countries, and products. This row has the `year`, `country`, and `products` columns set to `NULL`.

Other Considerations When using ROLLUP

The following items list some behaviors specific to the MySQL implementation of `ROLLUP`.

When you use `ROLLUP`, you cannot also use an `ORDER BY` clause to sort the results. In other words, `ROLLUP` and `ORDER BY` are mutually exclusive. However, you still have some control over sort order. `GROUP BY` in MySQL sorts results, and you can use explicit `ASC` and `DESC` keywords with columns named in the `GROUP BY` list to specify sort order for individual columns. (The higher-level summary rows added by `ROLLUP` still appear after the rows from which they are calculated, regardless of the sort order.)

`LIMIT` can be used to restrict the number of rows returned to the client. `LIMIT` is applied after `ROLLUP`, so the limit applies against the extra rows added by `ROLLUP`. For example:

```
mysql> SELECT year, country, product, SUM(profit)
    -> FROM sales
    -> GROUP BY year, country, product WITH ROLLUP
    -> LIMIT 5;
+------+---------+------------+-------------+
| year | country | product    | SUM(profit) |
+------+---------+------------+-------------+
| 2000 | Finland | Computer   |        1500 |
| 2000 | Finland | Phone      |         100 |
| 2000 | Finland | NULL       |        1600 |
| 2000 | India   | Calculator |         150 |
| 2000 | India   | Computer   |        1200 |
+------+---------+------------+-------------+
```

Using `LIMIT` with `ROLLUP` may produce results that are more difficult to interpret, because you have less context for understanding the super-aggregate rows.

The `NULL` indicators in each super-aggregate row are produced when the row is sent to the client. The server looks at the columns named in the `GROUP BY` clause following the leftmost one that has changed value. For any column in the result set with a name that is a lexical match to any of those names, its value is set to `NULL`. (If you specify grouping columns by column number, the server identifies which columns to set to `NULL` by number.)

Because the `NULL` values in the super-aggregate rows are placed into the result set at such a late stage in query processing, you cannot test them as `NULL` values within the query itself. For example, you cannot add `HAVING product IS NULL` to the query to eliminate from the output all but the super-aggregate rows.

On the other hand, the `NULL` values do appear as `NULL` on the client side and can be tested as such using any MySQL client programming interface.

MySQL permits a column that does not appear in the `GROUP BY` list to be named in the select list. In this case, the server is free to choose any value from this nonaggregated column in summary rows, and this includes the extra rows added by `WITH ROLLUP`. For example, in the following query, `country` is a nonaggregated column that does not appear in the `GROUP BY` list and values chosen for this column are indeterminate:

```
mysql> SELECT year, country, SUM(profit)
    -> FROM sales GROUP BY year WITH ROLLUP;
+------+---------+-------------+
| year | country | SUM(profit) |
+------+---------+-------------+
| 2000 | India   |        4525 |
| 2001 | USA     |        3010 |
| NULL | USA     |        7535 |
+------+---------+-------------+
```

This behavior occurs if the `ONLY_FULL_GROUP_BY` SQL mode is not enabled. If that mode is enabled, the server rejects the query as illegal because `country` is not listed in the `GROUP BY` clause. For more information about nonaggregated columns and `GROUP BY`, see Section 12.17.3, "MySQL Handling of GROUP BY".

12.17.3 MySQL Handling of GROUP BY

In standard SQL, a query that includes a `GROUP BY` clause cannot refer to nonaggregated columns in the select list that are not named in the `GROUP BY` clause. For example, this query is illegal in standard SQL because the nonaggregated `name` column in the select list does not appear in the `GROUP BY`:

```
SELECT o.custid, c.name, MAX(o.payment)
  FROM orders AS o, customers AS c
  WHERE o.custid = c.custid
  GROUP BY o.custid;
```

For the query to be legal, the `name` column must be omitted from the select list or named in the `GROUP BY` clause.

MySQL extends the standard SQL use of `GROUP BY` so that the select list can refer to nonaggregated columns not named in the `GROUP BY` clause. This means that the preceding query is legal in MySQL. You can use this feature to get better performance by avoiding unnecessary column sorting and grouping. However, this is useful primarily when all values in each nonaggregated column not named in the `GROUP BY` are the same for each group. The server is free to choose any value from each group, so unless they are the same, the values chosen are indeterminate. Furthermore, the selection of values from each group cannot be influenced by adding an `ORDER BY` clause. Result set sorting occurs after values have been chosen, and `ORDER BY` does not affect which values within each group the server chooses.

A similar MySQL extension applies to the `HAVING` clause. In standard SQL, a query cannot refer to nonaggregated columns in the `HAVING` clause that are not named in the `GROUP BY` clause. To simplify calculations, a MySQL extension permits references to such columns. This extension assumes that the nongrouped columns have the same group-wise values. Otherwise, the result is indeterminate.

To disable the MySQL `GROUP BY` extension and enable standard SQL behavior, enable the `ONLY_FULL_GROUP_BY` SQL mode. In this case, columns not named in the `GROUP BY` clause cannot be used in the select list or `HAVING` clause unless enclosed in an aggregate function.

The select list extension also applies to `ORDER BY`. That is, you can refer to nonaggregated columns in the `ORDER BY` clause that do not appear in the `GROUP BY` clause. (However, as mentioned previously, `ORDER BY` does not affect which values are chosen from nonaggregated columns; it only sorts them after they have been chosen.) This extension does not apply if the `ONLY_FULL_GROUP_BY` SQL mode is enabled.

If a query has aggregate functions and no `GROUP BY` clause, it cannot have nonaggregated columns in the select list, `HAVING` condition, or `ORDER BY` list with `ONLY_FULL_GROUP_BY` enabled:

```
mysql> SELECT name, MAX(age) FROM t;
ERROR 1140 (42000): Mixing of GROUP columns (MIN(),MAX(),COUNT(),...)
with no GROUP columns is illegal if there is no GROUP BY clause
```

Without `GROUP BY`, there is a single group and it is indeterminate which `name` value to choose for the group.

Another MySQL extension to standard SQL permits references in the `HAVING` clause to aliased expressions in the select list. Enabling `ONLY_FULL_GROUP_BY` prevents this. For example, the following

query returns `name` values that occur only once in table `orders`; the query is accepted regardless of whether `ONLY_FULL_GROUP_BY` is enabled:

```
SELECT name, COUNT(name) FROM orders
  GROUP BY name
  HAVING COUNT(name) = 1;
```

The following query is accepted only if `ONLY_FULL_GROUP_BY` is disabled.

```
SELECT name, COUNT(name) AS c FROM orders
  GROUP BY name
  HAVING c = 1;
```

If you are trying to follow standard SQL, you cannot use expressions in `GROUP BY` clauses. As a workaround, use an alias for the expression:

```
SELECT id, FLOOR(value/100) AS val
  FROM tbl_name
  GROUP BY id, val;
```

MySQL permits expressions in `GROUP BY` clauses, so the alias is unnecessary:

```
SELECT id, FLOOR(value/100)
  FROM tbl_name
  GROUP BY id, FLOOR(value/100);
```

12.18 Precision Math

MySQL 5.1 provides support for precision math: numeric value handling that results in extremely accurate results and a high degree control over invalid values. Precision math is based on these two features:

- SQL modes that control how strict the server is about accepting or rejecting invalid data.

- The MySQL library for fixed-point arithmetic.

These features have several implications for numeric operations and provide a high degree of compliance with standard SQL:

- **Precise calculations**: For exact-value numbers, calculations do not introduce floating-point errors. Instead, exact precision is used. For example, MySQL treats a number such as `.0001` as an exact value rather than as an approximation, and summing it 10,000 times produces a result of exactly `1`, not a value that is merely "close" to 1.

- **Well-defined rounding behavior**: For exact-value numbers, the result of `ROUND()` depends on its argument, not on environmental factors such as how the underlying C library works.

- **Platform independence**: Operations on exact numeric values are the same across different platforms such as Windows and Unix.

- **Control over handling of invalid values**: Overflow and division by zero are detectable and can be treated as errors. For example, you can treat a value that is too large for a column as an error rather than having the value truncated to lie within the range of the column's data type. Similarly, you can treat division by zero as an error rather than as an operation that produces a result of `NULL`. The choice of which approach to take is determined by the setting of the server SQL mode.

The following discussion covers several aspects of how precision math works, including possible incompatibilities with older applications. At the end, some examples are given that demonstrate how MySQL handles numeric operations precisely. For information about controlling the SQL mode, see Section 5.1.7, "Server SQL Modes".

12.18.1 Types of Numeric Values

The scope of precision math for exact-value operations includes the exact-value data types (integer and `DECIMAL` types) and exact-value numeric literals. Approximate-value data types and numeric literals are handled as floating-point numbers.

Exact-value numeric literals have an integer part or fractional part, or both. They may be signed. Examples: `1`, `.2`, `3.4`, `-5`, `-6.78`, `+9.10`.

Approximate-value numeric literals are represented in scientific notation with a mantissa and exponent. Either or both parts may be signed. Examples: `1.2E3`, `1.2E-3`, `-1.2E3`, `-1.2E-3`.

Two numbers that look similar may be treated differently. For example, `2.34` is an exact-value (fixed-point) number, whereas `2.34E0` is an approximate-value (floating-point) number.

The `DECIMAL` data type is a fixed-point type and calculations are exact. In MySQL, the `DECIMAL` type has several synonyms: `NUMERIC`, `DEC`, `FIXED`. The integer types also are exact-value types.

The `FLOAT` and `DOUBLE` data types are floating-point types and calculations are approximate. In MySQL, types that are synonymous with `FLOAT` or `DOUBLE` are `DOUBLE PRECISION` and `REAL`.

12.18.2 DECIMAL Data Type Characteristics

This section discusses the characteristics of the `DECIMAL` data type (and its synonyms) in MySQL 5.1, with particular regard to the following topics:

- Maximum number of digits

- Storage format

- Storage requirements

- The nonstandard MySQL extension to the upper range of `DECIMAL` columns

Possible incompatibilities with applications that are written for older versions of MySQL (prior to 5.0.3) are noted throughout this section.

The declaration syntax for a `DECIMAL` column is `DECIMAL(M,D)`. The ranges of values for the arguments in MySQL 5.1 are as follows:

- M is the maximum number of digits (the precision). It has a range of 1 to 65. (Older versions of MySQL permitted a range of 1 to 254.)

- D is the number of digits to the right of the decimal point (the scale). It has a range of 0 to 30 and must be no larger than M.

The maximum value of 65 for M means that calculations on `DECIMAL` values are accurate up to 65 digits. This limit of 65 digits of precision also applies to exact-value numeric literals, so the maximum range of such literals differs from before. (In older versions of MySQL, decimal values could have up to 254 digits. However, calculations were done using floating-point and thus were approximate, not exact.)

Values for `DECIMAL` columns in MySQL 5.1 are stored using a binary format that packs nine decimal digits into 4 bytes. The storage requirements for the integer and fractional parts of each value are determined

separately. Each multiple of nine digits requires 4 bytes, and any remaining digits left over require some fraction of 4 bytes. The storage required for remaining digits is given by the following table.

Leftover Digits	Number of Bytes
0	0
1–2	1
3–4	2
5–6	3
7–9	4

For example, a `DECIMAL(18,9)` column has nine digits on either side of the decimal point, so the integer part and the fractional part each require 4 bytes. A `DECIMAL(20,6)` column has fourteen integer digits and six fractional digits. The integer digits require four bytes for nine of the digits and 3 bytes for the remaining five digits. The six fractional digits require 3 bytes.

Unlike some older versions of MySQL, `DECIMAL` columns in MySQL 5.1 do not store a leading + character or – character or leading 0 digits. If you insert `+0003.1` into a `DECIMAL(5,1)` column, it is stored as `3.1`. For negative numbers, a literal – character is not stored. Applications that rely on the older behavior must be modified to account for this change.

`DECIMAL` columns in MySQL 5.1 do not permit values larger than the range implied by the column definition. For example, a `DECIMAL(3,0)` column supports a range of `-999` to `999`. A `DECIMAL(M,D)` column permits at most M - D digits to the left of the decimal point. This is not compatible with applications relying on older versions of MySQL that permitted storing an extra digit in lieu of a + sign.

The SQL standard requires that the precision of `NUMERIC(M,D)` be *exactly* M digits. For `DECIMAL(M,D)`, the standard requires a precision of at least M digits but permits more. In MySQL, `DECIMAL(M,D)` and `NUMERIC(M,D)` are the same, and both have a precision of exactly M digits.

For more detailed information about porting applications that rely on the old treatment of the `DECIMAL` data type, see the *MySQL 5.0 Reference Manual*.

12.18.3 Expression Handling

With precision math, exact-value numbers are used as given whenever possible. For example, numbers in comparisons are used exactly as given without a change in value. In strict SQL mode, for `INSERT` into a column with an exact data type (`DECIMAL` or integer), a number is inserted with its exact value if it is within the column range. When retrieved, the value should be the same as what was inserted. (If strict SQL mode is not enabled, truncation for `INSERT` is permissible.)

Handling of a numeric expression depends on what kind of values the expression contains:

- If any approximate values are present, the expression is approximate and is evaluated using floating-point arithmetic.

- If no approximate values are present, the expression contains only exact values. If any exact value contains a fractional part (a value following the decimal point), the expression is evaluated using `DECIMAL` exact arithmetic and has a precision of 65 digits. The term "exact" is subject to the limits of what can be represented in binary. For example, `1.0/3.0` can be approximated in decimal notation as `.333...`, but not written as an exact number, so `(1.0/3.0)*3.0` does not evaluate to exactly `1.0`.

- Otherwise, the expression contains only integer values. The expression is exact and is evaluated using integer arithmetic and has a precision the same as `BIGINT` (64 bits).

If a numeric expression contains any strings, they are converted to double-precision floating-point values and the expression is approximate.

Inserts into numeric columns are affected by the SQL mode, which is controlled by the `sql_mode` system variable. (See Section 5.1.7, "Server SQL Modes".) The following discussion mentions strict mode (selected by the `STRICT_ALL_TABLES` or `STRICT_TRANS_TABLES` mode values) and `ERROR_FOR_DIVISION_BY_ZERO`. To turn on all restrictions, you can simply use `TRADITIONAL` mode, which includes both strict mode values and `ERROR_FOR_DIVISION_BY_ZERO`:

```
mysql> SET sql_mode='TRADITIONAL';
```

If a number is inserted into an exact type column (`DECIMAL` or integer), it is inserted with its exact value if it is within the column range.

If the value has too many digits in the fractional part, rounding occurs and a warning is generated. Rounding is done as described in Section 12.18.4, "Rounding Behavior".

If the value has too many digits in the integer part, it is too large and is handled as follows:

- If strict mode is not enabled, the value is truncated to the nearest legal value and a warning is generated.

- If strict mode is enabled, an overflow error occurs.

Underflow is not detected, so underflow handling is undefined.

For inserts of strings into numeric columns, conversion from string to number is handled as follows if the string has nonnumeric contents:

- A string that does not begin with a number cannot be used as a number and produces an error in strict mode, or a warning otherwise. This includes the empty string.

- A string that begins with a number can be converted, but the trailing nonnumeric portion is truncated. If the truncated portion contains anything other than spaces, this produces an error in strict mode, or a warning otherwise.

By default, division by zero produces a result of `NULL` and no warning. By setting the SQL mode appropriately, division by zero can be restricted.

With the `ERROR_FOR_DIVISION_BY_ZERO` SQL mode enabled, MySQL handles division by zero differently:

- If strict mode is not enabled, a warning occurs.

- If strict mode is enabled, inserts and updates involving division by zero are prohibited, and an error occurs.

In other words, inserts and updates involving expressions that perform division by zero can be treated as errors, but this requires `ERROR_FOR_DIVISION_BY_ZERO` in addition to strict mode.

Suppose that we have this statement:

```
INSERT INTO t SET i = 1/0;
```

This is what happens for combinations of strict and `ERROR_FOR_DIVISION_BY_ZERO` modes.

`sql_mode` Value	Result
`''` (Default)	No warning, no error; `i` is set to `NULL`.

`sql_mode` Value	Result
strict	No warning, no error; `i` is set to `NULL`.
`ERROR_FOR_DIVISION_BY_ZERO`	Warning, no error; `i` is set to `NULL`.
strict,`ERROR_FOR_DIVISION_BY_ZERO`	Error condition; no row is inserted.

12.18.4 Rounding Behavior

This section discusses precision math rounding for the `ROUND()` function and for inserts into columns with exact-value types (`DECIMAL` and integer).

The `ROUND()` function rounds differently depending on whether its argument is exact or approximate:

- For exact-value numbers, `ROUND()` uses the "round half up" rule: A value with a fractional part of .5 or greater is rounded up to the next integer if positive or down to the next integer if negative. (In other words, it is rounded away from zero.) A value with a fractional part less than .5 is rounded down to the next integer if positive or up to the next integer if negative.

- For approximate-value numbers, the result depends on the C library. On many systems, this means that `ROUND()` uses the "round to nearest even" rule: A value with any fractional part is rounded to the nearest even integer.

The following example shows how rounding differs for exact and approximate values:

```
mysql> SELECT ROUND(2.5), ROUND(25E-1);
+------------+--------------+
| ROUND(2.5) | ROUND(25E-1) |
+------------+--------------+
| 3          |            2 |
+------------+--------------+
```

For inserts into a `DECIMAL` or integer column, the target is an exact data type, so rounding uses "round half away from zero," regardless of whether the value to be inserted is exact or approximate:

```
mysql> CREATE TABLE t (d DECIMAL(10,0));
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t VALUES(2.5),(2.5E0);
Query OK, 2 rows affected, 2 warnings (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 2

mysql> SELECT d FROM t;
+------+
| d    |
+------+
| 3    |
| 3    |
+------+
```

12.18.5 Precision Math Examples

This section provides some examples that show precision math query results in MySQL 5.1. These examples demonstrate the principles described in Section 12.18.3, "Expression Handling", and Section 12.18.4, "Rounding Behavior".

Example 1. Numbers are used with their exact value as given when possible:

```
mysql> SELECT (.1 + .2) = .3;
+-----------------+
| (.1 + .2) = .3 |
+-----------------+
|               1 |
+-----------------+
```

For floating-point values, results are inexact:

```
mysql> SELECT (.1E0 + .2E0) = .3E0;
+----------------------+
| (.1E0 + .2E0) = .3E0 |
+----------------------+
|                    0 |
+----------------------+
```

Another way to see the difference in exact and approximate value handling is to add a small number to a sum many times. Consider the following stored procedure, which adds `.0001` to a variable 1,000 times.

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 0;
  DECLARE d DECIMAL(10,4) DEFAULT 0;
  DECLARE f FLOAT DEFAULT 0;
  WHILE i < 10000 DO
    SET d = d + .0001;
    SET f = f + .0001E0;
    SET i = i + 1;
  END WHILE;
  SELECT d, f;
END;
```

The sum for both `d` and `f` logically should be 1, but that is true only for the decimal calculation. The floating-point calculation introduces small errors:

```
+--------+------------------+
| d      | f                |
+--------+------------------+
| 1.0000 | 0.99999999999991 |
+--------+------------------+
```

Example 2. Multiplication is performed with the scale required by standard SQL. That is, for two numbers *X1* and *X2* that have scale *S1* and *S2*, the scale of the result is *S1 + S2*:

```
mysql> SELECT .01 * .01;
+-----------+
| .01 * .01 |
+-----------+
| 0.0001    |
+-----------+
```

Example 3. Rounding behavior for exact-value numbers is well-defined:

Rounding behavior (for example, with the `ROUND()` function) is independent of the implementation of the underlying C library, which means that results are consistent from platform to platform.

- Rounding for exact-value columns (`DECIMAL` and integer) and exact-valued numbers uses the "round half away from zero" rule. Values with a fractional part of .5 or greater are rounded away from zero to the nearest integer, as shown here:

```
mysql> SELECT ROUND(2.5), ROUND(-2.5);
+------------+-------------+
| ROUND(2.5) | ROUND(-2.5) |
+------------+-------------+
| 3          | -3          |
+------------+-------------+
```

- Rounding for floating-point values uses the C library, which on many systems uses the "round to nearest even" rule. Values with any fractional part on such systems are rounded to the nearest even integer:

```
mysql> SELECT ROUND(2.5E0), ROUND(-2.5E0);
+--------------+---------------+
| ROUND(2.5E0) | ROUND(-2.5E0) |
+--------------+---------------+
|            2 |            -2 |
+--------------+---------------+
```

Example 4. In strict mode, inserting a value that is out of range for a column causes an error, rather than truncation to a legal value.

When MySQL is not running in strict mode, truncation to a legal value occurs:

```
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t SET i = 128;
Query OK, 1 row affected, 1 warning (0.00 sec)

mysql> SELECT i FROM t;
+------+
| i    |
+------+
|  127 |
+------+
1 row in set (0.00 sec)
```

However, an error occurs if strict mode is in effect:

```
mysql> SET sql_mode='STRICT_ALL_TABLES';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t SET i = 128;
ERROR 1264 (22003): Out of range value adjusted for column 'i' at row 1

mysql> SELECT i FROM t;
Empty set (0.00 sec)
```

Example 5: In strict mode and with ERROR_FOR_DIVISION_BY_ZERO set, division by zero causes an error, not a result of NULL.

In nonstrict mode, division by zero has a result of NULL:

```
mysql> SET sql_mode='';
```

```
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t SET i = 1 / 0;
Query OK, 1 row affected (0.00 sec)

mysql> SELECT i FROM t;
+------+
| i    |
+------+
| NULL |
+------+
1 row in set (0.03 sec)
```

However, division by zero is an error if the proper SQL modes are in effect:

```
mysql> SET sql_mode='STRICT_ALL_TABLES,ERROR_FOR_DIVISION_BY_ZERO';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t SET i = 1 / 0;
ERROR 1365 (22012): Division by 0

mysql> SELECT i FROM t;
Empty set (0.01 sec)
```

Example 6. Exact-value literals are evaluated as exact values.

Prior to MySQL 5.0.3, exact-value and approximate-value literals both are evaluated as double-precision floating-point values:

```
mysql> SELECT VERSION();
+------------+
| VERSION()  |
+------------+
| 4.1.18-log |
+------------+
1 row in set (0.01 sec)

mysql> CREATE TABLE t SELECT 2.5 AS a, 25E-1 AS b;
Query OK, 1 row affected (0.07 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> DESCRIBE t;
+-------+-------------+------+-----+---------+-------+
| Field | Type        | Null | Key | Default | Extra |
+-------+-------------+------+-----+---------+-------+
| a     | double(3,1) |      |     | 0.0     |       |
| b     | double      |      |     | 0       |       |
+-------+-------------+------+-----+---------+-------+
2 rows in set (0.04 sec)
```

As of MySQL 5.0.3, the approximate-value literal is evaluated using floating point, but the exact-value literal is handled as DECIMAL:

```
mysql> SELECT VERSION();
+-----------------+
| VERSION()       |
+-----------------+
```

```
| 5.1.6-alpha-log |
+-----------------+
1 row in set (0.11 sec)

mysql> CREATE TABLE t SELECT 2.5 AS a, 25E-1 AS b;
Query OK, 1 row affected (0.01 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> DESCRIBE t;
+-------+----------------------+------+-----+---------+-------+
| Field | Type                 | Null | Key | Default | Extra |
+-------+----------------------+------+-----+---------+-------+
| a     | decimal(2,1) unsigned | NO  |     | 0.0     |       |
| b     | double               | NO   |     | 0       |       |
+-------+----------------------+------+-----+---------+-------+
2 rows in set (0.01 sec)
```

Example 7. If the argument to an aggregate function is an exact numeric type, the result is also an exact numeric type, with a scale at least that of the argument.

Consider these statements:

```
mysql> CREATE TABLE t (i INT, d DECIMAL, f FLOAT);
mysql> INSERT INTO t VALUES(1,1,1);
mysql> CREATE TABLE y SELECT AVG(i), AVG(d), AVG(f) FROM t;
```

Before MySQL 5.0.3, the result is a double no matter the argument type:

```
mysql> DESCRIBE y;
+--------+-------------+------+-----+---------+-------+
| Field  | Type        | Null | Key | Default | Extra |
+--------+-------------+------+-----+---------+-------+
| AVG(i) | double(17,4) | YES |     | NULL    |       |
| AVG(d) | double(17,4) | YES |     | NULL    |       |
| AVG(f) | double      | YES  |     | NULL    |       |
+--------+-------------+------+-----+---------+-------+
```

As of MySQL 5.0.3, the result is a double only for the floating-point argument. For exact type arguments, the result is also an exact type:

```
mysql> DESCRIBE y;
+--------+--------------+------+-----+---------+-------+
| Field  | Type         | Null | Key | Default | Extra |
+--------+--------------+------+-----+---------+-------+
| AVG(i) | decimal(14,4) | YES |     | NULL    |       |
| AVG(d) | decimal(14,4) | YES |     | NULL    |       |
| AVG(f) | double       | YES  |     | NULL    |       |
+--------+--------------+------+-----+---------+-------+
```

The result is a double only for the floating-point argument. For exact type arguments, the result is also an exact type.

Chapter 13 SQL Statement Syntax

Table of Contents

This chapter describes the syntax for the SQL statements supported by MySQL.

13.1 Data Definition Statements

13.1.1 ALTER DATABASE Syntax

```
ALTER {DATABASE | SCHEMA} [db_name]
    alter_specification ...
ALTER {DATABASE | SCHEMA} db_name
    UPGRADE DATA DIRECTORY NAME

alter_specification:
    [DEFAULT] CHARACTER SET [=] charset_name
  | [DEFAULT] COLLATE [=] collation_name
```

ALTER DATABASE enables you to change the overall characteristics of a database. These characteristics are stored in the db.opt file in the database directory. To use ALTER DATABASE, you need the ALTER privilege on the database. ALTER SCHEMA is a synonym for ALTER DATABASE.

The database name can be omitted from the first syntax, in which case the statement applies to the default database.

National Language Characteristics

The `CHARACTER SET` clause changes the default database character set. The `COLLATE` clause changes the default database collation. Section 10.1, "Character Set Support", discusses character set and collation names.

You can see what character sets and collations are available using, respectively, the `SHOW CHARACTER SET` and `SHOW COLLATION` statements. See Section 13.7.5.4, "SHOW CHARACTER SET Syntax", and Section 13.7.5.5, "SHOW COLLATION Syntax", for more information.

If you change the default character set or collation for a database, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults. (In a stored routine, variables with character data types use the database defaults if the character set or collation are not specified explicitly. See Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax".)

Upgrading from Versions Older than MySQL 5.1

The syntax that includes the `UPGRADE DATA DIRECTORY NAME` clause was added in MySQL 5.1.23. It updates the name of the directory associated with the database to use the encoding implemented in MySQL 5.1 for mapping database names to database directory names (see Section 9.2.3, "Mapping of Identifiers to File Names"). This clause is for use under these conditions:

- It is intended when upgrading MySQL to 5.1 or later from older versions.

- It is intended to update a database directory name to the current encoding format if the name contains special characters that need encoding.

- The statement is used by `mysqlcheck` (as invoked by `mysql_upgrade`).

For example, if a database in MySQL 5.0 has the name `a-b-c`, the name contains instances of the `-` (dash) character. In MySQL 5.0, the database directory is also named `a-b-c`, which is not necessarily safe for all file systems. In MySQL 5.1 and later, the same database name is encoded as `a@002db@002dc` to produce a file system-neutral directory name.

When a MySQL installation is upgraded to MySQL 5.1 or later from an older version, the server displays a name such as `a-b-c` (which is in the old format) as `#mysql50#a-b-c`, and you must refer to the name using the `#mysql50#` prefix. Use `UPGRADE DATA DIRECTORY NAME` in this case to explicitly tell the server to re-encode the database directory name to the current encoding format:

```
ALTER DATABASE `#mysql50#a-b-c` UPGRADE DATA DIRECTORY NAME;
```

After executing this statement, you can refer to the database as `a-b-c` without the special `#mysql50#` prefix.

13.1.2 ALTER EVENT Syntax

```
ALTER
    [DEFINER = { user | CURRENT_USER }]
    EVENT event_name
    [ON SCHEDULE schedule]
    [ON COMPLETION [NOT] PRESERVE]
    [RENAME TO new_event_name]
    [ENABLE | DISABLE | DISABLE ON SLAVE]
```

```
    [COMMENT 'comment']
    [DO event_body]
```

The `ALTER EVENT` statement changes one or more of the characteristics of an existing event without the need to drop and recreate it. The syntax for each of the `DEFINER`, `ON SCHEDULE`, `ON COMPLETION`, `COMMENT`, `ENABLE` / `DISABLE`, and `DO` clauses is exactly the same as when used with `CREATE EVENT`. (See Section 13.1.11, "CREATE EVENT Syntax".)

Support for the `DEFINER` clause was added in MySQL 5.1.17.

Beginning with MySQL 5.1.12, this statement requires the `EVENT` privilege. When a user executes a successful `ALTER EVENT` statement, that user becomes the definer for the affected event.

(In MySQL 5.1.11 and earlier, an event could be altered only by its definer, or by a user having the `SUPER` privilege.)

`ALTER EVENT` works only with an existing event:

```
mysql> ALTER EVENT no_such_event
    >       ON SCHEDULE
    >           EVERY '2:3' DAY_HOUR;
ERROR 1517 (HY000): Unknown event 'no_such_event'
```

In each of the following examples, assume that the event named `myevent` is defined as shown here:

```
CREATE EVENT myevent
    ON SCHEDULE
      EVERY 6 HOUR
    COMMENT 'A sample comment.'
    DO
      UPDATE myschema.mytable SET mycol = mycol + 1;
```

The following statement changes the schedule for `myevent` from once every six hours starting immediately to once every twelve hours, starting four hours from the time the statement is run:

```
ALTER EVENT myevent
    ON SCHEDULE
      EVERY 12 HOUR
    STARTS CURRENT_TIMESTAMP + INTERVAL 4 HOUR;
```

It is possible to change multiple characteristics of an event in a single statement. This example changes the SQL statement executed by `myevent` to one that deletes all records from `mytable`; it also changes the schedule for the event such that it executes once, one day after this `ALTER EVENT` statement is run.

```
ALTER EVENT myevent
    ON SCHEDULE
      AT CURRENT_TIMESTAMP + INTERVAL 1 DAY
    DO
      TRUNCATE TABLE myschema.mytable;
```

Specify the options in an `ALTER EVENT` statement only for those characteristics that you want to change; omitted options keep their existing values. This includes any default values for `CREATE EVENT` such as `ENABLE`.

To disable `myevent`, use this `ALTER EVENT` statement:

```
ALTER EVENT myevent
    DISABLE;
```

The `ON SCHEDULE` clause may use expressions involving built-in MySQL functions and user variables to obtain any of the `timestamp` or `interval` values which it contains. You cannot use stored routines or user-defined functions in such expressions, and you cannot use any table references; however, you can use `SELECT FROM DUAL`. This is true for both `ALTER EVENT` and `CREATE EVENT` statements. Beginning with MySQL 5.1.13, references to stored routines, user-defined functions, and tables in such cases are specifically not permitted, and fail with an error (see Bug #22830).

Although an `ALTER EVENT` statement that contains another `ALTER EVENT` statement in its `DO` clause appears to succeed, when the server attempts to execute the resulting scheduled event, the execution fails with an error.

To rename an event, use the `ALTER EVENT` statement's `RENAME TO` clause. This statement renames the event `myevent` to `yourevent`:

```
ALTER EVENT myevent
    RENAME TO yourevent;
```

You can also move an event to a different database using `ALTER EVENT ... RENAME TO ...` and `db_name.event_name` notation, as shown here:

```
ALTER EVENT olddb.myevent
    RENAME TO newdb.myevent;
```

To execute the previous statement, the user executing it must have the `EVENT` privilege on both the `olddb` and `newdb` databases.

> **Note**
>
> There is no `RENAME EVENT` statement.

Beginning with MySQL 5.1.18, a third value may also appear in place of `ENABLE` or `DISABLE`; `DISABLE ON SLAVE` is used on a replication slave to indicate an event which was created on the master and replicated to the slave, but which is not executed on the slave. Normally, `DISABLE ON SLAVE` is set automatically as required; however, there are some circumstances under which you may want or need to change it manually. See Section 16.4.1.12, "Replication of Invoked Features", for more information.

13.1.3 ALTER LOGFILE GROUP Syntax

```
ALTER LOGFILE GROUP logfile_group
    ADD UNDOFILE 'file_name'
    [INITIAL_SIZE [=] size]
    [WAIT]
    ENGINE [=] engine_name
```

This statement adds an `UNDO` file named '`file_name`' to an existing log file group `logfile_group`. An `ALTER LOGFILE GROUP` statement has one and only one `ADD UNDOFILE` clause. No `DROP UNDOFILE` clause is currently supported.

> **Note**
>
> All MySQL Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data

> object of a given type). For example, you cannot have a tablespace and an undo
> log file with the same name, or an undo log file and a data file with the same name.

Prior to MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, path and file names for undo log files could not be longer than 128 characters. (Bug #31769)

The optional `INITIAL_SIZE` parameter sets the `UNDO` file's initial size in bytes; if not specified, the initial size default to `128M` (128 megabytes). You may optionally follow *size* with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (for megabytes) or `G` (for gigabytes).

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is `4G`. (Bug #29186)

Beginning with MySQL Cluster NDB 6.2.18, 6.3.24, and 7.0.4, the minimum permitted value for `INITIAL_SIZE` is `1M`. (Bug #29574)

> **Note**
>
> `WAIT` is parsed but otherwise ignored. This keyword has no effect in MySQL 5.1,
> MySQL Cluster NDB 6.x, or MySQL Cluster NDB 7.x, and is intended for future
> expansion.

The `ENGINE` parameter (required) determines the storage engine which is used by this log file group, with *engine_name* being the name of the storage engine. In MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x, the only accepted values for *engine_name* are "`NDBCLUSTER`" and "`NDB`". The two values are equivalent.

Here is an example, which assumes that the log file group `lg_3` has already been created using `CREATE LOGFILE GROUP` (see Section 13.1.14, "CREATE LOGFILE GROUP Syntax"):

```
ALTER LOGFILE GROUP lg_3
    ADD UNDOFILE 'undo_10.dat'
    INITIAL_SIZE=32M
    ENGINE=NDBCLUSTER;
```

When `ALTER LOGFILE GROUP` is used with `ENGINE = NDBCLUSTER` (alternatively, `ENGINE = NDB`), an `UNDO` log file is created on each MySQL Cluster data node. You can verify that the `UNDO` files were created and obtain information about them by querying the `INFORMATION_SCHEMA.FILES` table. For example:

```
mysql> SELECT FILE_NAME, LOGFILE_GROUP_NUMBER, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE LOGFILE_GROUP_NAME = 'lg_3';
+-------------+----------------------+---------------+
| FILE_NAME   | LOGFILE_GROUP_NUMBER | EXTRA         |
+-------------+----------------------+---------------+
| newdata.dat |                    0 | CLUSTER_NODE=3 |
| newdata.dat |                    0 | CLUSTER_NODE=4 |
| undo_10.dat |                   11 | CLUSTER_NODE=3 |
| undo_10.dat |                   11 | CLUSTER_NODE=4 |
+-------------+----------------------+---------------+
4 rows in set (0.01 sec)
```

(See Section 20.26.1, "The INFORMATION_SCHEMA FILES Table".)

Memory used for `UNDO_BUFFER_SIZE` comes from the global pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter. This includes any default value implied for this option by the setting of the `InitialLogFileGroup` data node configuration parameter.

ALTER LOGFILE GROUP was added in MySQL 5.1.6. It is useful only with Disk Data storage for MySQL Cluster. For more information, see Section 17.5.12, "MySQL Cluster Disk Data Tables".

13.1.4 ALTER FUNCTION Syntax

```
ALTER FUNCTION func_name [characteristic ...]

characteristic:
    COMMENT 'string'
  | LANGUAGE SQL
  | { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  | SQL SECURITY { DEFINER | INVOKER }
```

This statement can be used to change the characteristics of a stored function. More than one change may be specified in an ALTER FUNCTION statement. However, you cannot change the parameters or body of a stored function using this statement; to make such changes, you must drop and re-create the function using DROP FUNCTION and CREATE FUNCTION.

You must have the ALTER ROUTINE privilege for the function. (That privilege is granted automatically to the function creator.) If binary logging is enabled, the ALTER FUNCTION statement might also require the SUPER privilege, as described in Section 19.7, "Binary Logging of Stored Programs".

13.1.5 ALTER PROCEDURE Syntax

```
ALTER PROCEDURE proc_name [characteristic ...]

characteristic:
    COMMENT 'string'
  | LANGUAGE SQL
  | { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  | SQL SECURITY { DEFINER | INVOKER }
```

This statement can be used to change the characteristics of a stored procedure. More than one change may be specified in an ALTER PROCEDURE statement. However, you cannot change the parameters or body of a stored procedure using this statement; to make such changes, you must drop and re-create the procedure using DROP PROCEDURE and CREATE PROCEDURE.

You must have the ALTER ROUTINE privilege for the procedure. By default, that privilege is granted automatically to the procedure creator. This behavior can be changed by disabling the automatic_sp_privileges system variable. See Section 19.2.2, "Stored Routines and MySQL Privileges".

13.1.6 ALTER SERVER Syntax

```
ALTER SERVER  server_name
    OPTIONS (option [, option] ...)
```

Alters the server information for server_name, adjusting any of the options permitted in the CREATE SERVER statement. The corresponding fields in the mysql.servers table are updated accordingly. This statement requires the SUPER privilege.

For example, to update the USER option:

```
ALTER SERVER s OPTIONS (USER 'sally');
```

ALTER SERVER does not cause an automatic commit.

In MySQL 5.1, `ALTER SERVER` is written to the binary log only when using row-based logging. It is not logged when `binlog_format` is equal to `STATEMENT` or `MIXED`.

`ALTER SERVER` was added in MySQL 5.1.15.

13.1.7 ALTER TABLE Syntax

```
ALTER [ONLINE | OFFLINE] [IGNORE] TABLE tbl_name
    [alter_specification [, alter_specification] ...]
    [partition_options]

alter_specification:
    table_options
  | ADD [COLUMN] col_name column_definition
        [FIRST | AFTER col_name ]
  | ADD [COLUMN] (col_name column_definition,...)
  | ADD {INDEX|KEY} [index_name]
        [index_type] (index_col_name,...) [index_option] ...
  | ADD [CONSTRAINT [symbol]] PRIMARY KEY
        [index_type] (index_col_name,...) [index_option] ...
  | ADD [CONSTRAINT [symbol]]
        UNIQUE [INDEX|KEY] [index_name]
        [index_type] (index_col_name,...) [index_option] ...
  | ADD FULLTEXT [INDEX|KEY] [index_name]
        (index_col_name,...) [index_option] ...
  | ADD SPATIAL [INDEX|KEY] [index_name]
        (index_col_name,...) [index_option] ...
  | ADD [CONSTRAINT [symbol]]
        FOREIGN KEY [index_name] (index_col_name,...)
        reference_definition
  | ALTER [COLUMN] col_name {SET DEFAULT literal | DROP DEFAULT}
  | CHANGE [COLUMN] old_col_name new_col_name column_definition
        [FIRST|AFTER col_name]
  | MODIFY [COLUMN] col_name column_definition
        [FIRST | AFTER col_name]
  | DROP [COLUMN] col_name
  | DROP PRIMARY KEY
  | DROP {INDEX|KEY} index_name
  | DROP FOREIGN KEY fk_symbol
  | DISABLE KEYS
  | ENABLE KEYS
  | RENAME [TO|AS] new_tbl_name
  | ORDER BY col_name [, col_name] ...
  | CONVERT TO CHARACTER SET charset_name [COLLATE collation_name]
  | [DEFAULT] CHARACTER SET [=] charset_name [COLLATE [=] collation_name]
  | DISCARD TABLESPACE
  | IMPORT TABLESPACE
  | ADD PARTITION (partition_definition)
  | DROP PARTITION partition_names
  | COALESCE PARTITION number
  | REORGANIZE PARTITION [partition_names INTO (partition_definitions)]
  | ANALYZE PARTITION {partition_names | ALL}
  | CHECK PARTITION {partition_names | ALL}
  | OPTIMIZE PARTITION {partition_names | ALL}
  | REBUILD PARTITION {partition_names | ALL}
  | REPAIR PARTITION {partition_names | ALL}
  | PARTITION BY partitioning_expression
  | REMOVE PARTITIONING

index_col_name:
    col_name [(length)] [ASC | DESC]

index_type:
    USING {BTREE | HASH}
```

```
index_option:
    KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name

table_options:
    table_option [[,] table_option] ...  (see CREATE TABLE options)

partition_options:
    (see CREATE TABLE options)
```

`ALTER TABLE` changes the structure of a table. For example, you can add or delete columns, create or destroy indexes, change the type of existing columns, or rename columns or the table itself. You can also change characteristics such as the storage engine used for the table or the table comment.

Following the table name, specify the alterations to be made. If none are given, `ALTER TABLE` does nothing.

The syntax for many of the permissible alterations is similar to clauses of the `CREATE TABLE` statement. See Section 13.1.17, "CREATE TABLE Syntax", for more information.

`table_options` signifies table options of the kind that can be used in the `CREATE TABLE` statement, such as `ENGINE`, `AUTO_INCREMENT`, `AVG_ROW_LENGTH`, `MAX_ROWS`, or `ROW_FORMAT`. For a list of all table options and a description of each, see Section 13.1.17, "CREATE TABLE Syntax". However, `ALTER TABLE` ignores the `DATA DIRECTORY` and `INDEX DIRECTORY` table options.

`partition_options` signifies options that can be used with partitioned tables. A number of partitioning-related extensions to `ALTER TABLE` were added in MySQL 5.1.5. These can be used with partitioned tables for repartitioning, for adding, dropping, merging, and splitting partitions, and for performing partitioning maintenance. It is possible for an `ALTER TABLE` statement to contain a `PARTITION BY` or `REMOVE PARTITIONING` clause in an addition to other alter specifications, but the `PARTITION BY` or `REMOVE PARTITIONING` clause must be specified last after any other specifications. The `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REORGANIZE PARTITION`, `ANALYZE PARTITION`, `CHECK PARTITION`, and `REPAIR PARTITION` options cannot be combined with other alter specifications in a single `ALTER TABLE`, since the options just listed act on individual partitions. For a list of partition options and a description of each, see Section 13.1.17, "CREATE TABLE Syntax". For additional information, see Section 13.1.7.1, "ALTER TABLE Partition Operations".

Some operations may result in warnings if attempted on a table for which the storage engine does not support the operation. These warnings can be displayed with `SHOW WARNINGS`. See Section 13.7.5.42, "SHOW WARNINGS Syntax".

For information on troubleshooting `ALTER TABLE`, see Section B.5.6.1, "Problems with ALTER TABLE".

Storage, Performance, and Concurrency Considerations

In most cases, `ALTER TABLE` makes a temporary copy of the original table. MySQL waits for other operations that are modifying the table, then proceeds. It incorporates the alteration into the copy, deletes the original table, and renames the new one. While `ALTER TABLE` is executing, the original table is readable by other sessions. Updates and writes to the table that begin after the `ALTER TABLE` operation begins are stalled until the new table is ready, then are automatically redirected to the new table without any failed updates. The temporary copy of the original table is created in the database directory of the new table. This can differ from the database directory of the original table for `ALTER TABLE` operations that rename the table to a different database.

For `MyISAM` tables, you can speed up index re-creation (the slowest part of the alteration process) by setting the `myisam_sort_buffer_size` system variable to a high value.

For some operations, an in-place `ALTER TABLE` is possible that does not require a temporary table:

- For `ALTER TABLE` *tbl_name* `RENAME TO` *new_tbl_name* without any other options, MySQL simply renames any files that correspond to the table *tbl_name* without making a copy. (You can also use the `RENAME TABLE` statement to rename tables. See Section 13.1.33, "RENAME TABLE Syntax".) Any privileges granted specifically for the renamed table are not migrated to the new name. They must be changed manually.

- Alterations that modify only table metadata and not table data are immediate because the server only needs to alter the table `.frm` file, not touch table contents. The following changes are fast alterations that can be made this way:

  - Renaming a column, except for the `InnoDB` storage engine.

  - Changing the default value of a column (except for `NDB` tables; see Limitations of `NDBCLUSTER` online operations).

  - Changing the definition of an `ENUM` or `SET` column by adding new enumeration or set members to the *end* of the list of valid member values, as long as the storage size of the data type does not change. For example, adding a member to a `SET` column that has 8 members changes the required storage per value from 1 byte to 2 bytes; this will require a table copy. Adding members in the middle of the list causes renumbering of existing members, which requires a table copy.

- `ALTER TABLE` with `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REBUILD PARTITION`, or `REORGANIZE PARTITION` does not create any temporary tables (except when used with `NDB` tables); however, these operations can and do create temporary partition files.

  `ADD` or `DROP` operations for `RANGE` or `LIST` partitions are immediate operations or nearly so. `ADD` or `COALESCE` operations for `HASH` or `KEY` partitions copy data between all partitions, unless `LINEAR HASH` or `LINEAR KEY` was used; this is effectively the same as creating a new table, although the `ADD` or `COALESCE` operation is performed partition by partition. `REORGANIZE` operations copy only changed partitions and do not touch unchanged ones.

- Renaming an index, except for `InnoDB`.

- Adding or dropping an index, for `InnoDB` (if `InnoDB Plugin` is used) and `NDB`.

You can force an `ALTER TABLE` operation that would otherwise not require a table copy to use the temporary table method (as supported in MySQL 5.0) by setting the `old_alter_table` system variable to `ON`.

For `NDBCLUSTER` tables, operations that add and drop indexes on variable-width columns occur online, without any table copying and without blocking concurrent DML actions for most of their duration. See Section 13.1.7.2, "ALTER TABLE Online Operations in MySQL Cluster".

Usage Notes

- To use `ALTER TABLE`, you need `ALTER`, `CREATE`, and `INSERT` privileges for the table. Renaming a table requires `ALTER` and `DROP` on the old table, `ALTER`, `CREATE`, and `INSERT` on the new table.

- `IGNORE` is a MySQL extension to standard SQL. It controls how `ALTER TABLE` works if there are duplicates on unique keys in the new table or if warnings occur when strict mode is enabled. If `IGNORE` is not specified, the copy is aborted and rolled back if duplicate-key errors occur. If `IGNORE` is specified, only one row is used of rows with duplicates on a unique key. The other conflicting rows are deleted. Incorrect values are truncated to the closest matching acceptable value.

- Pending `INSERT DELAYED` statements are lost if a table is write locked and `ALTER TABLE` is used to modify the table structure.

- *table_options* signifies table options of the kind that can be used in the CREATE TABLE statement, such as ENGINE, AUTO_INCREMENT, AVG_ROW_LENGTH, MAX_ROWS, or ROW_FORMAT. For a list of all table options and a description of each, see Section 13.1.17, "CREATE TABLE Syntax". However, ALTER TABLE ignores the DATA DIRECTORY and INDEX DIRECTORY table options.

  For example, to convert a table to be an InnoDB table, use this statement:

  ```
  ALTER TABLE t1 ENGINE = InnoDB;
  ```

  See Section 14.6.6.4, "Converting Tables from MyISAM to InnoDB" for considerations when switching tables to the InnoDB storage engine.

  When you specify an ENGINE clause, ALTER TABLE rebuilds the table. This is true even if the table already has the specified storage engine.

  The outcome of attempting to change a table's storage engine is affected by whether the desired storage engine is available and the setting of the NO_ENGINE_SUBSTITUTION SQL mode, as described in Section 5.1.7, "Server SQL Modes".

  As of MySQL 5.1.11, to prevent inadvertent loss of data, ALTER TABLE cannot be used to change the storage engine of a table to MERGE or BLACKHOLE.

  To change the value of the AUTO_INCREMENT counter to be used for new rows, do this:

  ```
  ALTER TABLE t2 AUTO_INCREMENT = value;
  ```

  You cannot reset the counter to a value less than or equal to any that have already been used. For MyISAM, if the value is less than or equal to the maximum value currently in the AUTO_INCREMENT column, the value is reset to the current maximum plus one. For InnoDB, *if the value is less than the current maximum value in the column, no error occurs and the current sequence value is not changed.*

- You can issue multiple ADD, ALTER, DROP, and CHANGE clauses in a single ALTER TABLE statement, separated by commas. This is a MySQL extension to standard SQL, which permits only one of each clause per ALTER TABLE statement. For example, to drop multiple columns in a single statement, do this:

  ```
  ALTER TABLE t2 DROP COLUMN c, DROP COLUMN d;
  ```

- CHANGE *col_name*, DROP *col_name*, and DROP INDEX are MySQL extensions to standard SQL.

- The word COLUMN is optional and can be omitted.

- *column_definition* clauses use the same syntax for ADD and CHANGE as for CREATE TABLE. See Section 13.1.17, "CREATE TABLE Syntax".

- You can rename a column using a CHANGE *old_col_name new_col_name column_definition* clause. To do so, specify the old and new column names and the definition that the column currently has. For example, to rename an INTEGER column from a to b, you can do this:

  ```
  ALTER TABLE t1 CHANGE a b INTEGER;
  ```

  To change a column's type but not the name, CHANGE syntax still requires an old and new column name, even if they are the same. For example:

```
ALTER TABLE t1 CHANGE b b BIGINT NOT NULL;
```

You can also use `MODIFY` to change a column's type without renaming it:

```
ALTER TABLE t1 MODIFY b BIGINT NOT NULL;
```

`MODIFY` is an extension to `ALTER TABLE` for Oracle compatibility.

When you use `CHANGE` or `MODIFY`, *column_definition* must include the data type and all attributes that should apply to the new column, other than index attributes such as `PRIMARY KEY` or `UNIQUE`. Attributes present in the original definition but not specified for the new definition are not carried forward. Suppose that a column `col1` is defined as `INT UNSIGNED DEFAULT 1 COMMENT 'my column'` and you modify the column as follows:

```
ALTER TABLE t1 MODIFY col1 BIGINT;
```

The resulting column will be defined as `BIGINT`, but will not include the attributes `UNSIGNED DEFAULT 1 COMMENT 'my column'`. To retain them, the statement should be:

```
ALTER TABLE t1 MODIFY col1 BIGINT UNSIGNED DEFAULT 1 COMMENT 'my column';
```

- When you change a data type using `CHANGE` or `MODIFY`, MySQL tries to convert existing column values to the new type as well as possible.

  Warning

  This conversion may result in alteration of data. For example, if you shorten a string column, values may be truncated. To prevent the operation from succeeding if conversions to the new data type would result in loss of data, enable strict SQL mode before using `ALTER TABLE` (see Section 5.1.7, "Server SQL Modes").

- To add a column at a specific position within a table row, use `FIRST` or `AFTER` *col_name*. The default is to add the column last. You can also use `FIRST` and `AFTER` in `CHANGE` or `MODIFY` operations to reorder columns within a table.

- `ALTER ... SET DEFAULT` or `ALTER ... DROP DEFAULT` specify a new default value for a column or remove the old default value, respectively. If the old default is removed and the column can be `NULL`, the new default is `NULL`. If the column cannot be `NULL`, MySQL assigns a default value as described in Section 11.6, "Data Type Default Values".

- `DROP INDEX` removes an index. This is a MySQL extension to standard SQL. See Section 13.1.24, "DROP INDEX Syntax". If you are unsure of the index name, use `SHOW INDEX FROM` *tbl_name*.

- If columns are dropped from a table, the columns are also removed from any index of which they are a part. If all columns that make up an index are dropped, the index is dropped as well. If you use `CHANGE` or `MODIFY` to shorten a column for which an index exists on the column, and the resulting column length is less than the index length, MySQL shortens the index automatically.

- If a table contains only one column, the column cannot be dropped. If what you intend is to remove the table, use `DROP TABLE` instead.

- `DROP PRIMARY KEY` drops the primary key. If there is no primary key, an error occurs. For information about the performance characteristics of primary keys, especially for `InnoDB` tables, see Section 8.3.2, "Using Primary Keys".

If you add a `UNIQUE INDEX` or `PRIMARY KEY` to a table, MySQL stores it before any nonunique index to permit detection of duplicate keys as early as possible.

- Some storage engines permit you to specify an index type when creating an index. The syntax for the `index_type` specifier is `USING type_name`. For details about `USING`, see Section 13.1.13, "CREATE INDEX Syntax". Before MySQL 5.1.10, `USING` can be given only before the index column list. As of 5.1.10, the preferred position is after the column list. Support for use of the option before the column list will be removed in a future MySQL release.

  `index_option` values specify additional options for an index. `USING` is one such option. For details about permissible `index_option` values, see Section 13.1.13, "CREATE INDEX Syntax".

- After an `ALTER TABLE` statement, it may be necessary to run `ANALYZE TABLE` to update index cardinality information. See Section 13.7.5.23, "SHOW INDEX Syntax".

- `ORDER BY` enables you to create the new table with the rows in a specific order. This option is useful primarily when you know that you are mostly to query the rows in a certain order most of the time. By using this option after major changes to the table, you might be able to get higher performance. In some cases, it might make sorting easier for MySQL if the table is in order by the column that you want to order it by later.

  Note

  The table does not remain in the specified order after inserts and deletes.

  `ORDER BY` syntax permits one or more column names to be specified for sorting, each of which optionally can be followed by `ASC` or `DESC` to indicate ascending or descending sort order, respectively. The default is ascending order. Only column names are permitted as sort criteria; arbitrary expressions are not permitted. This clause should be given last after any other clauses.

  `ORDER BY` does not make sense for `InnoDB` tables because `InnoDB` always orders table rows according to the clustered index.

  Note

  When used on a partitioned table, `ALTER TABLE ... ORDER BY` orders rows within each partition only.

- If you use `ALTER TABLE` on a `MyISAM` table, all nonunique indexes are created in a separate batch (as for `REPAIR TABLE`). This should make `ALTER TABLE` much faster when you have many indexes.

  For `MyISAM` tables, key updating can be controlled explicitly. Use `ALTER TABLE ... DISABLE KEYS` to tell MySQL to stop updating nonunique indexes. Then use `ALTER TABLE ... ENABLE KEYS` to re-create missing indexes. `MyISAM` does this with a special algorithm that is much faster than inserting keys one by one, so disabling keys before performing bulk insert operations should give a considerable speedup. Using `ALTER TABLE ... DISABLE KEYS` requires the `INDEX` privilege in addition to the privileges mentioned earlier.

  While the nonunique indexes are disabled, they are ignored for statements such as `SELECT` and `EXPLAIN` that otherwise would use them.

  `ENABLE KEYS` and `DISABLE KEYS` were not supported for partitioned tables prior to MySQL 5.1.11.

- If `ALTER TABLE` for an `InnoDB` table results in changes to column values (for example, because a column is truncated), `InnoDB`'s `FOREIGN KEY` constraint checks do not notice possible violations caused by changing the values.

- The `FOREIGN KEY` and `REFERENCES` clauses are supported by the `InnoDB` storage engine, which implements `ADD [CONSTRAINT [symbol]] FOREIGN KEY [index_name] (...)` `REFERENCES ... (...)`. See Section 14.6.6, "InnoDB and FOREIGN KEY Constraints". For other storage engines, the clauses are parsed but ignored. The `CHECK` clause is parsed but ignored by all storage engines. See Section 13.1.17, "CREATE TABLE Syntax". The reason for accepting but ignoring syntax clauses is for compatibility, to make it easier to port code from other SQL servers, and to run applications that create tables with references. See Section 1.8.2, "MySQL Differences from Standard SQL".

  For `ALTER TABLE`, unlike `CREATE TABLE`, `ADD FOREIGN KEY` ignores *index_name* if given and uses an automatically generated foreign key name. As a workaround, include the `CONSTRAINT` clause to specify the foreign key name:

  ```
  ADD CONSTRAINT name FOREIGN KEY (....) ...
  ```

  > ⚠️ **Important**
  >
  > The inline `REFERENCES` specifications where the references are defined as part of the column specification are silently ignored by `InnoDB`. InnoDB only accepts `REFERENCES` clauses defined as part of a separate `FOREIGN KEY` specification.

  > 📝 **Note**
  >
  > Partitioned `InnoDB` tables do not support foreign keys. See Section 18.5.2, "Partitioning Limitations Relating to Storage Engines", for more information.

- `InnoDB` supports the use of `ALTER TABLE` to drop foreign keys:

  ```
  ALTER TABLE tbl_name DROP FOREIGN KEY fk_symbol;
  ```

  For more information, see Section 14.6.6, "InnoDB and FOREIGN KEY Constraints".

- Adding and dropping a foreign key in separate clauses of a single `ALTER TABLE` statement may be problematic in some cases and is therefore unsupported. Use separate statements for each operation.

- For an `InnoDB` table that is created with its own tablespace in an `.ibd` file, that file can be discarded and imported. To discard the `.ibd` file, use this statement:

  ```
  ALTER TABLE tbl_name DISCARD TABLESPACE;
  ```

  This deletes the current `.ibd` file, so be sure that you have a backup first. Attempting to access the table while the tablespace file is discarded results in an error.

  To import the backup `.ibd` file back into the table, copy it into the database directory, and then issue this statement:

  ```
  ALTER TABLE tbl_name IMPORT TABLESPACE;
  ```

  The tablespace file must have been created on the server into which it is imported later.

Note

The `ALTER TABLE ... IMPORT TABLESPACE` feature does not enforce foreign key constraints on imported data.

See Section 14.6.5.4, "InnoDB File-Per-Table Tablespaces".

- To change the table default character set and all character columns (`CHAR`, `VARCHAR`, `TEXT`) to a new character set, use a statement like this:

```
ALTER TABLE tbl_name
CONVERT TO CHARACTER SET charset_name [COLLATE collation_name];
```

The statement also changes the collation of all character columns. If you specify no `COLLATE` clause to indicate which collation to use, the statement uses default collation for the character set. If this collation is inappropriate for the intended table use (for example, if it would change from a case-sensitive collation to a case-insensitive collation), specify a collation explicitly.

For a column that has a data type of `VARCHAR` or one of the `TEXT` types, `CONVERT TO CHARACTER SET` will change the data type as necessary to ensure that the new column is long enough to store as many characters as the original column. For example, a `TEXT` column has two length bytes, which store the byte-length of values in the column, up to a maximum of 65,535. For a `latin1 TEXT` column, each character requires a single byte, so the column can store up to 65,535 characters. If the column is converted to `utf8`, each character might require up to three bytes, for a maximum possible length of 3 × 65,535 = 196,605 bytes. That length will not fit in a `TEXT` column's length bytes, so MySQL will convert the data type to `MEDIUMTEXT`, which is the smallest string type for which the length bytes can record a value of 196,605. Similarly, a `VARCHAR` column might be converted to `MEDIUMTEXT`.

To avoid data type changes of the type just described, do not use `CONVERT TO CHARACTER SET`. Instead, use `MODIFY` to change individual columns. For example:

```
ALTER TABLE t MODIFY latin1_text_col TEXT CHARACTER SET utf8;
ALTER TABLE t MODIFY latin1_varchar_col VARCHAR(M) CHARACTER SET utf8;
```

If you specify `CONVERT TO CHARACTER SET binary`, the `CHAR`, `VARCHAR`, and `TEXT` columns are converted to their corresponding binary string types (`BINARY`, `VARBINARY`, `BLOB`). This means that the columns no longer will have a character set and a subsequent `CONVERT TO` operation will not apply to them.

If `charset_name` is `DEFAULT`, the database character set is used.

Warning

The `CONVERT TO` operation converts column values between the character sets. This is *not* what you want if you have a column in one character set (like `latin1`) but the stored values actually use some other, incompatible character set (like `utf8`). In this case, you have to do the following for each such column:

```
ALTER TABLE t1 CHANGE c1 c1 BLOB;
ALTER TABLE t1 CHANGE c1 c1 TEXT CHARACTER SET utf8;
```

The reason this works is that there is no conversion when you convert to or from `BLOB` columns.

To change only the *default* character set for a table, use this statement:

```
ALTER TABLE tbl_name DEFAULT CHARACTER SET charset_name;
```

The word `DEFAULT` is optional. The default character set is the character set that is used if you do not specify the character set for columns that you add to a table later (for example, with `ALTER TABLE ... ADD column`).

When `foreign_key_checks` is enabled, which is the default setting, character set conversion is not permitted on tables that include a character string column used in a foreign key constraint. The workaround is to disable `foreign_key_checks` before performing the character set conversion. You must perform the conversion on both tables involved in the foreign key constraint before re-enabling `foreign_key_checks`. If you re-enable `foreign_key_checks` after converting only one of the tables, an `ON DELETE CASCADE` or `ON UPDATE CASCADE` operation could corrupt data in the referencing table due to implicit conversion that occurs during these operations (Bug #45290, Bug #74816).

With the `mysql_info()` C API function, you can find out how many rows were copied by `ALTER TABLE`, and (when `IGNORE` is used) how many rows were deleted due to duplication of unique key values. See Section 21.8.7.35, "mysql_info()".

13.1.7.1 ALTER TABLE Partition Operations

A number of partitioning-related extensions to `ALTER TABLE` were added in MySQL 5.1.5. These can be used with partitioned tables for repartitioning, for adding, dropping, merging, and splitting partitions, and for performing partitioning maintenance.

It is possible for an `ALTER TABLE` statement to contain a `PARTITION BY` or `REMOVE PARTITIONING` clause in an addition to other alter specifications, but the `PARTITION BY` or `REMOVE PARTITIONING` clause must be specified last after any other specifications. The `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REORGANIZE PARTITION`, `ANALYZE PARTITION`, `CHECK PARTITION`, and `REPAIR PARTITION` options cannot be combined with other alter specifications in a single `ALTER TABLE`, since the options just listed act on individual partitions.

- Simply using a *partition_options* clause with `ALTER TABLE` on a partitioned table repartitions the table according to the partitioning scheme defined by the *partition_options*. This clause always begins with `PARTITION BY`, and follows the same syntax and other rules as apply to the *partition_options* clause for `CREATE TABLE` (see Section 13.1.17, "CREATE TABLE Syntax", for more detailed information), and can also be used to partition an existing table that is not already partitioned. For example, consider a (nonpartitioned) table defined as shown here:

```
CREATE TABLE t1 (
    id INT,
    year_col INT
);
```

This table can be partitioned by `HASH`, using the `id` column as the partitioning key, into 8 partitions by means of this statement:

```
ALTER TABLE t1
    PARTITION BY HASH(id)
    PARTITIONS 8;
```

The table that results from using an `ALTER TABLE ... PARTITION BY` statement must follow the same rules as one created using `CREATE TABLE ... PARTITION BY`. This includes the rules governing the relationship between any unique keys (including any primary key) that the table might have, and the column or columns used in the partitioning expression, as discussed in Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys". The `CREATE TABLE ... PARTITION BY` rules for specifying the number of partitions also apply to `ALTER TABLE ... PARTITION BY`.

`ALTER TABLE ... PARTITION BY` became available in MySQL 5.1.6.

The *partition_definition* clause for `ALTER TABLE ADD PARTITION` supports the same options as the clause of the same name for the `CREATE TABLE` statement. (See Section 13.1.17, "CREATE TABLE Syntax", for the syntax and description.) Suppose that you have the partitioned table created as shown here:

```
CREATE TABLE t1 (
    id INT,
    year_col INT
)
PARTITION BY RANGE (year_col) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1995),
    PARTITION p2 VALUES LESS THAN (1999)
);
```

You can add a new partition `p3` to this table for storing values less than `2002` as follows:

```
ALTER TABLE t1 ADD PARTITION (PARTITION p3 VALUES LESS THAN (2002));
```

`DROP PARTITION` can be used to drop one or more `RANGE` or `LIST` partitions. This statement cannot be used with `HASH` or `KEY` partitions; instead, use `COALESCE PARTITION` (see below). Any data that was stored in the dropped partitions named in the *partition_names* list is discarded. For example, given the table `t1` defined previously, you can drop the partitions named `p0` and `p1` as shown here:

```
ALTER TABLE t1 DROP PARTITION p0, p1;
```

Note

> `DROP PARTITION` does not work with tables that use the `NDBCLUSTER` storage engine. See Section 18.3.1, "Management of RANGE and LIST Partitions", and Section 17.1.6, "Known Limitations of MySQL Cluster".

`ADD PARTITION` and `DROP PARTITION` do not currently support `IF [NOT] EXISTS`.

Renames of partitioned table are supported. You can rename individual partitions indirectly using `ALTER TABLE ... REORGANIZE PARTITION`; however, this operation makes a copy of the partition's data..

`COALESCE PARTITION` can be used with a table that is partitioned by `HASH` or `KEY` to reduce the number of partitions by *number*. Suppose that you have created table `t2` using the following definition:

```
CREATE TABLE t2 (
    name VARCHAR (30),
    started DATE
)
PARTITION BY HASH( YEAR(started) )
PARTITIONS 6;
```

You can reduce the number of partitions used by `t2` from 6 to 4 using the following statement:

```
ALTER TABLE t2 COALESCE PARTITION 2;
```

The data contained in the last *number* partitions will be merged into the remaining partitions. In this case, partitions 4 and 5 will be merged into the first 4 partitions (the partitions numbered 0, 1, 2, and 3).

To change some but not all the partitions used by a partitioned table, you can use `REORGANIZE PARTITION`. This statement can be used in several ways:

- To merge a set of partitions into a single partition. This can be done by naming several partitions in the *partition_names* list and supplying a single definition for *partition_definition*.

- To split an existing partition into several partitions. You can accomplish this by naming a single partition for *partition_names* and providing multiple *partition_definitions*.

- To change the ranges for a subset of partitions defined using `VALUES LESS THAN` or the value lists for a subset of partitions defined using `VALUES IN`.

- This statement may also be used without the *partition_names* `INTO (partition_definitions)` option on tables that are automatically partitioned using `HASH` partitioning to force redistribution of data. (Currently, only `NDBCLUSTER` tables are automatically partitioned in this way.) This is useful in MySQL Cluster NDB 7.0 and later where, after you have added new MySQL Cluster data nodes online to an existing MySQL Cluster, you wish to redistribute existing MySQL Cluster table data to the new data nodes. In such cases, you should invoke the statement with the `ONLINE` option; in other words, as shown here:

```
ALTER ONLINE TABLE table REORGANIZE PARTITION;
```

You cannot perform other DDL concurrently with online table reorganization—that is, no other DDL statements can be issued while an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement is executing. For more information about adding MySQL Cluster data nodes online, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

`ALTER ONLINE TABLE ... REORGANIZE PARTITION` does not work with tables which were created using the `MAX_ROWS` option, because it uses the constant `MAX_ROWS` value specified in the original `CREATE TABLE` statement to determine the number of partitions required, so no new partitions are created. Beginning with MySQL Cluster NDB 7.0.32 and MySQL Cluster NDB 7.1.21, you can use `ALTER ONLINE TABLE ... MAX_ROWS=rows` to increase the maximum number of rows for the table; after this, `ALTER ONLINE TABLE ... REORGANIZE PARTITION` can use this new, larger value to increase the number of partitions. The value of *rows* must be greater than the value specified for `MAX_ROWS` in the original `CREATE TABLE` statement for this to work.

Attempting to use `REORGANIZE PARTITION` without the *partition_names* `INTO (partition_definitions)` option on explicitly partitioned tables results in the error `REORGANIZE PARTITION without parameters can only be used on auto-partitioned tables using HASH partitioning`.

Note

For partitions that have not been explicitly named, MySQL automatically provides the default names `p0`, `p1`, `p2`, and so on. As of MySQL 5.1.7, the same is true with regard to subpartitions.

For more detailed information about and examples of `ALTER TABLE ... REORGANIZE PARTITION` statements, see Section 18.3.1, "Management of RANGE and LIST Partitions".

- Several additional options were introduced in MySQL 5.1.5 for providing partition maintenance and repair functionality analogous to that implemented for nonpartitioned tables by statements such as `CHECK TABLE` and `REPAIR TABLE` (which are also supported for partitioned tables, beginning with MySQL 5.1.27—see note at the end of this item). These include `ANALYZE PARTITION`, `CHECK PARTITION`, `OPTIMIZE PARTITION`, `REBUILD PARTITION`, and `REPAIR PARTITION`. Each of these options takes a *partition_names* clause consisting of one or more names of partitions, separated by commas. The partitions must already exist in the table to be altered. You can also use the `ALL` keyword in place of *partition_names*, in which case the statement acts on all partitions in the table. For more information and examples, see Section 18.3.3, "Maintenance of Partitions".

  Prior to MySQL 5.1.68, it was not safe to execute multiple concurrent `REBUILD TABLE` operations on partitioned tables, whether on the same or different tables. (Bug #14589559, Bug #66645)

  Some MySQL storage engines, such as `InnoDB`, do not support per-partition optimization. For a partitioned table using such a storage engine, `ALTER TABLE ... OPTIMIZE PARTITION` rebuilds the entire table. This is a known issue. Beginning with MySQL 5.1.68, running this statement on such a table causes the entire table to rebuilt and analyzed, and an appropriate warning to be issued. (Bug #11751825, Bug #42822)

  To work around this problem, use the statements `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION` instead.

  The `ANALYZE PARTITION`, `CHECK PARTITION`, `OPTIMIZE PARTITION`, and `REPAIR PARTITION` options were disabled in MySQL 5.1.24, and re-enabled in MySQL 5.1.27. (Bug #20129) They are not supported for tables which are not partitioned; beginning with MySQL 5.1.31, they are not permitted for such tables.

  Beginning with MySQL 5.1.27, you can use the statements `ANALYZE TABLE`, `CHECK TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` on partitioned tables. See Section 13.7.2, "Table Maintenance Statements", for more information.

- `REMOVE PARTITIONING` was introduced in MySQL 5.1.8 for the purpose of removing a table's partitioning without otherwise affecting the table or its data. (Previously, this was done using the `ENGINE` option.) This option can be combined with other `ALTER TABLE` options such as those used to add, drop, or rename columns or indexes.

- In MySQL 5.1.7 and earlier, using the `ENGINE` option with `ALTER TABLE` caused any partitioning that a table might have had to be removed. Beginning with MySQL 5.1.8, this option merely changes the storage engine used by the table and no longer affects partitioning in any way.

Only a single instance of any one of the following options can be used in a given `ALTER TABLE` statement: `PARTITION BY`, `ADD PARTITION`, `DROP PARTITION`, `TRUNCATE PARTITION`, `REORGANIZE PARTITION`, or `COALESCE PARTITION`, `ANALYZE PARTITION`, `CHECK PARTITION`, `OPTIMIZE PARTITION`, `REBUILD PARTITION`, `REMOVE PARTITIONING`.

For example, the following two statements are invalid:

```
ALTER TABLE t1 ANALYZE PARTITION p1, ANALYZE PARTITION p2;

ALTER TABLE t1 ANALYZE PARTITION p1, CHECK PARTITION p2;
```

In the first case, you can analyze partitions `p1` and `p2` of table `t1` concurrently using a single statement with a single `ANALYZE PARTITION` option that lists both of the partitions to be analyzed, like this:

```
ALTER TABLE t1 ANALYZE PARTITION p1, p2;
```

In the second case, it is not possible to perform ANALYZE and CHECK operations on different partitions of the same table concurrently. Instead, you must issue two separate statements, like this:

```
ALTER TABLE t1 ANALYZE PARTITION p1;
ALTER TABLE t1 CHECK PARTITION p2;
```

ANALYZE, CHECK, OPTIMIZE, REBUILD, REPAIR, and TRUNCATE operations are not allowed with subpartitions.

13.1.7.2 ALTER TABLE Online Operations in MySQL Cluster

Beginning with MySQL 5.1.17, operations that add and drop indexes on variable-width columns of NDBCLUSTER tables occur online. Online operations are noncopying; that is, they do not require that indexes be re-created. They do not lock the table being altered from access by other API nodes in a MySQL Cluster (but see *Limitations* later in this section). Such operations do not require single user mode for NDBCLUSTER table alterations made in a cluster with multiple API nodes; transactions can continue uninterrupted during online DDL operations.

The ONLINE keyword can be used to perform online ADD COLUMN, ADD INDEX (including CREATE INDEX statements), and DROP INDEX operations on NDBCLUSTER tables. Online renaming of NDBCLUSTER tables is also supported.

The ONLINE and OFFLINE keywords are supported only in MySQL Cluster NDB 6.2 (beginning with 6.2.5) and 6.3 (beginning with 6.3.2) or later. For earlier MySQL Cluster releases or standard MySQL 5.1 releases:

- The server determines automatically whether an ADD INDEX or DROP INDEX operation can be (and is) performed online or offline; if the column is of a variable-width data type, the operation is performed online. It is not possible to override the server behavior in this regard.

- Attempting to use the ONLINE or OFFLINE keyword in an ALTER TABLE, CREATE INDEX, or DROP INDEX statement results in an error.

Currently you cannot add disk-based columns to NDBCLUSTER tables online. This means that, if you wish to add an in-memory column to an NDBCLUSTER table that uses a table-level STORAGE DISK option, you must declare the new column as using memory-based storage explicitly. For example—assuming that you have already created tablespace ts1—suppose that you create table t1 as follows:

```
mysql> CREATE TABLE t1 (
    >     c1 INT NOT NULL PRIMARY KEY,
    >     c2 VARCHAR(30)
    >     )
    >     TABLESPACE ts1 STORAGE DISK
    >     ENGINE NDBCLUSTER;
Query OK, 0 rows affected (1.73 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

You can add a new in-memory column to this table online as shown here:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC STORAGE MEMORY;
Query OK, 0 rows affected (1.25 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

This statement fails if the STORAGE MEMORY option is omitted:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC;
ERROR 1235 (42000): This version of MySQL doesn't yet support
'ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC'
```

If you omit the `COLUMN_FORMAT DYNAMIC` option, the dynamic column format is employed automatically, but a warning is issued, as shown here:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT STORAGE MEMORY;
Query OK, 0 rows affected, 1 warning (1.17 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+------------------------------------------------------------+
| Level   | Code | Message                                                    |
+---------+------+------------------------------------------------------------+
| Warning | 1478 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+------------------------------------------------------------+
1 row in set (0.00 sec)

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
      Table: t1
Create Table: CREATE TABLE `t1` (
  `c1` int(11) NOT NULL,
  `c2` varchar(30) DEFAULT NULL,
  `c3` int(11) /*!50120 STORAGE MEMORY */ /*!50120 COLUMN_FORMAT DYNAMIC */ DEFAULT NULL,
  `t4` int(11) /*!50120 STORAGE MEMORY */ DEFAULT NULL,
  PRIMARY KEY (`c1`)
) /*!50100 TABLESPACE ts_1 STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.03 sec)
```

Prior to MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, adding in-memory columns to tables that were created using a table-level or column-level `STORAGE DISK` option did not work correctly. (Bug #42549)

> **Note**
>
> The `STORAGE` and `COLUMN_FORMAT` keywords are supported only in MySQL Cluster; in any other version of MySQL, attempting to use either of these keywords in a `CREATE TABLE` or `ALTER TABLE` statement results in an error.

In MySQL Cluster NDB 7.0 and later, it is also possible to use the statement `ALTER ONLINE TABLE ... REORGANIZE PARTITION` with no *partition_names* `INTO` (*partition_definitions*) option on `NDBCLUSTER` tables. This can be used to redistribute MySQL Cluster data among new data nodes that have been added to the cluster online. For more information about this statement, see Section 13.1.7.1, "ALTER TABLE Partition Operations" For more information about adding data nodes online to a MySQL Cluster, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

Prior to MySQL Cluster NDB 6.4.3, `ALTER ONLINE TABLE ... REORGANIZE PARTITION` with no *partition_names* `INTO` (*partition_definitions*) option did not work correctly with Disk Data tables or with in-memory `NDBCLUSTER` tables having one or more disk-based columns. (Bug #42549)

Limitations of NDBCLUSTER online operations

Online `DROP COLUMN` operations are not supported.

Online `ALTER TABLE`, `CREATE INDEX`, or `DROP INDEX` statements that add columns or add or drop indexes are subject to the following limitations:

- A given online `ALTER TABLE` can use only one of `ADD COLUMN`, `ADD INDEX`, or `DROP INDEX`. One or more columns can be added online in a single statement; only one index may be created or dropped online in a single statement.

- An `ALTER TABLE` statement that performs a rename while using the `ONLINE` or `OFFLINE` keyword cannot perform any other operations, including but not limited to `ADD COLUMN`, `ADD INDEX`, or `DROP INDEX`. Beginning with MySQL Cluster NDB 6.3.52, MySQL Cluster NDB 7.0.38, and MySQL Cluster NDB 7.1.27, such statements are specifically disallowed, and fail with `ER_NOT_SUPPORTED_YET`. (Bug #16021021)

- The table being altered is not locked with respect to API nodes other than the one on which an online `ALTER TABLE ADD COLUMN`, `ADD INDEX`, or `DROP INDEX` operation (or `CREATE INDEX` or `DROP INDEX` statement) is run. However, the table is locked against any other operations originating on the *same* API node while the online operation is being executed.

- The table to be altered must have an explicit primary key; the hidden primary key created by the `NDBCLUSTER` storage engine is not sufficient for this purpose.

- The storage engine used by the table cannot be changed online.

- When used with MySQL Cluster Disk Data tables, it is not possible to change the storage type (`DISK` or `MEMORY`) of a column online. This means, that when you add or drop an index in such a way that the operation would be performed online, and you want the storage type of the column or columns to be changed, you must use the `OFFLINE` keyword in the statement that adds or drops the index.

Columns to be added online cannot use the `BLOB` or `TEXT` type, and must meet the following criteria:

- The columns must be dynamic; that is, it must be possible to create them using `COLUMN_FORMAT DYNAMIC`. If you omit the `COLUMN_FORMAT DYNAMIC` option, the dynamic column format is employed automatically.

- The columns must permit `NULL` values and not have any explicit default value other than `NULL`. Columns added online are automatically created as `DEFAULT NULL`, as can be seen here:

```
mysql> CREATE TABLE t1 (
    >     c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY
    >     ) ENGINE=NDBCLUSTER;
Query OK, 0 rows affected (1.44 sec)

mysql> ALTER ONLINE TABLE t1
    >     ADD COLUMN c2 INT,
    >     ADD COLUMN c3 INT;
Query OK, 0 rows affected, 2 warnings (0.93 sec)

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
       Table: t1
Create Table: CREATE TABLE `t1` (
  `c1` int(11) NOT NULL AUTO_INCREMENT,
  `c2` int(11) DEFAULT NULL,
  `c3` int(11) DEFAULT NULL,
  PRIMARY KEY (`c1`)
) ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

- The columns must be added following any existing columns. If you attempt to add a column online before any existing columns or using the `FIRST` keyword, the statement fails with an error.

- Existing table columns cannot be reordered online.

For online `ALTER TABLE` operations on `NDBCLUSTER` tables, fixed-format columns are converted to dynamic when they are added online, or when indexes are created or dropped online, as shown here:

```
mysql> CREATE TABLE t1 (
```

```
>       c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY
>       ) ENGINE=NDBCLUSTER;
Query OK, 0 rows affected (1.44 sec)

mysql> ALTER ONLINE TABLE t1 ADD COLUMN c2 INT, ADD COLUMN c3 INT;
Query OK, 0 rows affected, 2 warnings (0.93 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+------------------------------------------------------------+
| Level   | Code | Message                                                    |
+---------+------+------------------------------------------------------------+
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+------------------------------------------------------------+
2 rows in set (0.00 sec)
```

> **Note**
>
> Existing columns, including the table's primary key, need not be dynamic; only the column or columns to be added online must be dynamic.

```
mysql> CREATE TABLE t2 (
>       c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY COLUMN_FORMAT FIXED
>       ) ENGINE=NDBCLUSTER;
Query OK, 0 rows affected (2.10 sec)

mysql> ALTER ONLINE TABLE t2 ADD COLUMN c2 INT;
Query OK, 0 rows affected, 1 warning (0.78 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+------------------------------------------------------------+
| Level   | Code | Message                                                    |
+---------+------+------------------------------------------------------------+
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+------------------------------------------------------------+
1 row in set (0.00 sec)
```

Columns are not converted from FIXED to DYNAMIC column format by renaming operations. For more information about COLUMN_FORMAT, see Section 13.1.17, "CREATE TABLE Syntax".

The KEY, CONSTRAINT, and IGNORE keywords are supported in ALTER TABLE statements using the ONLINE keyword.

13.1.7.3 ALTER TABLE Examples

Begin with a table t1 that is created as shown here:

```
CREATE TABLE t1 (a INTEGER,b CHAR(10));
```

To rename the table from t1 to t2:

```
ALTER TABLE t1 RENAME t2;
```

To change column a from INTEGER to TINYINT NOT NULL (leaving the name the same), and to change column b from CHAR(10) to CHAR(20) as well as renaming it from b to c:

```
ALTER TABLE t2 MODIFY a TINYINT NOT NULL, CHANGE b c CHAR(20);
```

To add a new TIMESTAMP column named d:

```
ALTER TABLE t2 ADD d TIMESTAMP;
```

To add an index on column `d` and a UNIQUE index on column `a`:

```
ALTER TABLE t2 ADD INDEX (d), ADD UNIQUE (a);
```

To remove column `c`:

```
ALTER TABLE t2 DROP COLUMN c;
```

To add a new AUTO_INCREMENT integer column named `c`:

```
ALTER TABLE t2 ADD c INT UNSIGNED NOT NULL AUTO_INCREMENT,
  ADD PRIMARY KEY (c);
```

We indexed `c` (as a PRIMARY KEY) because AUTO_INCREMENT columns must be indexed, and we declare `c` as NOT NULL because primary key columns cannot be NULL.

For NDB tables, it is also possible to change the storage type used for a table or column. For example, consider an NDB table created as shown here:

```
mysql> CREATE TABLE t1 (c1 INT) TABLESPACE ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.27 sec)
```

To convert this table to disk-based storage, you can use the following ALTER TABLE statement:

```
mysql> ALTER TABLE t1 TABLESPACE ts_1 STORAGE DISK;
Query OK, 0 rows affected (2.99 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
       Table: t1
Create Table: CREATE TABLE `t1` (
  `c1` int(11) DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */
ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.01 sec)
```

It is not necessary that the tablespace was referenced when the table was originally created; however, the tablespace must be referenced by the ALTER TABLE:

```
mysql> CREATE TABLE t2 (c1 INT) ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.00 sec)

mysql> ALTER TABLE t2 STORAGE DISK;
ERROR 1005 (HY000): Can't create table 'c.#sql-1750_3' (errno: 140)
mysql> ALTER TABLE t2 TABLESPACE ts_1 STORAGE DISK;
Query OK, 0 rows affected (3.42 sec)
Records: 0  Duplicates: 0  Warnings: 0
mysql> SHOW CREATE TABLE t2\G
*************************** 1. row ***************************
       Table: t1
Create Table: CREATE TABLE `t2` (
  `c1` int(11) DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */
ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.01 sec)
```

To change the storage type of an individual column, you can use `ALTER TABLE ... MODIFY [COLUMN]`. For example, suppose you create a MySQL Cluster Disk Data table with two columns, using this `CREATE TABLE` statement:

```
mysql> CREATE TABLE t3 (c1 INT, c2 INT)
    ->     TABLESPACE ts_1 STORAGE DISK ENGINE NDB;
Query OK, 0 rows affected (1.34 sec)
```

To change column `c2` from disk-based to in-memory storage, include a STORAGE MEMORY clause in the column definition used by the ALTER TABLE statement, as shown here:

```
mysql> ALTER TABLE t3 MODIFY c2 INT STORAGE MEMORY;
Query OK, 0 rows affected (3.14 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

You can make an in-memory column into a disk-based column by using `STORAGE DISK` in a similar fashion.

Column `c1` uses disk-based storage, since this is the default for the table (determined by the table-level `STORAGE DISK` clause in the `CREATE TABLE` statement). However, column `c2` uses in-memory storage, as can be seen here in the output of SHOW `CREATE TABLE`:

```
mysql> SHOW CREATE TABLE t3\G
*************************** 1. row ***************************
       Table: t3
Create Table: CREATE TABLE `t3` (
  `c1` int(11) DEFAULT NULL,
  `c2` int(11) /*!50120 STORAGE MEMORY */ DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.02 sec)
```

When you add an `AUTO_INCREMENT` column, column values are filled in with sequence numbers automatically. For `MyISAM` tables, you can set the first sequence number by executing `SET INSERT_ID=value` before `ALTER TABLE` or by using the `AUTO_INCREMENT=value` table option. See Section 5.1.4, "Server System Variables".

With `MyISAM` tables, if you do not change the `AUTO_INCREMENT` column, the sequence number is not affected. If you drop an `AUTO_INCREMENT` column and then add another `AUTO_INCREMENT` column, the numbers are resequenced beginning with 1.

When replication is used, adding an `AUTO_INCREMENT` column to a table might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to the table `t1`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 (id INT AUTO_INCREMENT PRIMARY KEY)
SELECT * FROM t1 ORDER BY col1, col2;
```

This assumes that the table `t1` has columns `col1` and `col2`.

This set of statements will also produce a new table `t2` identical to `t1`, with the addition of an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
```


Important

To guarantee the same ordering on both master and slave, *all* columns of `t1` must be referenced in the `ORDER BY` clause.

Regardless of the method used to create and populate the copy having the `AUTO_INCREMENT` column, the final step is to drop the original table and then rename the copy:

```
DROP TABLE t1;
ALTER TABLE t2 RENAME t1;
```

13.1.8 ALTER TABLESPACE Syntax

```
ALTER TABLESPACE tablespace_name
    {ADD|DROP} DATAFILE 'file_name'
    [INITIAL_SIZE [=] size]
    [WAIT]
    ENGINE [=] engine_name
```

This statement can be used either to add a new data file, or to drop a data file from a tablespace.

The `ADD DATAFILE` variant enables you to specify an initial size using an `INITIAL_SIZE` clause, where `size` is measured in bytes; the default value is `128M` (128 megabytes). You may optionally follow this integer value with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (for megabytes) or `G` (for gigabytes).

Note

All MySQL Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and an data file with the same name, or an undo log file and a with the same name.

Prior to MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, path and file names for data files could not be longer than 128 characters. (Bug #31770)

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is `4G`. (Bug #29186)

`INITIAL_SIZE` is rounded as for `CREATE TABLESPACE`. Beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2, this rounding is done explicitly (also as with `CREATE TABLESPACE`).

Once a data file has been created, its size cannot be changed; however, you can add more data files to the tablespace using additional `ALTER TABLESPACE ... ADD DATAFILE` statements.

Using `DROP DATAFILE` with `ALTER TABLESPACE` drops the data file '`file_name`' from the tablespace. You cannot drop a data file from a tablespace which is in use by any table; in other words, the data file must be empty (no extents used). See Section 17.5.12.1, "MySQL Cluster Disk Data Objects". In addition, any data file to be dropped must previously have been added to the tablespace with `CREATE TABLESPACE` or `ALTER TABLESPACE`.

Both `ALTER TABLESPACE ... ADD DATAFILE` and `ALTER TABLESPACE ... DROP DATAFILE` require an `ENGINE` clause which specifies the storage engine used by the tablespace. In MySQL 5.1, the only accepted values for `engine_name` are `NDB` and `NDBCLUSTER`.

WAIT is parsed but otherwise ignored, and so has no effect in MySQL 5.1. It is intended for future expansion.

When `ALTER TABLESPACE ... ADD DATAFILE` is used with `ENGINE = NDB`, a data file is created on each Cluster data node. You can verify that the data files were created and obtain information about them by querying the `INFORMATION_SCHEMA.FILES` table. For example, the following query shows all data files belonging to the tablespace named `newts`:

```
mysql> SELECT LOGFILE_GROUP_NAME, FILE_NAME, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE TABLESPACE_NAME = 'newts' AND FILE_TYPE = 'DATAFILE';
+--------------------+--------------+----------------+
| LOGFILE_GROUP_NAME | FILE_NAME    | EXTRA          |
+--------------------+--------------+----------------+
| lg_3               | newdata.dat  | CLUSTER_NODE=3 |
| lg_3               | newdata.dat  | CLUSTER_NODE=4 |
| lg_3               | newdata2.dat | CLUSTER_NODE=3 |
| lg_3               | newdata2.dat | CLUSTER_NODE=4 |
+--------------------+--------------+----------------+
2 rows in set (0.03 sec)
```

See Section 20.26.1, "The INFORMATION_SCHEMA FILES Table".

`ALTER TABLESPACE` was added in MySQL 5.1.6. In MySQL 5.1, it is useful only with Disk Data storage for MySQL Cluster. See Section 17.5.12, "MySQL Cluster Disk Data Tables".

13.1.9 ALTER VIEW Syntax

```
ALTER
    [ALGORITHM = {UNDEFINED | MERGE | TEMPTABLE}]
    [DEFINER = { user | CURRENT_USER }]
    [SQL SECURITY { DEFINER | INVOKER }]
    VIEW view_name [(column_list)]
    AS select_statement
    [WITH [CASCADED | LOCAL] CHECK OPTION]
```

This statement changes the definition of a view, which must exist. The syntax is similar to that for CREATE VIEW and the effect is the same as for `CREATE OR REPLACE VIEW`. See Section 13.1.20, "CREATE VIEW Syntax". This statement requires the CREATE VIEW and DROP privileges for the view, and some privilege for each column referred to in the SELECT statement. As of MySQL 5.1.23, `ALTER VIEW` is permitted only to the definer or users with the SUPER privilege.

13.1.10 CREATE DATABASE Syntax

```
CREATE {DATABASE | SCHEMA} [IF NOT EXISTS] db_name
    [create_specification] ...

create_specification:
    [DEFAULT] CHARACTER SET [=] charset_name
  | [DEFAULT] COLLATE [=] collation_name
```

CREATE DATABASE creates a database with the given name. To use this statement, you need the CREATE privilege for the database. CREATE SCHEMA is a synonym for CREATE DATABASE.

An error occurs if the database exists and you did not specify IF NOT EXISTS.

`create_specification` options specify database characteristics. Database characteristics are stored in the `db.opt` file in the database directory. The CHARACTER SET clause specifies the default database

character set. The `COLLATE` clause specifies the default database collation. Section 10.1, "Character Set Support", discusses character set and collation names.

A database in MySQL is implemented as a directory containing files that correspond to tables in the database. Because there are no tables in a database when it is initially created, the `CREATE DATABASE` statement creates only a directory under the MySQL data directory and the `db.opt` file. Rules for permissible database names are given in Section 9.2, "Schema Object Names". If a database name contains special characters, the name for the database directory contains encoded versions of those characters as described in Section 9.2.3, "Mapping of Identifiers to File Names".

If you manually create a directory under the data directory (for example, with `mkdir`), the server considers it a database directory and it shows up in the output of `SHOW DATABASES`.

You can also use the `mysqladmin` program to create databases. See Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".

13.1.11 CREATE EVENT Syntax

```
CREATE
    [DEFINER = { user | CURRENT_USER }]
    EVENT
    [IF NOT EXISTS]
    event_name
    ON SCHEDULE schedule
    [ON COMPLETION [NOT] PRESERVE]
    [ENABLE | DISABLE | DISABLE ON SLAVE]
    [COMMENT 'comment']
    DO event_body;

schedule:
    AT timestamp [+ INTERVAL interval] ...
  | EVERY interval
    [STARTS timestamp [+ INTERVAL interval] ...]
    [ENDS timestamp [+ INTERVAL interval] ...]

interval:
    quantity {YEAR | QUARTER | MONTH | DAY | HOUR | MINUTE |
              WEEK | SECOND | YEAR_MONTH | DAY_HOUR | DAY_MINUTE |
              DAY_SECOND | HOUR_MINUTE | HOUR_SECOND | MINUTE_SECOND}
```

This statement creates and schedules a new event. The event will not run unless the Event Scheduler is enabled. For information about checking Event Scheduler status and enabling it if necessary, see Section 19.4.2, "Event Scheduler Configuration".

`CREATE EVENT` requires the `EVENT` privilege for the schema in which the event is to be created. It might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section.

The minimum requirements for a valid `CREATE EVENT` statement are as follows:

- The keywords `CREATE EVENT` plus an event name, which uniquely identifies the event within a database schema. (Prior to MySQL 5.1.12, the event name needed to be unique only among events created by the same user within a schema.)

- An `ON SCHEDULE` clause, which determines when and how often the event executes.

- A `DO` clause, which contains the SQL statement to be executed by an event.

This is an example of a minimal `CREATE EVENT` statement:

```
CREATE EVENT myevent
    ON SCHEDULE AT CURRENT_TIMESTAMP + INTERVAL 1 HOUR
    DO
      UPDATE myschema.mytable SET mycol = mycol + 1;
```

The previous statement creates an event named `myevent`. This event executes once—one hour following its creation—by running an SQL statement that increments the value of the `myschema.mytable` table's `mycol` column by 1.

The `event_name` must be a valid MySQL identifier with a maximum length of 64 characters. Event names are not case sensitive, so you cannot have two events named `myevent` and `MyEvent` in the same schema. In general, the rules governing event names are the same as those for names of stored routines. See Section 9.2, "Schema Object Names".

An event is associated with a schema. If no schema is indicated as part of `event_name`, the default (current) schema is assumed. To create an event in a specific schema, qualify the event name with a schema using `schema_name.event_name` syntax.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at event execution time. If a `user` value is given, it should be a MySQL account specified as `'user_name'@'host_name'` (the same format used in the `GRANT` statement), `CURRENT_USER`, or `CURRENT_USER()`. The default `DEFINER` value is the user who executes the `CREATE EVENT` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

If you specify the `DEFINER` clause, these rules determine the valid `DEFINER` user values:

• If you do not have the `SUPER` privilege, the only permitted `user` value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.

• If you have the `SUPER` privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.

• Although it is possible to create an event with a nonexistent `DEFINER` account, an error occurs at event execution time if the account does not exist.

For more information about event security, see Section 19.6, "Access Control for Stored Programs and Views".

The `DEFINER` clause was added in MySQL 5.1.17.

Within an event, the `CURRENT_USER()` function returns the account used to check privileges at event execution time, which is the `DEFINER` user. For information about user auditing within events, see Section 6.3.6, "SQL-Based MySQL Account Activity Auditing".

`IF NOT EXISTS` has the same meaning for `CREATE EVENT` as for `CREATE TABLE`: If an event named `event_name` already exists in the same schema, no action is taken, and no error results. (However, a warning is generated in such cases.)

The `ON SCHEDULE` clause determines when, how often, and for how long the `event_body` defined for the event repeats. This clause takes one of two forms:

• `AT timestamp` is used for a one-time event. It specifies that the event executes one time only at the date and time given by `timestamp`, which must include both the date and time, or must be an expression that resolves to a datetime value. You may use a value of either the `DATETIME` or `TIMESTAMP` type for this purpose. If the date is in the past, a warning occurs, as shown here:

```
mysql> SELECT NOW();
+---------------------+
```

```
| NOW()               |
+---------------------+
| 2006-02-10 23:59:01 |
+---------------------+
1 row in set (0.04 sec)

mysql> CREATE EVENT e_totals
    ->     ON SCHEDULE AT '2006-02-10 23:59:00'
    ->     DO INSERT INTO test.totals VALUES (NOW());
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Note
   Code: 1588
Message: Event execution time is in the past and ON COMPLETION NOT
         PRESERVE is set. The event was dropped immediately after
         creation.
```

`CREATE EVENT` statements which are themselves invalid—for whatever reason—fail with an error.

You may use `CURRENT_TIMESTAMP` to specify the current date and time. In such a case, the event acts as soon as it is created.

To create an event which occurs at some point in the future relative to the current date and time—such as that expressed by the phrase "three weeks from now"—you can use the optional clause `+ INTERVAL` *interval*. The *interval* portion consists of two parts, a quantity and a unit of time, and follows the same syntax rules that govern intervals used in the `DATE_ADD()` function (see Section 12.7, "Date and Time Functions". The units keywords are also the same, except that you cannot use any units involving microseconds when defining an event. With some interval types, complex time units may be used. For example, "two minutes and ten seconds" can be expressed as `+ INTERVAL '2:10' MINUTE_SECOND`.

You can also combine intervals. For example, `AT CURRENT_TIMESTAMP + INTERVAL 3 WEEK + INTERVAL 2 DAY` is equivalent to "three weeks and two days from now". Each portion of such a clause must begin with `+ INTERVAL`.

- To repeat actions at a regular interval, use an `EVERY` clause. The `EVERY` keyword is followed by an *interval* as described in the previous discussion of the `AT` keyword. (`+ INTERVAL` is *not* used with `EVERY`.) For example, `EVERY 6 WEEK` means "every six weeks".

  Although `+ INTERVAL` clauses are not permitted in an `EVERY` clause, you can use the same complex time units permitted in a `+ INTERVAL`.

  An `EVERY` clause may contain an optional `STARTS` clause. `STARTS` is followed by a *timestamp* value that indicates when the action should begin repeating, and may also use `+ INTERVAL` *interval* to specify an amount of time "from now". For example, `EVERY 3 MONTH STARTS CURRENT_TIMESTAMP + INTERVAL 1 WEEK` means "every three months, beginning one week from now". Similarly, you can express "every two weeks, beginning six hours and fifteen minutes from now" as `EVERY 2 WEEK STARTS CURRENT_TIMESTAMP + INTERVAL '6:15' HOUR_MINUTE`. Not specifying `STARTS` is the same as using `STARTS CURRENT_TIMESTAMP`—that is, the action specified for the event begins repeating immediately upon creation of the event.

  An `EVERY` clause may contain an optional `ENDS` clause. The `ENDS` keyword is followed by a *timestamp* value that tells MySQL when the event should stop repeating. You may also use `+ INTERVAL` *interval* with `ENDS`; for instance, `EVERY 12 HOUR STARTS CURRENT_TIMESTAMP + INTERVAL 30 MINUTE ENDS CURRENT_TIMESTAMP + INTERVAL 4 WEEK` is equivalent to "every twelve hours, beginning thirty minutes from now, and ending four weeks from now". Not using `ENDS` means that the event continues executing indefinitely.

ENDS supports the same syntax for complex time units as STARTS does.

You may use STARTS, ENDS, both, or neither in an EVERY clause.

If a repeating event does not terminate within its scheduling interval, the result may be multiple instances of the event executing simultaneously. If this is undesirable, you should institute a mechanism to prevent simultaneous instances. For example, you could use the GET_LOCK() function, or row or table locking.

The ON SCHEDULE clause may use expressions involving built-in MySQL functions and user variables to obtain any of the *timestamp* or *interval* values which it contains. You may not use stored functions or user-defined functions in such expressions, nor may you use any table references; however, you may use SELECT FROM DUAL. This is true for both CREATE EVENT and ALTER EVENT statements. Beginning with MySQL 5.1.13, references to stored functions, user-defined functions, and tables in such cases are specifically not permitted, and fail with an error (see Bug #22830).

Times in the ON SCHEDULE clause are interpreted using the current session time_zone value. This becomes the event time zone; that is, the time zone that is used for event scheduling and is in effect within the event as it executes. These times are converted to UTC and stored along with the event time zone in the mysql.event table. This enables event execution to proceed as defined regardless of any subsequent changes to the server time zone or daylight saving time effects. For additional information about representation of event times, see Section 19.4.4, "Event Metadata". See also Section 13.7.5.19, "SHOW EVENTS Syntax", and Section 20.7, "The INFORMATION_SCHEMA EVENTS Table".

> **Note**
>
> Prior to MySQL 5.1.17, the event time zone is not stored. The mysql.event table must be updated before events created in earlier releases can be created, altered, viewed, or used in MySQL 5.1.17 or later. You can use mysql_upgrade for this (see Section 4.4.8, "mysql_upgrade — Check and Upgrade MySQL Tables").

Normally, once an event has expired, it is immediately dropped. You can override this behavior by specifying ON COMPLETION PRESERVE. Using ON COMPLETION NOT PRESERVE merely makes the default nonpersistent behavior explicit.

You can create an event but prevent it from being active using the DISABLE keyword. Alternatively, you can use ENABLE to make explicit the default status, which is active. This is most useful in conjunction with ALTER EVENT (see Section 13.1.2, "ALTER EVENT Syntax").

Beginning with MySQL 5.1.18, a third value may also appear in place of ENABLE or DISABLE; DISABLE ON SLAVE is set for the status of an event on a replication slave to indicate that the event was created on the master and replicated to the slave, but is not executed on the slave. See Section 16.4.1.12, "Replication of Invoked Features".

You may supply a comment for an event using a COMMENT clause. *comment* may be any string of up to 64 characters that you wish to use for describing the event. The comment text, being a string literal, must be surrounded by quotation marks.

The DO clause specifies an action carried by the event, and consists of an SQL statement. Nearly any valid MySQL statement that can be used in a stored routine can also be used as the action statement for a scheduled event. (See Section C.1, "Restrictions on Stored Programs".) For example, the following event e_hourly deletes all rows from the sessions table once per hour, where this table is part of the site_activity schema:

```
CREATE EVENT e_hourly
    ON SCHEDULE
      EVERY 1 HOUR
```

```
  COMMENT 'Clears out sessions table each hour.'
  DO
    DELETE FROM site_activity.sessions;
```

MySQL stores the `sql_mode` system variable setting in effect when an event is created or altered, and always executes the event with this setting in force, *regardless of the current server SQL mode when the event begins executing*.

A `CREATE EVENT` statement that contains an `ALTER EVENT` statement in its `DO` clause appears to succeed; however, when the server attempts to execute the resulting scheduled event, the execution fails with an error.

> **Note**
>
> Statements such as `SELECT` or `SHOW` that merely return a result set have no effect when used in an event; the output from these is not sent to the MySQL Monitor, nor is it stored anywhere. However, you can use statements such as `SELECT ... INTO` and `INSERT INTO ... SELECT` that store a result. (See the next example in this section for an instance of the latter.)

The schema to which an event belongs is the default schema for table references in the `DO` clause. Any references to tables in other schemas must be qualified with the proper schema name. (In MySQL 5.1.6, all tables referenced in event `DO` clauses had to include a reference to the schema.)

As with stored routines, you can use compound-statement syntax in the `DO` clause by using the `BEGIN` and `END` keywords, as shown here:

```
delimiter |

CREATE EVENT e_daily
    ON SCHEDULE
      EVERY 1 DAY
    COMMENT 'Saves total number of sessions then clears the table each day'
    DO
      BEGIN
        INSERT INTO site_activity.totals (time, total)
          SELECT CURRENT_TIMESTAMP, COUNT(*)
            FROM site_activity.sessions;
        DELETE FROM site_activity.sessions;
      END |

delimiter ;
```

This example uses the `delimiter` command to change the statement delimiter. See Section 19.1, "Defining Stored Programs".

More complex compound statements, such as those used in stored routines, are possible in an event. This example uses local variables, an error handler, and a flow control construct:

```
delimiter |

CREATE EVENT e
    ON SCHEDULE
      EVERY 5 SECOND
    DO
      BEGIN
        DECLARE v INTEGER;
        DECLARE CONTINUE HANDLER FOR SQLEXCEPTION BEGIN END;

        SET v = 0;
```

```
        WHILE v < 5 DO
          INSERT INTO t1 VALUES (0);
          UPDATE t2 SET s1 = s1 + 1;
          SET v = v + 1;
        END WHILE;
    END |

delimiter ;
```

There is no way to pass parameters directly to or from events; however, it is possible to invoke a stored routine with parameters within an event:

```
CREATE EVENT e_call_myproc
    ON SCHEDULE
      AT CURRENT_TIMESTAMP + INTERVAL 1 DAY
    DO CALL myproc(5, 27);
```

If an event's definer has the `SUPER` privilege, the event can read and write global variables. As granting this privilege entails a potential for abuse, extreme care must be taken in doing so.

Generally, any statements that are valid in stored routines may be used for action statements executed by events. For more information about statements permitted within stored routines, see Section 19.2.1, "Stored Routine Syntax". You can create an event as part of a stored routine, but an event cannot be created by another event.

13.1.12 CREATE FUNCTION Syntax

The `CREATE FUNCTION` statement is used to create stored functions and user-defined functions (UDFs):

- For information about creating stored functions, see Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax".

- For information about creating user-defined functions, see Section 13.7.3.1, "CREATE FUNCTION Syntax for User-Defined Functions".

13.1.13 CREATE INDEX Syntax

```
CREATE [ONLINE|OFFLINE] [UNIQUE|FULLTEXT|SPATIAL] INDEX index_name
    [index_type]
    ON tbl_name (index_col_name,...)
    [index_option] ...

index_col_name:
    col_name [(length)] [ASC | DESC]

index_type:
    USING {BTREE | HASH}

index_option:
    KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name
```

`CREATE INDEX` is mapped to an `ALTER TABLE` statement to create indexes. See Section 13.1.7, "ALTER TABLE Syntax". `CREATE INDEX` cannot be used to create a `PRIMARY KEY`; use `ALTER TABLE` instead. For more information about indexes, see Section 8.3.1, "How MySQL Uses Indexes".

Normally, you create all indexes on a table at the time the table itself is created with `CREATE TABLE`. See Section 13.1.17, "CREATE TABLE Syntax". This guideline is especially important for `InnoDB` tables, where

the primary key determines the physical layout of rows in the data file. `CREATE INDEX` enables you to add indexes to existing tables.

A column list of the form `(col1,col2,...)` creates a multiple-column index. Index key values are formed by concatenating the values of the given columns.

For string columns, indexes can be created that use only the leading part of column values, using `col_name(length)` syntax to specify an index prefix length:

- Prefixes can be specified for `CHAR`, `VARCHAR`, `BINARY`, and `VARBINARY` column indexes.

- Prefixes *must* be specified for `BLOB` and `TEXT` column indexes.

- Prefix limits are measured in bytes, whereas the prefix length in `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements is interpreted as number of characters for nonbinary string types (`CHAR`, `VARCHAR`, `TEXT`) and number of bytes for binary string types (`BINARY`, `VARBINARY`, `BLOB`). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

- For spatial columns, prefix values cannot be given, as described later in this section.

The statement shown here creates an index using the first 10 characters of the `name` column (assuming that `name` has a nonbinary string type):

```
CREATE INDEX part_of_name ON customer (name(10));
```

If names in the column usually differ in the first 10 characters, this index should not be much slower than an index created from the entire `name` column. Also, using column prefixes for indexes can make the index file much smaller, which could save a lot of disk space and might also speed up `INSERT` operations.

Prefix support and lengths of prefixes (where supported) are storage engine dependent. For example, a prefix can be up to 1000 bytes long for `MyISAM` tables, and 767 bytes for `InnoDB` tables. The `NDB` storage engine does not support prefixes (see Section 17.1.6.6, "Unsupported or Missing Features in MySQL Cluster").

Beginning with MySQL 5.1.17, indexes on variable-width columns of `NDBCLUSTER` tables are created online; that is, without any table copying. The table is not locked against access from other MySQL Cluster API nodes, although it is locked against other operations on the *same* API node for the duration of the operation. This is done automatically by the server whenever it determines that it is possible to do so; you do not have to use any special SQL syntax or server options to cause it to happen.

In standard MySQL 5.1 releases, it is not possible to override the server when it determines that an index is to be created without table copying. In MySQL Cluster, you can create indexes offline (which causes the table to be locked to all API nodes in the cluster) using the `OFFLINE` keyword. The rules and limitations governing `CREATE OFFLINE INDEX` and `CREATE ONLINE INDEX` are the same as for `ALTER OFFLINE TABLE ... ADD INDEX` and `ALTER ONLINE TABLE ... ADD INDEX`. You cannot cause the noncopying creation of an index that would normally be created offline by using the `ONLINE` keyword: If it is not possible to perform the `CREATE INDEX` operation without table copying, the server ignores the `ONLINE` keyword. For more information, see Section 13.1.7.2, "ALTER TABLE Online Operations in MySQL Cluster".

Note

The `ONLINE` and `OFFLINE` keywords are available only in MySQL Cluster NDB 6.2.5, 6.3.2, and later MySQL Cluster releases; attempting to use these keywords in earlier MySQL Cluster releases or standard MySQL 5.1 releases results in a syntax error.

A `UNIQUE` index creates a constraint such that all values in the index must be distinct. An error occurs if you try to add a new row with a key value that matches an existing row. For all engines, a `UNIQUE` index permits multiple `NULL` values for columns that can contain `NULL`. If you specify a prefix value for a column in a `UNIQUE` index, the column values must be unique within the prefix.

`FULLTEXT` indexes are supported only for `MyISAM` tables and can include only `CHAR`, `VARCHAR`, and `TEXT` columns. Indexing always happens over the entire column; column prefix indexing is not supported and any prefix length is ignored if specified. See Section 12.9, "Full-Text Search Functions", for details of operation.

The `MyISAM`, `InnoDB`, `NDB`, and `ARCHIVE` storage engines support spatial columns such as (`POINT` and `GEOMETRY`. (Section 11.5, "Extensions for Spatial Data", describes the spatial data types.) However, support for spatial column indexing varies among engines. Spatial and nonspatial indexes are available according to the following rules.

Spatial indexes (created using `SPATIAL INDEX`) have these characteristics:

- Available only for `MyISAM` tables. Specifying `SPATIAL INDEX` for other storage engines results in an error.

- Indexed columns must be `NOT NULL`.

- Column prefix lengths are prohibited. The full width of each column is indexed.

Characteristics of nonspatial indexes (created with `INDEX`, `UNIQUE`, or `PRIMARY KEY`):

- Permitted for any storage engine that supports spatial columns except `ARCHIVE`.

- Columns can be `NULL` unless the index is a primary key.

- For each spatial column in a non-`SPATIAL` index except `POINT` columns, a column prefix length must be specified. (This is the same requirement as for indexed `BLOB` columns.) The prefix length is given in bytes.

- The index type for a non-`SPATIAL` index depends on the storage engine. Currently, B-tree is used.

- You can add an index on a column that can have `NULL` values only for `MyISAM`, `InnoDB`, and `MEMORY` tables

- You can add an index on a `BLOB` or `TEXT` column only for `MyISAM` and `InnoDB` tables

An *index_col_name* specification can end with `ASC` or `DESC`. These keywords are permitted for future extensions for specifying ascending or descending index value storage. Currently, they are parsed but ignored; index values are always stored in ascending order.

As of MySQL 5.1.10, index options can be given following the index column list. An *index_option* value can be any of the following:

- `KEY_BLOCK_SIZE [=] value`

  For `MyISAM` tables, `KEY_BLOCK_SIZE` optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A `KEY_BLOCK_SIZE` value specified for an individual index definition overrides a table-level `KEY_BLOCK_SIZE` value.

- *index_type*

  Some storage engines permit you to specify an index type when creating an index. Table 13.1, "Index Types Per Storage Engine" shows the permissible index type values supported by different storage engines. Where multiple index types are listed, the first one is the default when no index type specifier is given. Storage engines not listed in the table do not support an *index_type* clause in index definitions.

Table 13.1 Index Types Per Storage Engine

Storage Engine	Permissible Index Types
MyISAM	BTREE
InnoDB	BTREE
MEMORY/HEAP	HASH, BTREE
NDB	BTREE, HASH (see note in text)

Example:

```
CREATE TABLE lookup (id INT) ENGINE = MEMORY;
CREATE INDEX id_index ON lookup (id) USING BTREE;
```

The `index_type` clause cannot be used for `FULLTEXT INDEX` or `SPATIAL INDEX` specifications. Full-text index implementation is storage engine dependent. Spatial indexes are implemented as R-tree indexes.

`BTREE` indexes are implemented by the `NDB` storage engine as T-tree indexes.

> **Note**
>
> For indexes on `NDB` table columns, the `USING` option can be specified only for a unique index or primary key. `USING HASH` prevents the creation of an ordered index; otherwise, creating a unique index or primary key on an `NDB` table automatically results in the creation of both an ordered index and a hash index, each of which indexes the same set of columns.
>
> For unique indexes that include one or more `NULL` columns of an `NDB` table, the hash index can be used only to look up literal values, which means that `IS [NOT] NULL` conditions require a full scan of the table. One workaround is to make sure that a unique index using one or more `NULL` columns on such a table is always created in such a way that it includes the ordered index; that is, avoid employing `USING HASH` when creating the index.

If you specify an index type that is not valid for a given storage engine, but another index type is available that the engine can use without affecting query results, the engine uses the available type. The parser recognizes `RTREE` as a type name, but currently this cannot be specified for any storage engine.

> **Note**
>
> Before MySQL 5.1.10, the `index_type` option can be given only before the `ON tbl_name` clause. Use of the option in this position is deprecated as of 5.1.10 and support for it there will be removed in a future MySQL release. If an `index_type` option is given in both the earlier and later positions, the final option applies.

`TYPE type_name` is recognized as a synonym for `USING type_name`. However, `USING` is the preferred form.

- `WITH PARSER parser_name`

This option can be used only with `FULLTEXT` indexes. It associates a parser plugin with the index if full-text indexing and searching operations need special handling. See Section 22.2, "The MySQL Plugin API", for details on creating plugins.

13.1.14 CREATE LOGFILE GROUP Syntax

```
CREATE LOGFILE GROUP logfile_group
    ADD UNDOFILE 'undo_file'
    [INITIAL_SIZE [=] initial_size]
    [UNDO_BUFFER_SIZE [=] undo_buffer_size]
    [REDO_BUFFER_SIZE [=] redo_buffer_size]
    [NODEGROUP [=] nodegroup_id]
    [WAIT]
    [COMMENT [=] comment_text]
    ENGINE [=] engine_name
```

This statement creates a new log file group named `logfile_group` having a single `UNDO` file named '`undo_file`'. A `CREATE LOGFILE GROUP` statement has one and only one `ADD UNDOFILE` clause. For rules covering the naming of log file groups, see Section 9.2, "Schema Object Names".

> **Note**
>
> All MySQL Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group with the same name, or a tablespace and a data file with the same name.

Beginning with MySQL 5.1.8, you can have only one log file group per Cluster at any given time. (See Bug #16386)

Prior to MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, path and file names for undo log files could not be longer than 128 characters. (Bug #31769)

The optional `INITIAL_SIZE` parameter sets the `UNDO` file's initial size; if not specified, it defaults to `128M` (128 megabytes). The optional `UNDO_BUFFER_SIZE` parameter sets the size used by the `UNDO` buffer for the log file group; The default value for `UNDO_BUFFER_SIZE` is `8M` (eight megabytes); this value cannot exceed the amount of system memory available. Both of these parameters are specified in bytes. You may optionally follow either or both of these with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (for megabytes) or `G` (for gigabytes).

Memory used for `UNDO_BUFFER_SIZE` comes from the global pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter. This includes any default value implied for this option by the setting of the `InitialLogFileGroup` data node configuration parameter.

Beginning with MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, the maximum permitted for `UNDO_BUFFER_SIZE` is `600M`; previously, it was `150M`. (Bug #34102)

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is `4G`. (Bug #29186)

Beginning with MySQL Cluster NDB 2.1.18, 6.3.24, and 7.0.4, the minimum permitted value for `INITIAL_SIZE` is `1M`. (Bug #29574)

The `ENGINE` option determines the storage engine to be used by this log file group, with `engine_name` being the name of the storage engine. In MySQL 5.1, this must be `NDB` (or `NDBCLUSTER`). If `ENGINE` is not set, MySQL tries to use the engine specified by the `storage_engine` server system variable. In any case, if the engine is not specified as `NDB` or `NDBCLUSTER`, the `CREATE LOGFILE GROUP` statement appears to succeed but actually fails to create the log file group, as shown here:

```
mysql> CREATE LOGFILE GROUP lg1
    ->       ADD UNDOFILE 'undo.dat' INITIAL_SIZE = 10M;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+-------+------+-------------------------------------------------------------------------------------
| Level | Code | Message
+-------+------+-------------------------------------------------------------------------------------
| Error | 1478 | Table storage engine 'MyISAM' does not support the create option 'TABLESPACE or LOGFILE GROUP
+-------+------+-------------------------------------------------------------------------------------
1 row in set (0.00 sec)

mysql> DROP LOGFILE GROUP lg1 ENGINE = NDB;
ERROR 1529 (HY000): Failed to drop LOGFILE GROUP

mysql> CREATE LOGFILE GROUP lg1
    ->       ADD UNDOFILE 'undo.dat' INITIAL_SIZE = 10M
    ->       ENGINE = NDB;
Query OK, 0 rows affected (2.97 sec)
```

The fact that the CREATE LOGFILE GROUP statement does not actually return an error when a non-NDB storage engine is named, but rather appears to succeed, is a known issue which we hope to address in a future release of MySQL Cluster.

REDO_BUFFER_SIZE, NODEGROUP, WAIT, and COMMENT are parsed but ignored, and so have no effect in MySQL 5.1. These options are intended for future expansion.

When used with ENGINE [=] NDB, a log file group and associated UNDO log file are created on each Cluster data node. You can verify that the UNDO files were created and obtain information about them by querying the INFORMATION_SCHEMA.FILES table. For example:

```
mysql> SELECT LOGFILE_GROUP_NAME, LOGFILE_GROUP_NUMBER, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE FILE_NAME = 'undo_10.dat';
+--------------------+----------------------+----------------+
| LOGFILE_GROUP_NAME | LOGFILE_GROUP_NUMBER | EXTRA          |
+--------------------+----------------------+----------------+
| lg_3               |                   11 | CLUSTER_NODE=3 |
| lg_3               |                   11 | CLUSTER_NODE=4 |
+--------------------+----------------------+----------------+
2 rows in set (0.06 sec)
```

CREATE LOGFILE GROUP was added in MySQL 5.1.6. In MySQL 5.1, it is useful only with Disk Data storage for MySQL Cluster. See Section 17.5.12, "MySQL Cluster Disk Data Tables".

13.1.15 CREATE PROCEDURE and CREATE FUNCTION Syntax

```
CREATE
    [DEFINER = { user | CURRENT_USER }]
    PROCEDURE sp_name ([proc_parameter[,...]])
    [characteristic ...] routine_body

CREATE
    [DEFINER = { user | CURRENT_USER }]
    FUNCTION sp_name ([func_parameter[,...]])
    RETURNS type
    [characteristic ...] routine_body

proc_parameter:
    [ IN | OUT | INOUT ] param_name type
```

```
func_parameter:
    param_name type

type:
    Any valid MySQL data type

characteristic:
    COMMENT 'string'
  | LANGUAGE SQL
  | [NOT] DETERMINISTIC
  | { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  | SQL SECURITY { DEFINER | INVOKER }

routine_body:
    Valid SQL routine statement
```

These statements create stored routines. By default, a routine is associated with the default database. To associate the routine explicitly with a given database, specify the name as `db_name.sp_name` when you create it.

The `CREATE FUNCTION` statement is also used in MySQL to support UDFs (user-defined functions). See Section 22.3, "Adding New Functions to MySQL". A UDF can be regarded as an external stored function. Stored functions share their namespace with UDFs. See Section 9.2.4, "Function Name Parsing and Resolution", for the rules describing how the server interprets references to different kinds of functions.

To invoke a stored procedure, use the `CALL` statement (see Section 13.2.1, "CALL Syntax"). To invoke a stored function, refer to it in an expression. The function returns a value during expression evaluation.

`CREATE PROCEDURE` and `CREATE FUNCTION` require the `CREATE ROUTINE` privilege. They might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section. If binary logging is enabled, `CREATE FUNCTION` might require the `SUPER` privilege, as described in Section 19.7, "Binary Logging of Stored Programs".

By default, MySQL automatically grants the `ALTER ROUTINE` and `EXECUTE` privileges to the routine creator. This behavior can be changed by disabling the `automatic_sp_privileges` system variable. See Section 19.2.2, "Stored Routines and MySQL Privileges".

The `DEFINER` and `SQL SECURITY` clauses specify the security context to be used when checking access privileges at routine execution time, as described later in this section.

If the routine name is the same as the name of a built-in SQL function, a syntax error occurs unless you use a space between the name and the following parenthesis when defining the routine or invoking it later. For this reason, avoid using the names of existing SQL functions for your own stored routines.

The `IGNORE_SPACE` SQL mode applies to built-in functions, not to stored routines. It is always permissible to have spaces after a stored routine name, regardless of whether `IGNORE_SPACE` is enabled.

The parameter list enclosed within parentheses must always be present. If there are no parameters, an empty parameter list of `()` should be used. Parameter names are not case sensitive.

Each parameter is an `IN` parameter by default. To specify otherwise for a parameter, use the keyword `OUT` or `INOUT` before the parameter name.

Note

Specifying a parameter as `IN`, `OUT`, or `INOUT` is valid only for a `PROCEDURE`. For a `FUNCTION`, parameters are always regarded as `IN` parameters.

An `IN` parameter passes a value into a procedure. The procedure might modify the value, but the modification is not visible to the caller when the procedure returns. An `OUT` parameter passes a value from

the procedure back to the caller. Its initial value is `NULL` within the procedure, and its value is visible to the caller when the procedure returns. An `INOUT` parameter is initialized by the caller, can be modified by the procedure, and any change made by the procedure is visible to the caller when the procedure returns.

For each `OUT` or `INOUT` parameter, pass a user-defined variable in the `CALL` statement that invokes the procedure so that you can obtain its value when the procedure returns. If you are calling the procedure from within another stored procedure or function, you can also pass a routine parameter or local routine variable as an `IN` or `INOUT` parameter.

Routine parameters cannot be referenced in statements prepared within the routine; see Section C.1, "Restrictions on Stored Programs".

The following example shows a simple stored procedure that uses an `OUT` parameter:

```
mysql> delimiter //

mysql> CREATE PROCEDURE simpleproc (OUT param1 INT)
    -> BEGIN
    ->   SELECT COUNT(*) INTO param1 FROM t;
    -> END//
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter ;

mysql> CALL simpleproc(@a);
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @a;
+------+
| @a   |
+------+
| 3    |
+------+
1 row in set (0.00 sec)
```

The example uses the `mysql` client `delimiter` command to change the statement delimiter from `;` to `//` while the procedure is being defined. This enables the `;` delimiter used in the procedure body to be passed through to the server rather than being interpreted by `mysql` itself. See Section 19.1, "Defining Stored Programs".

The `RETURNS` clause may be specified only for a `FUNCTION`, for which it is mandatory. It indicates the return type of the function, and the function body must contain a `RETURN` *value* statement. If the `RETURN` statement returns a value of a different type, the value is coerced to the proper type. For example, if a function specifies an `ENUM` or `SET` value in the `RETURNS` clause, but the `RETURN` statement returns an integer, the value returned from the function is the string for the corresponding `ENUM` member of set of `SET` members.

The following example function takes a parameter, performs an operation using an SQL function, and returns the result. In this case, it is unnecessary to use `delimiter` because the function definition contains no internal `;` statement delimiters:

```
mysql> CREATE FUNCTION hello (s CHAR(20))
mysql> RETURNS CHAR(50) DETERMINISTIC
    -> RETURN CONCAT('Hello, ',s,'!');
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT hello('world');
+----------------+
| hello('world') |
+----------------+
```

```
| Hello, world! |
+----------------+
1 row in set (0.00 sec)
```

Parameter types and function return types can be declared to use any valid data type, except that the `COLLATE` attribute cannot be used.

The `routine_body` consists of a valid SQL routine statement. This can be a simple statement such as `SELECT` or `INSERT`, or a compound statement written using `BEGIN` and `END`. Compound statements can contain declarations, loops, and other control structure statements. The syntax for these statements is described in Section 13.6, "MySQL Compound-Statement Syntax".

MySQL permits routines to contain DDL statements, such as `CREATE` and `DROP`. MySQL also permits stored procedures (but not stored functions) to contain SQL transaction statements such as `COMMIT`. Stored functions may not contain statements that perform explicit or implicit commit or rollback. Support for these statements is not required by the SQL standard, which states that each DBMS vendor may decide whether to permit them.

Statements that return a result set can be used within a stored procedure but not within a stored function. This prohibition includes `SELECT` statements that do not have an `INTO` `var_list` clause and other statements such as `SHOW`, `EXPLAIN`, and `CHECK TABLE`. For statements that can be determined at function definition time to return a result set, a `Not allowed to return a result set from a function` error occurs (`ER_SP_NO_RETSET`). For statements that can be determined only at runtime to return a result set, a `PROCEDURE %s can't return a result set in the given context` error occurs (`ER_SP_BADSELECT`).

`USE` statements within stored routines are not permitted. When a routine is invoked, an implicit `USE` `db_name` is performed (and undone when the routine terminates). This causes the routine to have the given default database while it executes. References to objects in databases other than the routine default database should be qualified with the appropriate database name.

For additional information about statements that are not permitted in stored routines, see Section C.1, "Restrictions on Stored Programs".

For information about invoking stored procedures from within programs written in a language that has a MySQL interface, see Section 13.2.1, "CALL Syntax".

MySQL stores the `sql_mode` system variable setting in effect when a routine is created or altered, and always executes the routine with this setting in force, *regardless of the current server SQL mode when the routine begins executing*.

The switch from the SQL mode of the invoker to that of the routine occurs after evaluation of arguments and assignment of the resulting values to routine parameters. If you define a routine in strict SQL mode but invoke it in nonstrict mode, assignment of arguments to routine parameters does not take place in strict mode. If you require that expressions passed to a routine be assigned in strict SQL mode, you should invoke the routine with strict mode in effect.

The `COMMENT` characteristic is a MySQL extension, and may be used to describe the stored routine. This information is displayed by the `SHOW CREATE PROCEDURE` and `SHOW CREATE FUNCTION` statements.

The `LANGUAGE` characteristic indicates the language in which the routine is written. The server ignores this characteristic; only SQL routines are supported.

A routine is considered "deterministic" if it always produces the same result for the same input parameters, and "not deterministic" otherwise. If neither `DETERMINISTIC` nor `NOT DETERMINISTIC` is given in the routine definition, the default is `NOT DETERMINISTIC`. To declare that a function is deterministic, you must specify `DETERMINISTIC` explicitly.

Assessment of the nature of a routine is based on the "honesty" of the creator: MySQL does not check that a routine declared `DETERMINISTIC` is free of statements that produce nondeterministic results. However, misdeclaring a routine might affect results or affect performance. Declaring a nondeterministic routine as `DETERMINISTIC` might lead to unexpected results by causing the optimizer to make incorrect execution plan choices. Declaring a deterministic routine as `NONDETERMINISTIC` might diminish performance by causing available optimizations not to be used. Prior to MySQL 5.1.21, the `DETERMINISTIC` characteristic is accepted, but not used by the optimizer.

If binary logging is enabled, the `DETERMINISTIC` characteristic affects which routine definitions MySQL accepts. See Section 19.7, "Binary Logging of Stored Programs".

A routine that contains the `NOW()` function (or its synonyms) or `RAND()` is nondeterministic, but it might still be replication-safe. For `NOW()`, the binary log includes the timestamp and replicates correctly. `RAND()` also replicates correctly as long as it is called only a single time during the execution of a routine. (You can consider the routine execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

Several characteristics provide information about the nature of data use by the routine. In MySQL, these characteristics are advisory only. The server does not use them to constrain what kinds of statements a routine will be permitted to execute.

- `CONTAINS SQL` indicates that the routine does not contain statements that read or write data. This is the default if none of these characteristics is given explicitly. Examples of such statements are `SET @x = 1` or `DO RELEASE_LOCK('abc')`, which execute but neither read nor write data.

- `NO SQL` indicates that the routine contains no SQL statements.

- `READS SQL DATA` indicates that the routine contains statements that read data (for example, `SELECT`), but not statements that write data.

- `MODIFIES SQL DATA` indicates that the routine contains statements that may write data (for example, `INSERT` or `DELETE`).

The `SQL SECURITY` characteristic can be `DEFINER` or `INVOKER` to specify the security context; that is, whether the routine executes using the privileges of the account named in the routine `DEFINER` clause or the user who invokes it. This account must have permission to access the database with which the routine is associated. The default value is `DEFINER`. The user who invokes the routine must have the `EXECUTE` privilege for it, as must the `DEFINER` account if the routine executes in definer security context.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at routine execution time for routines that have the `SQL SECURITY DEFINER` characteristic. The `DEFINER` clause was added in MySQL 5.1.8.

If a *user* value is given for the `DEFINER` clause, it should be a MySQL account specified as `'user_name'@'host_name'` (the same format used in the `GRANT` statement), `CURRENT_USER`, or `CURRENT_USER()`. The default `DEFINER` value is the user who executes the `CREATE PROCEDURE` or `CREATE FUNCTION` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

If you specify the `DEFINER` clause, these rules determine the valid `DEFINER` user values:

- If you do not have the `SUPER` privilege, the only permitted *user* value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.

- If you have the `SUPER` privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.

- Although it is possible to create a routine with a nonexistent `DEFINER` account, an error occurs at routine execution time if the `SQL SECURITY` value is `DEFINER` but the definer account does not exist.

For more information about stored routine security, see Section 19.6, "Access Control for Stored Programs and Views".

Within a stored routine that is defined with the `SQL SECURITY DEFINER` characteristic, `CURRENT_USER` returns the routine's `DEFINER` value. For information about user auditing within stored routines, see Section 6.3.6, "SQL-Based MySQL Account Activity Auditing".

Consider the following procedure, which displays a count of the number of MySQL accounts listed in the `mysql.user` table:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE account_count()
BEGIN
  SELECT 'Number of accounts:', COUNT(*) FROM mysql.user;
END;
```

The procedure is assigned a `DEFINER` account of `'admin'@'localhost'` no matter which user defines it. It executes with the privileges of that account no matter which user invokes it (because the default security characteristic is `DEFINER`). The procedure succeeds or fails depending on whether invoker has the `EXECUTE` privilege for it and `'admin'@'localhost'` has the `SELECT` privilege for the `mysql.user` table.

Now suppose that the procedure is defined with the `SQL SECURITY INVOKER` characteristic:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE account_count()
SQL SECURITY INVOKER
BEGIN
  SELECT 'Number of accounts:', COUNT(*) FROM mysql.user;
END;
```

The procedure still has a `DEFINER` of `'admin'@'localhost'`, but in this case, it executes with the privileges of the invoking user. Thus, the procedure succeeds or fails depending on whether the invoker has the `EXECUTE` privilege for it and the `SELECT` privilege for the `mysql.user` table.

The server handles the data type of a routine parameter, local routine variable created with `DECLARE`, or function return value as follows:

- Assignments are checked for data type mismatches and overflow. Conversion and overflow problems result in warnings, or errors in strict SQL mode.

- Only scalar values can be assigned. For example, a statement such as `SET x = (SELECT 1, 2)` is invalid.

- For character data types, if there is a `CHARACTER SET` attribute in the declaration, the specified character set and its default collation are used. If there is no such attribute, the database character set in effect at routine creation time and its default collation are used. The `COLLATE` attribute is not supported. (This includes use of `BINARY`, which in this context specifies the binary collation of the character set.)

  To avoid having the server use the database character set and collation, provide an explicit `CHARACTER SET` attribute for character data parameters.

  If you change the database default character set or collation, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults.

  The database character set and collation are given by the value of the `character_set_database` and `collation_database` system variables. For more information, see Section 10.1.3.2, "Database Character Set and Collation".

13.1.16 CREATE SERVER Syntax

```
CREATE SERVER server_name
    FOREIGN DATA WRAPPER wrapper_name
    OPTIONS (option [, option] ...)

option:
  { HOST character-literal
  | DATABASE character-literal
  | USER character-literal
  | PASSWORD character-literal
  | SOCKET character-literal
  | OWNER character-literal
  | PORT numeric-literal }
```

This statement creates the definition of a server for use with the `FEDERATED` storage engine. The `CREATE SERVER` statement creates a new row in the `servers` table in the `mysql` database. This statement requires the `SUPER` privilege.

The `server_name` should be a unique reference to the server. Server definitions are global within the scope of the server, it is not possible to qualify the server definition to a specific database. `server_name` has a maximum length of 64 characters (names longer than 64 characters are silently truncated), and is case insensitive. You may specify the name as a quoted string.

The `wrapper_name` should be `mysql`, and may be quoted with single quotation marks. Other values for `wrapper_name` are not currently supported.

For each `option` you must specify either a character literal or numeric literal. Character literals are UTF-8, support a maximum length of 64 characters and default to a blank (empty) string. String literals are silently truncated to 64 characters. Numeric literals must be a number between 0 and 9999, default value is 0.

> **Note**
>
> The `OWNER` option is currently not applied, and has no effect on the ownership or operation of the server connection that is created.

The `CREATE SERVER` statement creates an entry in the `mysql.servers` table that can later be used with the `CREATE TABLE` statement when creating a `FEDERATED` table. The options that you specify will be used to populate the columns in the `mysql.servers` table. The table columns are `Server_name`, `Host`, `Db`, `Username`, `Password`, `Port` and `Socket`.

For example:

```
CREATE SERVER s
FOREIGN DATA WRAPPER mysql
OPTIONS (USER 'Remote', HOST '192.168.1.106', DATABASE 'test');
```

Be sure to specify all options necessary to establish a connection to the server. The user name, host name, and database name are mandatory. Other options might be required as well, such as password.

The data stored in the table can be used when creating a connection to a `FEDERATED` table:

```
CREATE TABLE t (s1 INT) ENGINE=FEDERATED CONNECTION='s';
```

For more information, see Section 14.11, "The FEDERATED Storage Engine".

`CREATE SERVER` causes an implicit commit.

In MySQL 5.1, `CREATE SERVER` is written to the binary log only when using row-based logging. It is not logged when `binlog_format` is equal to `STATEMENT` or `MIXED`.

`CREATE` `SERVER` was added in MySQL 5.1.15.

13.1.17 CREATE TABLE Syntax

```
CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    (create_definition,...)
    [table_options]
    [partition_options]

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    [(create_definition,...)]
    [table_options]
    [partition_options]
    select_statement

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    { LIKE old_tbl_name | (LIKE old_tbl_name) }

create_definition:
    col_name column_definition
  | [CONSTRAINT [symbol]] PRIMARY KEY [index_type] (index_col_name,...)
      [index_option] ...
  | {INDEX|KEY} [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] UNIQUE [INDEX|KEY]
      [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | {FULLTEXT|SPATIAL} [INDEX|KEY] [index_name] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] FOREIGN KEY
      [index_name] (index_col_name,...) reference_definition
  | CHECK (expr)

column_definition:
    data_type [NOT NULL | NULL] [DEFAULT default_value]
      [AUTO_INCREMENT] [UNIQUE [KEY] | [PRIMARY] KEY]
      [COMMENT 'string']
      [COLUMN_FORMAT {FIXED|DYNAMIC|DEFAULT}]
      [STORAGE {DISK|MEMORY|DEFAULT}]
      [reference_definition]

data_type:
    BIT[(length)]
  | TINYINT[(length)] [UNSIGNED] [ZEROFILL]
  | SMALLINT[(length)] [UNSIGNED] [ZEROFILL]
  | MEDIUMINT[(length)] [UNSIGNED] [ZEROFILL]
  | INT[(length)] [UNSIGNED] [ZEROFILL]
  | INTEGER[(length)] [UNSIGNED] [ZEROFILL]
  | BIGINT[(length)] [UNSIGNED] [ZEROFILL]
  | REAL[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DOUBLE[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | FLOAT[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DECIMAL[(length[,decimals])] [UNSIGNED] [ZEROFILL]
  | NUMERIC[(length[,decimals])] [UNSIGNED] [ZEROFILL]
  | DATE
  | TIME
  | TIMESTAMP
  | DATETIME
  | YEAR
  | CHAR[(length)] [BINARY]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | VARCHAR(length) [BINARY]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | BINARY[(length)]
  | VARBINARY(length)
```

```
  | TINYBLOB
  | BLOB
  | MEDIUMBLOB
  | LONGBLOB
  | TINYTEXT [BINARY]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | TEXT [BINARY]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | MEDIUMTEXT [BINARY]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | LONGTEXT [BINARY]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | ENUM(value1,value2,value3,...)
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | SET(value1,value2,value3,...)
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | spatial_type

index_col_name:
    col_name [(length)] [ASC | DESC]

index_type:
    USING {BTREE | HASH}

index_option:
    KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name

reference_definition:
    REFERENCES tbl_name (index_col_name,...)
      [MATCH FULL | MATCH PARTIAL | MATCH SIMPLE]
      [ON DELETE reference_option]
      [ON UPDATE reference_option]

reference_option:
    RESTRICT | CASCADE | SET NULL | NO ACTION

table_options:
    table_option [[,] table_option] ...

table_option:
    ENGINE [=] engine_name
  | AUTO_INCREMENT [=] value
  | AVG_ROW_LENGTH [=] value
  | [DEFAULT] CHARACTER SET [=] charset_name
  | CHECKSUM [=] {0 | 1}
  | [DEFAULT] COLLATE [=] collation_name
  | COMMENT [=] 'string'
  | CONNECTION [=] 'connect_string'
  | DATA DIRECTORY [=] 'absolute path to directory'
  | DELAY_KEY_WRITE [=] {0 | 1}
  | INDEX DIRECTORY [=] 'absolute path to directory'
  | INSERT_METHOD [=] { NO | FIRST | LAST }
  | KEY_BLOCK_SIZE [=] value
  | MAX_ROWS [=] value
  | MIN_ROWS [=] value
  | PACK_KEYS [=] {0 | 1 | DEFAULT}
  | PASSWORD [=] 'string'
  | ROW_FORMAT [=] {DEFAULT|DYNAMIC|FIXED|COMPRESSED|REDUNDANT|COMPACT}
  | TABLESPACE tablespace_name [STORAGE {DISK|MEMORY|DEFAULT}]
  | UNION [=] (tbl_name[,tbl_name]...)

partition_options:
    PARTITION BY
        { [LINEAR] HASH(expr)
        | [LINEAR] KEY(column_list)
```

```
            | RANGE(expr)
            | LIST(expr) }
    [PARTITIONS num]
    [SUBPARTITION BY
        { [LINEAR] HASH(expr)
        | [LINEAR] KEY(column_list) }
      [SUBPARTITIONS num]
    ]
    [(partition_definition [, partition_definition] ...)]

partition_definition:
    PARTITION partition_name
        [VALUES
            {LESS THAN {(expr) | MAXVALUE}
            |
            IN (value_list)}]
        [[STORAGE] ENGINE [=] engine_name]
        [COMMENT [=] 'comment_text' ]
        [DATA DIRECTORY [=] 'data_dir']
        [INDEX DIRECTORY [=] 'index_dir']
        [MAX_ROWS [=] max_number_of_rows]
        [MIN_ROWS [=] min_number_of_rows]
        [TABLESPACE [=] tablespace_name]
        [NODEGROUP [=] node_group_id]
        [(subpartition_definition [, subpartition_definition] ...)]

subpartition_definition:
    SUBPARTITION logical_name
        [[STORAGE] ENGINE [=] engine_name]
        [COMMENT [=] 'comment_text' ]
        [DATA DIRECTORY [=] 'data_dir']
        [INDEX DIRECTORY [=] 'index_dir']
        [MAX_ROWS [=] max_number_of_rows]
        [MIN_ROWS [=] min_number_of_rows]
        [TABLESPACE [=] tablespace_name]
        [NODEGROUP [=] node_group_id]

select_statement:
    [IGNORE | REPLACE] [AS] SELECT ...   (Some valid select statement)
```

CREATE TABLE creates a table with the given name. You must have the CREATE privilege for the table.

Rules for permissible table names are given in Section 9.2, "Schema Object Names". By default, the table is created in the default database. An error occurs if the table exists, if there is no default database, or if the database does not exist.

The table name can be specified as *db_name*.*tbl_name* to create the table in a specific database. This works regardless of whether there is a default database, assuming that the database exists. If you use quoted identifiers, quote the database and table names separately. For example, write `mydb`.`mytbl`, not `mydb.mytbl`.

Cloning or Copying a Table

Use CREATE TABLE ... LIKE to create an empty table based on the definition of another table, including any column attributes and indexes defined in the original table:

```
CREATE TABLE new_tbl LIKE orig_tbl;
```

For more information, see Section 13.1.17.1, "CREATE TABLE ... LIKE Syntax".

To create one table from another, add a SELECT statement at the end of the CREATE TABLE statement:

```
CREATE TABLE new_tbl SELECT * FROM orig_tbl;
```

For more information, see Section 13.1.17.2, "CREATE TABLE ... SELECT Syntax".

Temporary Tables

You can use the `TEMPORARY` keyword when creating a table. A `TEMPORARY` table is visible only to the current session, and is dropped automatically when the session is closed. This means that two different sessions can use the same temporary table name without conflicting with each other or with an existing non-`TEMPORARY` table of the same name. (The existing table is hidden until the temporary table is dropped.) To create temporary tables, you must have the `CREATE TEMPORARY TABLES` privilege.

> **Note**
>
> `CREATE TABLE` does not automatically commit the current active transaction if you use the `TEMPORARY` keyword.

> **Note**
>
> `TEMPORARY` tables have a very loose relationship with databases (schemas). Dropping a database does not automatically drop any `TEMPORARY` tables created within that database. Also, you can create a `TEMPORARY` table in a nonexistent database if you qualify the table name with the database name in the `CREATE TABLE` statement. In this case, all subsequent references to the table must be qualified with the database name.

Existing Table with Same Name

The keywords `IF NOT EXISTS` prevent an error from occurring if the table exists. However, there is no verification that the existing table has a structure identical to that indicated by the `CREATE TABLE` statement.

Physical Representation

MySQL represents each table by an `.frm` table format (definition) file in the database directory. The storage engine for the table might create other files as well.

For `InnoDB` tables, the file storage is controlled by the `innodb_file_per_table` configuration option. For each `InnoDB` table created when this option is turned on, the table data and all associated indexes are stored in a .ibd file located inside the database directory. When this option is turned off, all `InnoDB` tables and indexes are stored in the system tablespace, represented by one or more ibdata* files.

For `MyISAM` tables, the storage engine creates data and index files. Thus, for each `MyISAM` table `tbl_name`, there are three disk files.

File	Purpose
`tbl_name.frm`	Table format (definition) file
`tbl_name.MYD`	Data file
`tbl_name.MYI`	Index file

Chapter 14, *Storage Engines*, describes what files each storage engine creates to represent tables. If a table name contains special characters, the names for the table files contain encoded versions of those characters as described in Section 9.2.3, "Mapping of Identifiers to File Names".

Data Types and Attributes for Columns

`data_type` represents the data type in a column definition. `spatial_type` represents a spatial data type. The data type syntax shown is representative only. For a full description of the syntax available for

specifying column data types, as well as information about the properties of each type, see Chapter 11, *Data Types*, and Section 11.5, "Extensions for Spatial Data".

Some attributes do not apply to all data types. `AUTO_INCREMENT` applies only to integer and floating-point types. `DEFAULT` does not apply to the `BLOB` or `TEXT` types.

- If neither `NULL` nor `NOT NULL` is specified, the column is treated as though `NULL` had been specified.

- An integer or floating-point column can have the additional attribute `AUTO_INCREMENT`. When you insert a value of `NULL` (recommended) or `0` into an indexed `AUTO_INCREMENT` column, the column is set to the next sequence value. Typically this is *value*+1, where *value* is the largest value for the column currently in the table. `AUTO_INCREMENT` sequences begin with `1`.

  To retrieve an `AUTO_INCREMENT` value after inserting a row, use the `LAST_INSERT_ID()` SQL function or the `mysql_insert_id()` C API function. See Section 12.14, "Information Functions", and Section 21.8.7.37, "mysql_insert_id()".

  If the `NO_AUTO_VALUE_ON_ZERO` SQL mode is enabled, you can store `0` in `AUTO_INCREMENT` columns as `0` without generating a new sequence value. See Section 5.1.7, "Server SQL Modes".

  > **Note**
  >
  > There can be only one `AUTO_INCREMENT` column per table, it must be indexed, and it cannot have a `DEFAULT` value. An `AUTO_INCREMENT` column works properly only if it contains only positive values. Inserting a negative number is regarded as inserting a very large positive number. This is done to avoid precision problems when numbers "wrap" over from positive to negative and also to ensure that you do not accidentally get an `AUTO_INCREMENT` column that contains `0`.

  For `MyISAM` tables, you can specify an `AUTO_INCREMENT` secondary column in a multiple-column key. See Section 3.6.9, "Using AUTO_INCREMENT".

  To make MySQL compatible with some ODBC applications, you can find the `AUTO_INCREMENT` value for the last inserted row with the following query:

  ```
  SELECT * FROM tbl_name WHERE auto_col IS NULL
  ```

  This method requires that `sql_auto_is_null` variable is not set to 0. See Section 5.1.4, "Server System Variables".

  For `InnoDB` and `AUTO_INCREMENT`, see Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB". For information about `AUTO_INCREMENT` and MySQL Replication, see Section 16.4.1.1, "Replication and AUTO_INCREMENT".

- Character data types (`CHAR`, `VARCHAR`, `TEXT`) can include `CHARACTER SET` and `COLLATE` attributes to specify the character set and collation for the column. For details, see Section 10.1, "Character Set Support". `CHARSET` is a synonym for `CHARACTER SET`. Example:

  ```
  CREATE TABLE t (c CHAR(20) CHARACTER SET utf8 COLLATE utf8_bin);
  ```

  MySQL 5.1 interprets length specifications in character column definitions in characters. Lengths for `BINARY` and `VARBINARY` are in bytes.

- The `DEFAULT` clause specifies a default value for a column. With one exception, the default value must be a constant; it cannot be a function or an expression. This means, for example, that you cannot

set the default for a date column to be the value of a function such as `NOW()` or `CURRENT_DATE`. The exception is that you can specify `CURRENT_TIMESTAMP` as the default for a `TIMESTAMP` column. See Section 11.3.5, "Automatic Initialization and Updating for TIMESTAMP".

If a column definition includes no explicit `DEFAULT` value, MySQL determines the default value as described in Section 11.6, "Data Type Default Values".

`BLOB` and `TEXT` columns cannot be assigned a default value.

`CREATE TABLE` fails if a date-valued default is not correct according to the `NO_ZERO_IN_DATE` SQL mode, even if strict SQL mode is not enabled. For example, `c1 DATE DEFAULT '2010-00-00'` causes `CREATE TABLE` to fail with `Invalid default value for 'c1'`.

Native default value handling in MySQL Cluster NDB 7.0.15, MySQL Cluster NDB 7.1.4, and later. Starting with MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, default values for table columns are stored by `NDBCLUSTER`, rather than by the MySQL server as was previously the case. Because less data must be sent from an SQL node to the data nodes, inserts on tables having column value defaults can be performed more efficiently than before.

Tables created using MySQL Cluster releases previous to the introduction of native default value support can still be used in MySQL Cluster NDB 7.0.15 and later, as well as well as MySQL Cluster NDB 7.1.4 and later. However, such tables continue to use defaults supplied by the MySQL server until they are upgraded. This upgrade can be done by means of an offline `ALTER TABLE` statement.

> **⚠ Important**
>
> You cannot set or change a table column's default value using a noncopying `ALTER TABLE` operation.

Tables created in versions of MySQL Cluster that support native default values cannot be used with versions of MySQL Cluster that lack this support.

`NDBCLUSTER` tables supporting native default values are still subject to the restrictions on default values imposed by the MySQL server. For more information, see Section 11.6, "Data Type Default Values".

- A comment for a column can be specified with the `COMMENT` option, up to 255 characters long. The comment is displayed by the `SHOW CREATE TABLE` and `SHOW FULL COLUMNS` statements.

- In MySQL Cluster—beginning with MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2—it is also possible to specify a data storage format for individual columns of `NDB` tables using `COLUMN_FORMAT`. Permissible column formats are `FIXED`, `DYNAMIC`, and `DEFAULT`. `FIXED` is used to specify fixed-width storage, `DYNAMIC` permits the column to be variable-width, and `DEFAULT` causes the column to use fixed-width or variable-width storage as determined by the column's data type (possibly overridden by a `ROW_FORMAT` specifier).

  For `NDB` tables, the default value for `COLUMN_FORMAT` is `DEFAULT`.

  `COLUMN_FORMAT` currently has no effect on columns of tables using storage engines other than `NDB`. The `COLUMN_FORMAT` keyword is supported only in the build of `mysqld` that is supplied with MySQL Cluster; it is not recognized in MySQL 5.1, where attempting to use `COLUMN_FORMAT` causes a syntax error.

- For `NDB` tables, beginning with MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2, it is also possible to specify whether the column is stored on disk or in memory by using a `STORAGE` clause. `STORAGE DISK` causes the column to be stored on disk, and `STORAGE MEMORY` causes in-memory storage to be used. The `CREATE TABLE` statement used must still include a `TABLESPACE` clause:

```
mysql> CREATE TABLE t1 (
    ->        c1 INT STORAGE DISK,
    ->        c2 INT STORAGE MEMORY
    -> ) ENGINE NDB;
ERROR 1005 (HY000): Can't create table 'c.t1' (errno: 140)

mysql> CREATE TABLE t1 (
    ->        c1 INT STORAGE DISK,
    ->        c2 INT STORAGE MEMORY
    -> ) TABLESPACE ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.06 sec)
```

For `NDB` tables, `STORAGE DEFAULT` is equivalent to `STORAGE MEMORY`.

The `STORAGE` clause has no effect on tables using storage engines other than `NDB`. The `STORAGE` keyword is supported only in the build of `mysqld` that is supplied with MySQL Cluster; it is not recognized in any other version of MySQL, where any attempt to use the `STORAGE` keyword causes a syntax error.

- `KEY` is normally a synonym for `INDEX`. The key attribute `PRIMARY KEY` can also be specified as just `KEY` when given in a column definition. This was implemented for compatibility with other database systems.

- A `UNIQUE` index creates a constraint such that all values in the index must be distinct. An error occurs if you try to add a new row with a key value that matches an existing row. For all engines, a `UNIQUE` index permits multiple `NULL` values for columns that can contain `NULL`.

- A `PRIMARY KEY` is a unique index where all key columns must be defined as `NOT NULL`. If they are not explicitly declared as `NOT NULL`, MySQL declares them so implicitly (and silently). A table can have only one `PRIMARY KEY`. The name of a `PRIMARY KEY` is always `PRIMARY`, which thus cannot be used as the name for any other kind of index.

  If you do not have a `PRIMARY KEY` and an application asks for the `PRIMARY KEY` in your tables, MySQL returns the first `UNIQUE` index that has no `NULL` columns as the `PRIMARY KEY`.

  In `InnoDB` tables, keep the `PRIMARY KEY` short to minimize storage overhead for secondary indexes. Each secondary index entry contains a copy of the primary key columns for the corresponding row. (See Section 14.6.3.2, "InnoDB Table and Index Structures".)

- In the created table, a `PRIMARY KEY` is placed first, followed by all `UNIQUE` indexes, and then the nonunique indexes. This helps the MySQL optimizer to prioritize which index to use and also more quickly to detect duplicated `UNIQUE` keys.

- A `PRIMARY KEY` can be a multiple-column index. However, you cannot create a multiple-column index using the `PRIMARY KEY` key attribute in a column specification. Doing so only marks that single column as primary. You must use a separate `PRIMARY KEY(index_col_name, ...)` clause.

- If a `PRIMARY KEY` or `UNIQUE` index consists of only one column that has an integer type, you can also refer to the column as `_rowid` in `SELECT` statements.

- In MySQL, the name of a `PRIMARY KEY` is `PRIMARY`. For other indexes, if you do not assign a name, the index is assigned the same name as the first indexed column, with an optional suffix (`_2`, `_3`, ...) to make it unique. You can see index names for a table using `SHOW INDEX FROM tbl_name`. See Section 13.7.5.23, "SHOW INDEX Syntax".

- Some storage engines permit you to specify an index type when creating an index. The syntax for the `index_type` specifier is `USING type_name`.

Example:

```
CREATE TABLE lookup
  (id INT, INDEX USING BTREE (id))
  ENGINE = MEMORY;
```

Before MySQL 5.1.10, `USING` can be given only before the index column list. As of 5.1.10, the preferred position is after the column list. Support for use of the option before the column list will be removed in a future MySQL release.

`index_option` values specify additional options for an index. `USING` is one such option. For details about permissible `index_option` values, see Section 13.1.13, "CREATE INDEX Syntax".

For more information about indexes, see Section 8.3.1, "How MySQL Uses Indexes".

• In MySQL 5.1, only the `InnoDB`, `MyISAM`, and `MEMORY` storage engines support indexes on columns that can have `NULL` values. In other cases, you must declare indexed columns as `NOT NULL` or an error results.

• For `CHAR`, `VARCHAR`, `BINARY`, and `VARBINARY` columns, indexes can be created that use only the leading part of column values, using `col_name(length)` syntax to specify an index prefix length. `BLOB` and `TEXT` columns also can be indexed, but a prefix length *must* be given. Prefix lengths are given in characters for nonbinary string types and in bytes for binary string types. That is, index entries consist of the first `length` characters of each column value for `CHAR`, `VARCHAR`, and `TEXT` columns, and the first `length` bytes of each column value for `BINARY`, `VARBINARY`, and `BLOB` columns. Indexing only a prefix of column values like this can make the index file much smaller. For additional information about index prefixes, see Section 13.1.13, "CREATE INDEX Syntax".

Only the `InnoDB` and `MyISAM` storage engines support indexing on `BLOB` and `TEXT` columns. For example:

```
CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));
```

Prefixes can be up to 1000 bytes long (767 bytes for `InnoDB` tables).

Note

Prefix limits are measured in bytes, whereas the prefix length in `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements is interpreted as number of characters for nonbinary string types (`CHAR`, `VARCHAR`, `TEXT`) and number of bytes for binary string types (`BINARY`, `VARBINARY`, `BLOB`). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

• An `index_col_name` specification can end with `ASC` or `DESC`. These keywords are permitted for future extensions for specifying ascending or descending index value storage. Currently, they are parsed but ignored; index values are always stored in ascending order.

• When you use `ORDER BY` or `GROUP BY` on a column in a `SELECT`, the server sorts values using only the initial number of bytes indicated by the `max_sort_length` system variable.

• You can create special `FULLTEXT` indexes, which are used for full-text searches. Only the `MyISAM` storage engine supports `FULLTEXT` indexes. They can be created only from `CHAR`, `VARCHAR`, and `TEXT` columns. Indexing always happens over the entire column; column prefix indexing is not supported and any prefix length is ignored if specified. See Section 12.9, "Full-Text Search Functions", for details of

operation. A `WITH PARSER` clause can be specified as an *`index_option`* value to associate a parser plugin with the index if full-text indexing and searching operations need special handling. This clause is valid only for `FULLTEXT` indexes. See Section 22.2, "The MySQL Plugin API", for details on creating plugins.

- You can create `SPATIAL` indexes on spatial data types. Spatial types are supported only for `MyISAM` tables and indexed columns must be declared as `NOT NULL`. See Section 11.5, "Extensions for Spatial Data".

- `InnoDB` tables support checking of foreign key constraints. The columns of the referenced table must always be explicitly named. Both `ON DELETE` and `ON UPDATE` actions on foreign keys. For more detailed information and examples, see Section 13.1.17.3, "Using FOREIGN KEY Constraints". For information specific to foreign keys in `InnoDB`, see Section 14.6.6.6, "InnoDB and FOREIGN KEY Constraints".

  For other storage engines, MySQL Server parses and ignores the `FOREIGN KEY` and `REFERENCES` syntax in `CREATE TABLE` statements. The `CHECK` clause is parsed but ignored by all storage engines. See Section 1.8.2.4, "Foreign Key Differences".

  Important

  For users familiar with the ANSI/ISO SQL Standard, please note that no storage engine, including `InnoDB`, recognizes or enforces the `MATCH` clause used in referential integrity constraint definitions. Use of an explicit `MATCH` clause will not have the specified effect, and also causes `ON DELETE` and `ON UPDATE` clauses to be ignored. For these reasons, specifying `MATCH` should be avoided.

  The `MATCH` clause in the SQL standard controls how `NULL` values in a composite (multiple-column) foreign key are handled when comparing to a primary key. `InnoDB` essentially implements the semantics defined by `MATCH SIMPLE`, which permit a foreign key to be all or partially `NULL`. In that case, the (child table) row containing such a foreign key is permitted to be inserted, and does not match any row in the referenced (parent) table. It is possible to implement other semantics using triggers.

  Additionally, MySQL requires that the referenced columns be indexed for performance. However, `InnoDB` does not enforce any requirement that the referenced columns be declared `UNIQUE` or `NOT NULL`. The handling of foreign key references to nonunique keys or keys that contain `NULL` values is not well defined for operations such as `UPDATE` or `DELETE CASCADE`. You are advised to use foreign keys that reference only keys that are both `UNIQUE` (or `PRIMARY`) and `NOT NULL`.

  MySQL parses but ignores "inline `REFERENCES` specifications" (as defined in the SQL standard) where the references are defined as part of the column specification. MySQL accepts `REFERENCES` clauses only when specified as part of a separate `FOREIGN KEY` specification.

  Note

  Partitioned tables employing the `InnoDB` storage engine do not support foreign keys. See Section 18.5, "Restrictions and Limitations on Partitioning", for more information.

- There is a hard limit of 4096 columns per table, but the effective maximum may be less for a given table and depends on the factors discussed in Section C.7.4, "Limits on Table Column Count and Row Size".

The `TABLESPACE` and `STORAGE` table options were both introduced in MySQL 5.1.6. In MySQL 5.1, they are employed only with `NDBCLUSTER` tables. The tablespace named *`tablespace_name`* must already have been created using `CREATE TABLESPACE`. `STORAGE` determines the type of storage used (disk or memory), and can be one of `DISK`, `MEMORY`, or `DEFAULT`.

`TABLESPACE ... STORAGE DISK` assigns a table to a MySQL Cluster Disk Data tablespace. See Section 17.5.12, "MySQL Cluster Disk Data Tables", for more information.

> **Important**
>
> A `STORAGE` clause cannot be used in a `CREATE TABLE` statement without a `TABLESPACE` clause.

The `ENGINE` table option specifies the storage engine for the table.

Storage Engines

The `ENGINE` table option specifies the storage engine for the table, using one of the names shown in the following table. The engine name can be unquoted or quoted. The quoted name `'DEFAULT'` is equivalent to specifying the default storage engine name.

Storage Engine	Description
`ARCHIVE`	The archiving storage engine. See Section 14.12, "The ARCHIVE Storage Engine".
`CSV`	Tables that store rows in comma-separated values format. See Section 14.13, "The CSV Storage Engine".
`EXAMPLE`	An example engine. See Section 14.10, "The EXAMPLE Storage Engine".
`FEDERATED`	Storage engine that accesses remote tables. See Section 14.11, "The FEDERATED Storage Engine".
`HEAP`	This is a synonym for `MEMORY`.
`InnoDB`	Transaction-safe tables with row locking and foreign keys. See Section 14.6, "The InnoDB Storage Engine".
`MEMORY`	The data for this storage engine is stored only in memory. See Section 14.9, "The MEMORY Storage Engine".
`MERGE`	A collection of `MyISAM` tables used as one table. Also known as `MRG_MyISAM`. See Section 14.8, "The MERGE Storage Engine".
`MyISAM`	The binary portable storage engine that is the default storage engine used by MySQL. See Section 14.5, "The MyISAM Storage Engine".
`NDBCLUSTER`	Clustered, fault-tolerant, memory-based tables. Also known as `NDB`. See Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*.

If a storage engine is specified that is not available, MySQL uses the default engine instead. Normally, this is `MyISAM`. For example, if a table definition includes the `ENGINE=INNODB` option but the MySQL server does not support `INNODB` tables, the table is created as a `MyISAM` table. This makes it possible to have a replication setup where you have transactional tables on the master but tables created on the slave are nontransactional (to get more speed). In MySQL 5.1, a warning occurs if the storage engine specification is not honored.

Engine substitution can be controlled by the setting of the `NO_ENGINE_SUBSTITUTION` SQL mode, as described in Section 5.1.7, "Server SQL Modes".

> **Note**
>
> The older `TYPE` option was synonymous with `ENGINE`. `TYPE` has been deprecated since MySQL 4.0 but is still supported for backward compatibility in MySQL 5.1 (excepting MySQL 5.1.7). Since MySQL 5.1.8, it produces a warning. It is removed in MySQL 5.5. *You should not use `TYPE` in any new applications, and you should immediately begin conversion of existing applications to use `ENGINE` instead.* (See the Release Notes for MySQL 5.1.8.)

Optimizing Performance

The other table options are used to optimize the behavior of the table. In most cases, you do not have to specify any of them. These options apply to all storage engines unless otherwise indicated. Options that do not apply to a given storage engine may be accepted and remembered as part of the table definition. Such options then apply if you later use `ALTER TABLE` to convert the table to use a different storage engine.

- `AUTO_INCREMENT`

  The initial `AUTO_INCREMENT` value for the table. In MySQL 5.1, this works for `MyISAM`, `MEMORY`, and `InnoDB` tables. It also works for `ARCHIVE` tables as of MySQL 5.1.6. To set the first auto-increment value for engines that do not support the `AUTO_INCREMENT` table option, insert a "dummy" row with a value one less than the desired value after creating the table, and then delete the dummy row.

  For engines that support the `AUTO_INCREMENT` table option in `CREATE TABLE` statements, you can also use `ALTER TABLE` *tbl_name* `AUTO_INCREMENT = ` *N* to reset the `AUTO_INCREMENT` value. The value cannot be set lower than the maximum value currently in the column.

- `AVG_ROW_LENGTH`

  An approximation of the average row length for your table. You need to set this only for large tables with variable-size rows.

  When you create a `MyISAM` table, MySQL uses the product of the `MAX_ROWS` and `AVG_ROW_LENGTH` options to decide how big the resulting table is. If you don't specify either option, the maximum size for `MyISAM` data and index files is 256TB by default. (If your operating system does not support files that large, table sizes are constrained by the file size limit.) If you want to keep down the pointer sizes to make the index smaller and faster and you don't really need big files, you can decrease the default pointer size by setting the `myisam_data_pointer_size` system variable. (See Section 5.1.4, "Server System Variables".) If you want all your tables to be able to grow above the default limit and are willing to have your tables slightly slower and larger than necessary, you can increase the default pointer size by setting this variable. Setting the value to 7 permits table sizes up to 65,536TB.

- `[DEFAULT] CHARACTER SET`

  Specify a default character set for the table. `CHARSET` is a synonym for `CHARACTER SET`. If the character set name is `DEFAULT`, the database character set is used.

- `CHECKSUM`

  Set this to 1 if you want MySQL to maintain a live checksum for all rows (that is, a checksum that MySQL updates automatically as the table changes). This makes the table a little slower to update, but also makes it easier to find corrupted tables. The `CHECKSUM TABLE` statement reports the checksum. (`MyISAM` only.)

- `[DEFAULT] COLLATE`

  Specify a default collation for the table.

- `COMMENT`

  A comment for the table, up to 60 characters long.

- `CONNECTION`

  The connection string for a `FEDERATED` table.

  > **Note**
  >
  > Older versions of MySQL used a `COMMENT` option for the connection string.

- `DATA DIRECTORY`, `INDEX DIRECTORY`

  By using `DATA DIRECTORY='directory'` or `INDEX DIRECTORY='directory'` you can specify where the `MyISAM` storage engine should put a table's data file and index file. The directory must be the full path name to the directory, not a relative path.

  > **Important**
  >
  > Beginning with MySQL 5.1.23, table-level `DATA DIRECTORY` and `INDEX DIRECTORY` options are ignored for partitioned tables. (Bug #32091)

  These options work only when you are not using the `--skip-symbolic-links` option. Your operating system must also have a working, thread-safe `realpath()` call. See Section 8.12.4.2, "Using Symbolic Links for MyISAM Tables on Unix", for more complete information.

  If a `MyISAM` table is created with no `DATA DIRECTORY` option, the `.MYD` file is created in the database directory. By default, if `MyISAM` finds an existing `.MYD` file in this case, it overwrites it. The same applies to `.MYI` files for tables created with no `INDEX DIRECTORY` option. As of MySQL 5.1.23, to suppress this behavior, start the server with the `--keep_files_on_create` option, in which case `MyISAM` will not overwrite existing files and returns an error instead.

  If a `MyISAM` table is created with a `DATA DIRECTORY` or `INDEX DIRECTORY` option and an existing `.MYD` or `.MYI` file is found, MyISAM always returns an error. It will not overwrite a file in the specified directory.

  > **Important**
  >
  > Beginning with MySQL 5.1.24, you cannot use path names that contain the MySQL data directory with `DATA DIRECTORY` or `INDEX DIRECTORY`. This includes partitioned tables and individual table partitions. (See Bug #32167.)

- `DELAY_KEY_WRITE`

  Set this to 1 if you want to delay key updates for the table until the table is closed. See the description of the `delay_key_write` system variable in Section 5.1.4, "Server System Variables". (`MyISAM` only.)

- `INSERT_METHOD`

  If you want to insert data into a `MERGE` table, you must specify with `INSERT_METHOD` the table into which the row should be inserted. `INSERT_METHOD` is an option useful for `MERGE` tables only. Use a value of `FIRST` or `LAST` to have inserts go to the first or last table, or a value of `NO` to prevent inserts. See Section 14.8, "The MERGE Storage Engine".

- `KEY_BLOCK_SIZE`

For `MyISAM` tables, `KEY_BLOCK_SIZE` optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A `KEY_BLOCK_SIZE` value specified for an individual index definition overrides the table-level `KEY_BLOCK_SIZE` value.

`KEY_BLOCK_SIZE` was added in MySQL 5.1.10.

- `MAX_ROWS`

The maximum number of rows you plan to store in the table. This is not a hard limit, but rather a hint to the storage engine that the table must be able to store at least this many rows.

The `NDB` storage engine treats this value as a maximum. If you plan to create very large MySQL Cluster tables (containing millions of rows), you should use this option to insure that `NDB` allocates sufficient number of index slots in the hash table used for storing hashes of the table's primary keys by setting `MAX_ROWS = 2 * rows`, where `rows` is the number of rows that you expect to insert into the table.

> **Note**
>
> This option was incorrectly ignored by MySQL Cluster NDB 7.0 prior to version 7.0.20 and MySQL Cluster NDB 7.1 prior to version 7.1.9 (see Bug #57360).

The maximum `MAX_ROWS` value is 4294967295; larger values are truncated to this limit.

- `MIN_ROWS`

The minimum number of rows you plan to store in the table. The `MEMORY` storage engine uses this option as a hint about memory use.

- `PACK_KEYS`

`PACK_KEYS` takes effect only with `MyISAM` tables. Set this option to 1 if you want to have smaller indexes. This usually makes updates slower and reads faster. Setting the option to 0 disables all packing of keys. Setting it to `DEFAULT` tells the storage engine to pack only long `CHAR`, `VARCHAR`, `BINARY`, or `VARBINARY` columns.

If you do not use `PACK_KEYS`, the default is to pack strings, but not numbers. If you use `PACK_KEYS=1`, numbers are packed as well.

When packing binary number keys, MySQL uses prefix compression:

- Every key needs one extra byte to indicate how many bytes of the previous key are the same for the next key.

- The pointer to the row is stored in high-byte-first order directly after the key, to improve compression.

This means that if you have many equal keys on two consecutive rows, all following "same" keys usually only take two bytes (including the pointer to the row). Compare this to the ordinary case where the following keys takes `storage_size_for_key + pointer_size` (where the pointer size is usually 4). Conversely, you get a significant benefit from prefix compression only if you have many numbers that are the same. If all keys are totally different, you use one byte more per key, if the key is not a key that can have `NULL` values. (In this case, the packed key length is stored in the same byte that is used to mark if a key is `NULL`.)

- `PASSWORD`

This option is unused. If you have a need to scramble your `.frm` files and make them unusable to any other MySQL server, please contact our sales department.

- `ROW_FORMAT`

  Defines the physical format in which the rows are stored. The choices differ depending on the storage engine used for the table.

  For `InnoDB` tables:

  - Rows are stored in compact format (`ROW_FORMAT=COMPACT`) by default.

  - The noncompact format used in older versions of MySQL can still be requested by specifying `ROW_FORMAT=REDUNDANT`.

  - To enable compression for `InnoDB` tables, specify `ROW_FORMAT=COMPRESSED` and follow the procedures in InnoDB Table Compression. This feature is available when you use the InnoDB Plugin for MySQL 5.1.

  - For more efficient `InnoDB` storage of data types, especially `BLOB` types, specify `ROW_FORMAT=DYNAMIC` and follow the procedures in DYNAMIC and COMPRESSED Row Formats. This feature is available when you use the InnoDB Plugin for MySQL 5.1. Both the `COMPRESSED` and `DYNAMIC` row formats require creating the table with the configuration settings `innodb_file_per_table=1` and `innodb_file_format=barracuda`.

  - When you specify a non-default `ROW_FORMAT` clause, consider also enabling the `innodb_strict_mode` configuration option.

  - `ROW_FORMAT=FIXED` is not supported. If `ROW_FORMAT=FIXED` is specified while `innodb_strict_mode` is disabled, `InnoDB` defaults to `ROW_FORMAT=COMPACT`. If `ROW_FORMAT=FIXED` is specified while `innodb_strict_mode` is enabled, `InnoDB` returns an error.

  For `MyISAM` tables, the option value can be `FIXED` or `DYNAMIC` for static or variable-length row format. `myisampack` sets the type to `COMPRESSED`. See Section 14.5.3, "MyISAM Table Storage Formats".

  > **Note**
  >
  > When executing a `CREATE TABLE` statement, if you specify a row format which is not supported by the storage engine that is used for the table, the table is created using that storage engine's default row format. The information reported in this column in response to `SHOW TABLE STATUS` is the actual row format used. This may differ from the value in the `Create_options` column because the original `CREATE TABLE` definition is retained during creation.

- `UNION`

  `UNION` is used when you want to access a collection of identical `MyISAM` tables as one. This works only with `MERGE` tables. See Section 14.8, "The MERGE Storage Engine".

  You must have `SELECT`, `UPDATE`, and `DELETE` privileges for the tables you map to a `MERGE` table.

  > **Note**
  >
  > Formerly, all tables used had to be in the same database as the `MERGE` table itself. This restriction no longer applies.

Creating Partitioned Tables

`partition_options` can be used to control partitioning of the table created with `CREATE TABLE`.

> **Important**
>
> Not all options shown in the syntax for `partition_options` at the beginning of this section are available for all partitioning types. Please see the listings for the following individual types for information specific to each type, and see Chapter 18, *Partitioning*, for more complete information about the workings of and uses for partitioning in MySQL, as well as additional examples of table creation and other statements relating to MySQL partitioning.

If used, a `partition_options` clause begins with `PARTITION BY`. This clause contains the function that is used to determine the partition; the function returns an integer value ranging from 1 to *num*, where *num* is the number of partitions. (The maximum number of user-defined partitions which a table may contain is 1024; the number of subpartitions—discussed later in this section—is included in this maximum.) The choices that are available for this function in MySQL 5.1 are shown in the following list:

- `HASH(expr)`: Hashes one or more columns to create a key for placing and locating rows. *expr* is an expression using one or more table columns. This can be any valid MySQL expression (including MySQL functions) that yields a single integer value. For example, these are both valid `CREATE TABLE` statements using `PARTITION BY HASH`:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5))
    PARTITION BY HASH(col1);

CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATETIME)
    PARTITION BY HASH ( YEAR(col3) );
```

You may not use either `VALUES LESS THAN` or `VALUES IN` clauses with `PARTITION BY HASH`.

`PARTITION BY HASH` uses the remainder of *expr* divided by the number of partitions (that is, the modulus). For examples and additional information, see Section 18.2.3, "HASH Partitioning".

The `LINEAR` keyword entails a somewhat different algorithm. In this case, the number of the partition in which a row is stored is calculated as the result of one or more logical `AND` operations. For discussion and examples of linear hashing, see Section 18.2.3.1, "LINEAR HASH Partitioning".

- `KEY(column_list)`: This is similar to `HASH`, except that MySQL supplies the hashing function so as to guarantee an even data distribution. The *column_list* argument is simply a list of table columns. This example shows a simple table partitioned by key, with 4 partitions:

```
CREATE TABLE tk (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY KEY(col3)
    PARTITIONS 4;
```

For tables that are partitioned by key, you can employ linear partitioning by using the `LINEAR` keyword. This has the same effect as with tables that are partitioned by `HASH`. That is, the partition number is found using the `&` operator rather than the modulus (see Section 18.2.3.1, "LINEAR HASH Partitioning", and Section 18.2.4, "KEY Partitioning", for details). This example uses linear partitioning by key to distribute data between 5 partitions:

```
CREATE TABLE tk (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY LINEAR KEY(col3)
    PARTITIONS 5;
```

You may not use either `VALUES LESS THAN` or `VALUES IN` clauses with `PARTITION BY KEY`.

- `RANGE(expr)`: In this case, `expr` shows a range of values using a set of `VALUES LESS THAN` operators. When using range partitioning, you must define at least one partition using `VALUES LESS THAN`. You cannot use `VALUES IN` with range partitioning.

  `VALUES LESS THAN` can be used with either a literal value or an expression that evaluates to a single value.

  Suppose that you have a table that you wish to partition on a column containing year values, according to the following scheme.

Partition Number:	Years Range:
0	1990 and earlier
1	1991 to 1994
2	1995 to 1998
3	1999 to 2002
4	2003 to 2005
5	2006 and later

  A table implementing such a partitioning scheme can be realized by the `CREATE TABLE` statement shown here:

```
CREATE TABLE t1 (
    year_col  INT,
    some_data INT
)
PARTITION BY RANGE (year_col) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1995),
    PARTITION p2 VALUES LESS THAN (1999),
    PARTITION p3 VALUES LESS THAN (2002),
    PARTITION p4 VALUES LESS THAN (2006),
    PARTITION p5 VALUES LESS THAN MAXVALUE
);
```

  `PARTITION ... VALUES LESS THAN ...` statements work in a consecutive fashion. `VALUES LESS THAN MAXVALUE` works to specify "leftover" values that are greater than the maximum value otherwise specified.

  `VALUES LESS THAN` clauses work sequentially in a manner similar to that of the `case` portions of a `switch ... case` block (as found in many programming languages such as C, Java, and PHP). That is, the clauses must be arranged in such a way that the upper limit specified in each successive `VALUES LESS THAN` is greater than that of the previous one, with the one referencing `MAXVALUE` coming last of all in the list.

- `LIST(expr)`: This is useful when assigning partitions based on a table column with a restricted set of possible values, such as a state or country code. In such a case, all rows pertaining to a certain state or country can be assigned to a single partition, or a partition can be reserved for a certain set of states or countries. It is similar to `RANGE`, except that only `VALUES IN` may be used to specify permissible values for each partition.

  `VALUES IN` is used with a list of values to be matched. For instance, you could create a partitioning scheme such as the following:

```
CREATE TABLE client_firms (
    id    INT,
    name VARCHAR(35)
)
PARTITION BY LIST (id) (
    PARTITION r0 VALUES IN (1, 5, 9, 13, 17, 21),
    PARTITION r1 VALUES IN (2, 6, 10, 14, 18, 22),
    PARTITION r2 VALUES IN (3, 7, 11, 15, 19, 23),
    PARTITION r3 VALUES IN (4, 8, 12, 16, 20, 24)
);
```

When using list partitioning, you must define at least one partition using `VALUES IN`. You cannot use `VALUES LESS THAN` with `PARTITION BY LIST`.

> **Note**
>
> Currently, the value list used with `VALUES IN` must consist of integer values only.

* The number of partitions may optionally be specified with a `PARTITIONS` *num* clause, where *num* is the number of partitions. If both this clause *and* any `PARTITION` clauses are used, *num* must be equal to the total number of any partitions that are declared using `PARTITION` clauses.

> **Note**
>
> Whether or not you use a `PARTITIONS` clause in creating a table that is partitioned by `RANGE` or `LIST`, you must still include at least one `PARTITION VALUES` clause in the table definition (see below).

* A partition may optionally be divided into a number of subpartitions. This can be indicated by using the optional `SUBPARTITION BY` clause. Subpartitioning may be done by `HASH` or `KEY`. Either of these may be `LINEAR`. These work in the same way as previously described for the equivalent partitioning types. (It is not possible to subpartition by `LIST` or `RANGE`.)

  The number of subpartitions can be indicated using the `SUBPARTITIONS` keyword followed by an integer value.

* MySQL 5.1.12 introduces rigorous checking of the value used in a `PARTITIONS` or `SUBPARTITIONS` clause. Beginning with this version, this value must adhere to the following rules:

  * The value must be a positive, nonzero integer.

  * No leading zeros are permitted.

  * The value must be an integer literal, and cannot not be an expression. For example, `PARTITIONS 0.2E+01` is not permitted, even though `0.2E+01` evaluates to `2`. (Bug #15890)

> **Note**
>
> The expression (`expr`) used in a `PARTITION BY` clause cannot refer to any columns not in the table being created; beginning with MySQL 5.1.23, such references are specifically not permitted and cause the statement to fail with an error. (Bug #29444)

Each partition may be individually defined using a `partition_definition` clause. The individual parts making up this clause are as follows:

* `PARTITION partition_name`: This specifies a logical name for the partition.

- A `VALUES` clause: For range partitioning, each partition must include a `VALUES LESS THAN` clause; for list partitioning, you must specify a `VALUES IN` clause for each partition. This is used to determine which rows are to be stored in this partition. See the discussions of partitioning types in Chapter 18, *Partitioning*, for syntax examples.

- An optional `COMMENT` clause may be used to specify a string that describes the partition. Example:

```
COMMENT = 'Data for the years previous to 1999'
```

- `DATA DIRECTORY` and `INDEX DIRECTORY` may be used to indicate the directory where, respectively, the data and indexes for this partition are to be stored. Both the `data_dir` and the `index_dir` must be absolute system path names. Example:

```
CREATE TABLE th (id INT, name VARCHAR(30), adate DATE)
PARTITION BY LIST(YEAR(adate))
(
  PARTITION p1999 VALUES IN (1995, 1999, 2003)
    DATA DIRECTORY = '/var/appdata/95/data'
    INDEX DIRECTORY = '/var/appdata/95/idx',
  PARTITION p2000 VALUES IN (1996, 2000, 2004)
    DATA DIRECTORY = '/var/appdata/96/data'
    INDEX DIRECTORY = '/var/appdata/96/idx',
  PARTITION p2001 VALUES IN (1997, 2001, 2005)
    DATA DIRECTORY = '/var/appdata/97/data'
    INDEX DIRECTORY = '/var/appdata/97/idx',
  PARTITION p2002 VALUES IN (1998, 2002, 2006)
    DATA DIRECTORY = '/var/appdata/98/data'
    INDEX DIRECTORY = '/var/appdata/98/idx'
);
```

  `DATA DIRECTORY` and `INDEX DIRECTORY` behave in the same way as in the `CREATE TABLE` statement's `table_option` clause as used for `MyISAM` tables.

  One data directory and one index directory may be specified per partition. If left unspecified, the data and indexes are stored by default in the table's database directory.

  On Windows, the `DATA DIRECTORY` and `INDEX DIRECTORY` options are not supported for individual partitions or subpartitions. Beginning with MySQL 5.1.24, these options are ignored on Windows, except that a warning is generated. (Bug #30459)

  Note

  Prior to MySQL 5.1.18, `DATA DIRECTORY` and `INDEX DIRECTORY` were permitted even if the `NO_DIR_IN_CREATE` server SQL mode was in effect at the time that a partitioned table was created. Beginning with MySQL 5.1.18, these options are ignored for creating partitioned tables if `NO_DIR_IN_CREATE` is in effect. (Bug #24633)

- `MAX_ROWS` and `MIN_ROWS` may be used to specify, respectively, the maximum and minimum number of rows to be stored in the partition. The values for `max_number_of_rows` and `min_number_of_rows` must be positive integers. As with the table-level options with the same names, these act only as "suggestions" to the server and are not hard limits.

- The optional `TABLESPACE` clause may be used to designate a tablespace for the partition. Used for MySQL Cluster only.

- The partitioning handler accepts a `[STORAGE] ENGINE` option for both `PARTITION` and `SUBPARTITION`. Currently, the only way in which this can be used is to set all partitions or all

subpartitions to the same storage engine, and an attempt to set different storage engines for partitions or subpartitions in the same table will give rise to the error `ERROR 1469 (HY000): The mix of handlers in the partitions is not permitted in this version of MySQL`. We expect to lift this restriction on partitioning in a future MySQL release.

- The `NODEGROUP` option can be used to make this partition act as part of the node group identified by `node_group_id`. This option is applicable only to MySQL Cluster.

- The partition definition may optionally contain one or more `subpartition_definition` clauses. Each of these consists at a minimum of the `SUBPARTITION` `name`, where `name` is an identifier for the subpartition. Except for the replacement of the `PARTITION` keyword with `SUBPARTITION`, the syntax for a subpartition definition is identical to that for a partition definition.

  Subpartitioning must be done by `HASH` or `KEY`, and can be done only on `RANGE` or `LIST` partitions. See Section 18.2.5, "Subpartitioning".

Partitions can be modified, merged, added to tables, and dropped from tables. For basic information about the MySQL statements to accomplish these tasks, see Section 13.1.7, "ALTER TABLE Syntax". For more detailed descriptions and examples, see Section 18.3, "Partition Management".

> **Important**
>
> The original `CREATE TABLE` statement, including all specifications and table options are stored by MySQL when the table is created. The information is retained so that if you change storage engines, collations or other settings using an `ALTER TABLE` statement, the original table options specified are retained. This enables you to change between `InnoDB` and `MyISAM` table types even though the row formats supported by the two engines are different.
>
> Because the text of the original statement is retained, but due to the way that certain values and options may be silently reconfigured (such as the `ROW_FORMAT`), the active table definition (accessible through `DESCRIBE` or with `SHOW TABLE STATUS`) and the table creation string (accessible through `SHOW CREATE TABLE`) will report different values.

13.1.17.1 CREATE TABLE ... LIKE Syntax

Use `CREATE TABLE ... LIKE` to create an empty table based on the definition of another table, including any column attributes and indexes defined in the original table:

```
CREATE TABLE new_tbl LIKE orig_tbl;
```

The copy is created using the same version of the table storage format as the original table. The `SELECT` privilege is required on the original table.

`LIKE` works only for base tables, not for views.

`CREATE TABLE ... LIKE` does not preserve any `DATA DIRECTORY` or `INDEX DIRECTORY` table options that were specified for the original table, or any foreign key definitions.

If the original table is a `TEMPORARY` table, `CREATE TABLE ... LIKE` does not preserve `TEMPORARY`. To create a `TEMPORARY` destination table, use `CREATE TEMPORARY TABLE ... LIKE`.

In MySQL 5.1, changes to the SQL mode do not affect `CREATE TABLE ... LIKE`. If the current SQL mode is different from the mode in effect when the original table was created, the statement succeeds even if the table definition is invalid for the new mode.

13.1.17.2 CREATE TABLE ... SELECT Syntax

You can create one table from another by adding a `SELECT` statement at the end of the `CREATE TABLE` statement:

```
CREATE TABLE new_tbl [AS] SELECT * FROM orig_tbl;
```

MySQL creates new columns for all elements in the `SELECT`. For example:

```
mysql> CREATE TABLE test (a INT NOT NULL AUTO_INCREMENT,
    ->        PRIMARY KEY (a), KEY(b))
    ->        ENGINE=MyISAM SELECT b,c FROM test2;
```

This creates a `MyISAM` table with three columns, `a`, `b`, and `c`. The `ENGINE` option is part of the `CREATE TABLE` statement, and should not be used following the `SELECT`; this would result in a syntax error. The same is true for other `CREATE TABLE` options such as `CHARSET`.

Notice that the columns from the `SELECT` statement are appended to the right side of the table, not overlapped onto it. Take the following example:

```
mysql> SELECT * FROM foo;
+---+
| n |
+---+
| 1 |
+---+

mysql> CREATE TABLE bar (m INT) SELECT n FROM foo;
Query OK, 1 row affected (0.02 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM bar;
+------+---+
| m    | n |
+------+---+
| NULL | 1 |
+------+---+
1 row in set (0.00 sec)
```

For each row in table `foo`, a row is inserted in `bar` with the values from `foo` and default values for the new columns.

In a table resulting from `CREATE TABLE ... SELECT`, columns named only in the `CREATE TABLE` part come first. Columns named in both parts or only in the `SELECT` part come after that. The data type of `SELECT` columns can be overridden by also specifying the column in the `CREATE TABLE` part.

If any errors occur while copying the data to the table, it is automatically dropped and not created.

You can precede the `SELECT` by `IGNORE` or `REPLACE` to indicate how to handle rows that duplicate unique key values. With `IGNORE`, rows that duplicate an existing row on a unique key value are discarded. With `REPLACE`, new rows replace rows that have the same unique key value. If neither `IGNORE` nor `REPLACE` is specified, duplicate unique key values result in an error.

`CREATE TABLE ... SELECT` does not automatically create any indexes for you. This is done intentionally to make the statement as flexible as possible. If you want to have indexes in the created table, you should specify these before the `SELECT` statement:

```
mysql> CREATE TABLE bar (UNIQUE (n)) SELECT n FROM foo;
```

Some conversion of data types might occur. For example, the AUTO_INCREMENT attribute is not preserved, and VARCHAR columns can become CHAR columns. Retrained attributes are NULL (or NOT NULL) and, for those columns that have them, CHARACTER SET, COLLATION, COMMENT, and the DEFAULT clause.

When creating a table with CREATE TABLE ... SELECT, make sure to alias any function calls or expressions in the query. If you do not, the CREATE statement might fail or result in undesirable column names.

```
CREATE TABLE artists_and_works
  SELECT artist.name, COUNT(work.artist_id) AS number_of_works
  FROM artist LEFT JOIN work ON artist.id = work.artist_id
  GROUP BY artist.id;
```

You can also explicitly specify the data type for a column in the created table:

```
CREATE TABLE foo (a TINYINT NOT NULL) SELECT b+1 AS a FROM bar;
```

For CREATE TABLE ... SELECT, if IF NOT EXISTS is given and the destination table already exists, the result is version dependent. Before MySQL 5.5.6, MySQL handles the statement as follows:

- The table definition given in the CREATE TABLE part is ignored. No error occurs, even if the definition does not match that of the existing table. MySQL attempts to insert the rows from the SELECT part anyway.

- If there is a mismatch between the number of columns in the table and the number of columns produced by the SELECT part, the selected values are assigned to the rightmost columns. For example, if the table contains n columns and the SELECT produces m columns, where $m < n$, the selected values are assigned to the m rightmost columns in the table. Each of the initial $n - m$ columns is assigned its default value, either that specified explicitly in the column definition or the implicit column data type default if the definition contains no default. If the SELECT part produces too many columns ($m > n$), an error occurs.

- If strict SQL mode is enabled and any of these initial columns do not have an explicit default value, the statement fails with an error.

The following example illustrates IF NOT EXISTS handling:

```
mysql> CREATE TABLE t1 (i1 INT DEFAULT 0, i2 INT, i3 INT, i4 INT);
Query OK, 0 rows affected (0.05 sec)

mysql> CREATE TABLE IF NOT EXISTS t1 (c1 CHAR(10)) SELECT 1, 2;
Query OK, 1 row affected, 1 warning (0.01 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t1;
+------+------+------+------+
| i1   | i2   | i3   | i4   |
+------+------+------+------+
|    0 | NULL |    1 |    2 |
+------+------+------+------+
1 row in set (0.00 sec)
```

As of MySQL 5.5.6, handling of CREATE TABLE IF NOT EXISTS ... SELECT statements was changed for the case that the destination table already exists. This change also involves a change in MySQL 5.1 beginning with 5.1.51.

- Previously, for `CREATE TABLE IF NOT EXISTS ... SELECT`, MySQL produced a warning that the table exists, but inserted the rows and wrote the statement to the binary log anyway. By contrast, `CREATE TABLE ... SELECT` (without `IF NOT EXISTS`) failed with an error, but MySQL inserted no rows and did not write the statement to the binary log.

- MySQL now handles both statements the same way when the destination table exists, in that neither statement inserts rows or is written to the binary log. The difference between them is that MySQL produces a warning when `IF NOT EXISTS` is present and an error when it is not.

This change means that, for the preceding example, the `CREATE TABLE IF NOT EXISTS ... SELECT` statement inserts nothing into the destination table as of MySQL 5.5.6.

This change in handling of `IF NOT EXISTS` results in an incompatibility for statement-based replication from a MySQL 5.1 master with the original behavior and a MySQL 5.5 slave with the new behavior. Suppose that `CREATE TABLE IF NOT EXISTS ... SELECT` is executed on the master and the destination table exists. The result is that rows are inserted on the master but not on the slave. (Row-based replication does not have this problem.)

To address this issue, statement-based binary logging for `CREATE TABLE IF NOT EXISTS ... SELECT` is changed in MySQL 5.1 as of 5.1.51:

- If the destination table does not exist, there is no change: The statement is logged as is.

- If the destination table does exist, the statement is logged as the equivalent pair of `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements. (If the `SELECT` in the original statement is preceded by `IGNORE` or `REPLACE`, the `INSERT` becomes `INSERT IGNORE` or `REPLACE`, respectively.)

This change provides forward compatibility for statement-based replication from MySQL 5.1 to 5.5 because when the destination table exists, the rows will be inserted on both the master and slave. To take advantage of this compatibility measure, the 5.1 server must be at least 5.1.51 and the 5.5 server must be at least 5.5.6.

To upgrade an existing 5.1-to-5.5 replication scenario, upgrade the master first to 5.1.51 or higher. Note that this differs from the usual replication upgrade advice of upgrading the slave first.

A workaround for applications that wish to achieve the original effect (rows inserted regardless of whether the destination table exists) is to use `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements rather than `CREATE TABLE IF NOT EXISTS ... SELECT` statements.

Along with the change just described, the following related change was made: Previously, if an existing view was named as the destination table for `CREATE TABLE IF NOT EXISTS ... SELECT`, rows were inserted into the underlying base table and the statement was written to the binary log. As of MySQL 5.1.51 and 5.5.6, nothing is inserted or logged.

To ensure that the binary log can be used to re-create the original tables, MySQL does not permit concurrent inserts during `CREATE TABLE ... SELECT`.

13.1.17.3 Using FOREIGN KEY Constraints

MySQL supports foreign keys, which let you cross-reference related data across tables, and foreign key constraints, which help keep this spread-out data consistent. The essential syntax for a foreign key constraint definition in a `CREATE TABLE` or `ALTER TABLE` statement looks like this:

```
[CONSTRAINT [symbol]] FOREIGN KEY
    [index_name] (index_col_name, ...)
```

```
    REFERENCES tbl_name (index_col_name,...)
    [ON DELETE reference_option]
    [ON UPDATE reference_option]

reference_option:
    RESTRICT | CASCADE | SET NULL | NO ACTION
```

index_name represents a foreign key ID. The *index_name* value is ignored if there is already an explicitly defined index on the child table that can support the foreign key. Otherwise, MySQL implicitly creates a foreign key index that is named according to the following rules:

- If defined, the `CONSTRAINT` *symbol* value is used. Otherwise, the `FOREIGN KEY` *index_name* value is used.

- If neither a `CONSTRAINT` *symbol* or `FOREIGN KEY` *index_name* is defined, the foreign key index name is generated using the name of the referencing foreign key column.

Foreign keys definitions are subject to the following conditions:

- Foreign key relationships involve a parent table that holds the central data values, and a child table with identical values pointing back to its parent. The `FOREIGN KEY` clause is specified in the child table. The parent and child tables must use the same storage engine. They must not be `TEMPORARY` tables.

- Corresponding columns in the foreign key and the referenced key must have similar data types. *The size and sign of integer types must be the same*. The length of string types need not be the same. For nonbinary (character) string columns, the character set and collation must be the same.

- When `foreign_key_checks` is enabled, which is the default setting, character set conversion is not permitted on tables that include a character string column used in a foreign key constraint. The workaround is described in Section 13.1.7, "ALTER TABLE Syntax".

- MySQL requires indexes on foreign keys and referenced keys so that foreign key checks can be fast and not require a table scan. In the referencing table, there must be an index where the foreign key columns are listed as the *first* columns in the same order. Such an index is created on the referencing table automatically if it does not exist. This index might be silently dropped later, if you create another index that can be used to enforce the foreign key constraint. *index_name*, if given, is used as described previously.

- `InnoDB` permits a foreign key to reference any index column or group of columns. However, in the referenced table, there must be an index where the referenced columns are listed as the *first* columns in the same order.

- Index prefixes on foreign key columns are not supported. One consequence of this is that `BLOB` and `TEXT` columns cannot be included in a foreign key because indexes on those columns must always include a prefix length.

- If the `CONSTRAINT` *symbol* clause is given, the *symbol* value, if used, must be unique in the database. A duplicate *symbol* will result in an error similar to: `ERROR 1005 (HY000): Can't create table 'test.#sql-211d_3' (errno: 121)`. If the clause is not given, or a *symbol* is not included following the `CONSTRAINT` keyword, a name for the constraint is created automatically.

- `InnoDB` does not currently support foreign keys for tables with user-defined partitioning. This includes both parent and child tables.

Referential Actions

This section describes how foreign keys help guarantee referential integrity.

For storage engines supporting foreign keys, MySQL rejects any `INSERT` or `UPDATE` operation that attempts to create a foreign key value in a child table if there is no a matching candidate key value in the parent table.

When an `UPDATE` or `DELETE` operation affects a key value in the parent table that has matching rows in the child table, the result depends on the *referential action* specified using `ON UPDATE` and `ON DELETE` subclauses of the `FOREIGN KEY` clause. MySQL supports five options regarding the action to be taken, listed here:

- `CASCADE`: Delete or update the row from the parent table, and automatically delete or update the matching rows in the child table. Both `ON DELETE CASCADE` and `ON UPDATE CASCADE` are supported. Between two tables, do not define several `ON UPDATE CASCADE` clauses that act on the same column in the parent table or in the child table.

  > **Note**
  >
  > Cascaded foreign key actions do not activate triggers.

- `SET NULL`: Delete or update the row from the parent table, and set the foreign key column or columns in the child table to `NULL`. Both `ON DELETE SET NULL` and `ON UPDATE SET NULL` clauses are supported.

  If you specify a `SET NULL` action, *make sure that you have not declared the columns in the child table as* `NOT NULL`.

- `RESTRICT`: Rejects the delete or update operation for the parent table. Specifying `RESTRICT` (or `NO ACTION`) is the same as omitting the `ON DELETE` or `ON UPDATE` clause.

- `NO ACTION`: A keyword from standard SQL. In MySQL, equivalent to `RESTRICT`. The MySQL Server rejects the delete or update operation for the parent table if there is a related foreign key value in the referenced table. Some database systems have deferred checks, and `NO ACTION` is a deferred check. In MySQL, foreign key constraints are checked immediately, so `NO ACTION` is the same as `RESTRICT`.

- `SET DEFAULT`: This action is recognized by the MySQL parser, but `InnoDB` rejects table definitions containing `ON DELETE SET DEFAULT` or `ON UPDATE SET DEFAULT` clauses.

For an `ON DELETE` or `ON UPDATE` that is not specified, the default action is always `RESTRICT`.

MySQL supports foreign key references between one column and another within a table. (A column cannot have a foreign key reference to itself.) In these cases, "child table records" really refers to dependent records within the same table.

Examples of Foreign Key Clauses

Here is a simple example that relates `parent` and `child` tables through a single-column foreign key:

```
CREATE TABLE parent (
    id INT NOT NULL,
    PRIMARY KEY (id)
) ENGINE=INNODB;

CREATE TABLE child (
    id INT,
    parent_id INT,
    INDEX par_ind (parent_id),
    FOREIGN KEY (parent_id)
        REFERENCES parent(id)
        ON DELETE CASCADE
```

```
) ENGINE=INNODB;
```

A more complex example in which a `product_order` table has foreign keys for two other tables. One foreign key references a two-column index in the `product` table. The other references a single-column index in the `customer` table:

```
CREATE TABLE product (
    category INT NOT NULL, id INT NOT NULL,
    price DECIMAL,
    PRIMARY KEY(category, id)
)   ENGINE=INNODB;

CREATE TABLE customer (
    id INT NOT NULL,
    PRIMARY KEY (id)
)   ENGINE=INNODB;

CREATE TABLE product_order (
    no INT NOT NULL AUTO_INCREMENT,
    product_category INT NOT NULL,
    product_id INT NOT NULL,
    customer_id INT NOT NULL,

    PRIMARY KEY(no),
    INDEX (product_category, product_id),
    INDEX (customer_id),

    FOREIGN KEY (product_category, product_id)
      REFERENCES product(category, id)
      ON UPDATE CASCADE ON DELETE RESTRICT,

    FOREIGN KEY (customer_id)
      REFERENCES customer(id)
)   ENGINE=INNODB;
```

Adding foreign keys

You can add a new foreign key constraint to an existing table by using ALTER TABLE. The syntax relating to foreign keys for this statement is shown here:

```
ALTER TABLE tbl_name
    ADD [CONSTRAINT [symbol]] FOREIGN KEY
    [index_name] (index_col_name, ...)
    REFERENCES tbl_name (index_col_name,...)
    [ON DELETE reference_option]
    [ON UPDATE reference_option]
```

The foreign key can be self referential (referring to the same table). When you add a foreign key constraint to a table using ALTER TABLE, *remember to create the required indexes first.*

Dropping Foreign Keys

You can also use ALTER TABLE to drop foreign keys, using the syntax shown here:

```
ALTER TABLE tbl_name DROP FOREIGN KEY fk_symbol;
```

If the FOREIGN KEY clause included a CONSTRAINT name when you created the foreign key, you can refer to that name to drop the foreign key. Otherwise, the `fk_symbol` value is generated internally when the foreign key is created. To find out the symbol value when you want to drop a foreign key, use a SHOW CREATE TABLE statement, as shown here:

```
mysql> SHOW CREATE TABLE ibtest11c\G
*************************** 1. row ***************************
       Table: ibtest11c
Create Table: CREATE TABLE `ibtest11c` (
  `A` int(11) NOT NULL auto_increment,
  `D` int(11) NOT NULL default '0',
  `B` varchar(200) NOT NULL default '',
  `C` varchar(175) default NULL,
  PRIMARY KEY  (`A`,`D`,`B`),
  KEY `B` (`B`,`C`),
  KEY `C` (`C`),
  CONSTRAINT `0_38775` FOREIGN KEY (`A`, `D`)
REFERENCES `ibtest11a` (`A`, `D`)
ON DELETE CASCADE ON UPDATE CASCADE,
  CONSTRAINT `0_38776` FOREIGN KEY (`B`, `C`)
REFERENCES `ibtest11a` (`B`, `C`)
ON DELETE CASCADE ON UPDATE CASCADE
) ENGINE=INNODB CHARSET=latin1
1 row in set (0.01 sec)

mysql> ALTER TABLE ibtest11c DROP FOREIGN KEY `0_38775`;
```

Adding and dropping a foreign key in separate clauses of a single ALTER TABLE statement may be problematic in some cases and is therefore unsupported. Use separate statements for each operation.

If an ALTER TABLE statement results in changes to column values (for example, because a column is truncated), MySQL's foreign key constraint checks do not notice possible violations caused by changing the values.

Foreign Keys and Other MySQL Statements

Table and column identifiers in a FOREIGN KEY ... REFERENCES ... clause can be quoted within backticks (`). Alternatively, double quotation marks (") can be used if the ANSI_QUOTES SQL mode is enabled. The setting of the lower_case_table_names system variable is also taken into account.

You can view a child table's foreign key definitions as part of the output of the SHOW CREATE TABLE statement:

```
SHOW CREATE TABLE tbl_name;
```

You can also obtain information about foreign keys by querying the INFORMATION_SCHEMA.KEY_COLUMN_USAGE table.

mysqldump produces correct definitions of tables in the dump file, including the foreign keys for child tables.

To make it easier to reload dump files for tables that have foreign key relationships, mysqldump automatically includes a statement in the dump output to set foreign_key_checks to 0. This avoids problems with tables having to be reloaded in a particular order when the dump is reloaded. It is also possible to set this variable manually:

```
mysql> SET foreign_key_checks = 0;
mysql> SOURCE dump_file_name;
mysql> SET foreign_key_checks = 1;
```

This enables you to import the tables in any order if the dump file contains tables that are not correctly ordered for foreign keys. It also speeds up the import operation. Setting foreign_key_checks to 0 can also be useful for ignoring foreign key constraints during LOAD DATA and ALTER TABLE operations.

However, even if `foreign_key_checks = 0`, MySQL does not permit the creation of a foreign key constraint where a column references a nonmatching column type. Also, if a table has foreign key constraints, `ALTER TABLE` cannot be used to alter the table to use another storage engine. To change the storage engine, you must drop any foreign key constraints first.

You cannot issue `DROP TABLE` for a table that is referenced by a `FOREIGN KEY` constraint, unless you do `SET foreign_key_checks = 0`. When you drop a table, any constraints that were defined in the statement used to create that table are also dropped.

If you re-create a table that was dropped, it must have a definition that conforms to the foreign key constraints referencing it. It must have the correct column names and types, and it must have indexes on the referenced keys, as stated earlier. If these are not satisfied, MySQL returns Error 1005 and refers to Error 150 in the error message, which means that a foreign key constraint was not correctly formed. Similarly, if an `ALTER TABLE` fails due to Error 150, this means that a foreign key definition would be incorrectly formed for the altered table.

For `InnoDB` tables, you can obtain a detailed explanation of the most recent `InnoDB` foreign key error in the MySQL Server, by checking the output of `SHOW ENGINE INNODB STATUS`.

Important

For users familiar with the ANSI/ISO SQL Standard, please note that no storage engine, including `InnoDB`, recognizes or enforces the `MATCH` clause used in referential-integrity constraint definitions. Use of an explicit `MATCH` clause will not have the specified effect, and also causes `ON DELETE` and `ON UPDATE` clauses to be ignored. For these reasons, specifying `MATCH` should be avoided.

The `MATCH` clause in the SQL standard controls how `NULL` values in a composite (multiple-column) foreign key are handled when comparing to a primary key. MySQL essentially implements the semantics defined by `MATCH SIMPLE`, which permit a foreign key to be all or partially `NULL`. In that case, the (child table) row containing such a foreign key is permitted to be inserted, and does not match any row in the referenced (parent) table. It is possible to implement other semantics using triggers.

Additionally, MySQL requires that the referenced columns be indexed for performance reasons. However, the system does not enforce a requirement that the referenced columns be `UNIQUE` or be declared `NOT NULL`. The handling of foreign key references to nonunique keys or keys that contain `NULL` values is not well defined for operations such as `UPDATE` or `DELETE CASCADE`. You are advised to use foreign keys that reference only `UNIQUE` (including `PRIMARY`) and `NOT NULL` keys.

Furthermore, MySQL parses but ignores "inline `REFERENCES` specifications" (as defined in the SQL standard) where the references are defined as part of the column specification. MySQL accepts `REFERENCES` clauses only when specified as part of a separate `FOREIGN KEY` specification. For storage engines that do not support foreign keys (such as `MyISAM`), MySQL Server parses and ignores foreign key specifications.

13.1.17.4 Silent Column Specification Changes

In some cases, MySQL silently changes column specifications from those given in a `CREATE TABLE` or `ALTER TABLE` statement. These might be changes to a data type, to attributes associated with a data type, or to an index specification.

All changes are subject to the internal row-size limit of 65,535 bytes, which may cause some attempts at data type changes to fail. See Section C.7.4, "Limits on Table Column Count and Row Size".

- `TIMESTAMP` display sizes are discarded.

  Also note that `TIMESTAMP` columns are `NOT NULL` by default.

- Columns that are part of a `PRIMARY KEY` are made `NOT NULL` even if not declared that way.

- Trailing spaces are automatically deleted from `ENUM` and `SET` member values when the table is created.

- MySQL maps certain data types used by other SQL database vendors to MySQL types. See Section 11.9, "Using Data Types from Other Database Engines".

- If you include a `USING` clause to specify an index type that is not permitted for a given storage engine, but there is another index type available that the engine can use without affecting query results, the engine uses the available type.

- If strict SQL mode is not enabled, a `VARCHAR` column with a length specification greater than 65535 is converted to `TEXT`, and a `VARBINARY` column with a length specification greater than 65535 is converted to `BLOB`. Otherwise, an error occurs in either of these cases.

- Specifying the `CHARACTER SET binary` attribute for a character data type causes the column to be created as the corresponding binary data type: `CHAR` becomes `BINARY`, `VARCHAR` becomes `VARBINARY`, and `TEXT` becomes `BLOB`. For the `ENUM` and `SET` data types, this does not occur; they are created as declared. Suppose that you specify a table using this definition:

```
CREATE TABLE t
(
  c1 VARCHAR(10) CHARACTER SET binary,
  c2 TEXT CHARACTER SET binary,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

  The resulting table has this definition:

```
CREATE TABLE t
(
  c1 VARBINARY(10),
  c2 BLOB,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

  To see whether MySQL used a data type other than the one you specified, issue a `DESCRIBE` or `SHOW CREATE TABLE` statement after creating or altering the table.

  Certain other data type changes can occur if you compress a table using `myisampack`. See Section 14.5.3.3, "Compressed Table Characteristics".

13.1.18 CREATE TABLESPACE Syntax

```
CREATE TABLESPACE tablespace_name
    ADD DATAFILE 'file_name'
    USE LOGFILE GROUP logfile_group
    [EXTENT_SIZE [=] extent_size]
    [INITIAL_SIZE [=] initial_size]
    [AUTOEXTEND_SIZE [=] autoextend_size]
    [MAX_SIZE [=] max_size]
```

```
   [NODEGROUP [=] nodegroup_id]
   [WAIT]
   [COMMENT [=] comment_text]
   ENGINE [=] engine_name
```

This statement is used to create a tablespace, which can contain one or more data files, providing storage space for tables. One data file is created and added to the tablespace using this statement. Additional data files may be added to the tablespace by using the `ALTER TABLESPACE` statement (see Section 13.1.8, "ALTER TABLESPACE Syntax"). For rules covering the naming of tablespaces, see Section 9.2, "Schema Object Names".

> **Note**
>
> All MySQL Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group with the same name, or a tablespace and a data file with the same name.

Prior to MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, path and file names for data files could not be longer than 128 characters. (Bug #31770)

A log file group of one or more `UNDO` log files must be assigned to the tablespace to be created with the `USE LOGFILE GROUP` clause. `logfile_group` must be an existing log file group created with `CREATE LOGFILE GROUP` (see Section 13.1.14, "CREATE LOGFILE GROUP Syntax"). Multiple tablespaces may use the same log file group for `UNDO` logging.

The `EXTENT_SIZE` sets the size, in bytes, of the extents used by any files belonging to the tablespace. The default value is 1M. The minimum size is 32K, and theoretical maximum is 2G, although the practical maximum size depends on a number of factors. In most cases, changing the extent size does not have any measurable effect on performance, and the default value is recommended for all but the most unusual situations.

An *extent* is a unit of disk space allocation. One extent is filled with as much data as that extent can contain before another extent is used. In theory, up to 65,535 (64K) extents may used per data file; however, the recommended maximum is 32,768 (32K). The recommended maximum size for a single data file is 32G— that is, 32K extents × 1 MB per extent. In addition, once an extent is allocated to a given partition, it cannot be used to store data from a different partition; an extent cannot store data from more than one partition. This means, for example that a tablespace having a single datafile whose `INITIAL_SIZE` is 256 MB and whose `EXTENT_SIZE` is 128M has just two extents, and so can be used to store data from at most two different disk data table partitions.

You can see how many extents remain free in a given data file by querying the `INFORMATION_SCHEMA.FILES` table, and so derive an estimate for how much space remains free in the file. For further discussion and examples, see Section 20.26.1, "The INFORMATION_SCHEMA FILES Table".

The `INITIAL_SIZE` parameter sets the data file's total size in bytes. Once the file has been created, its size cannot be changed; however, you can add more data files to the tablespace using `ALTER TABLESPACE ... ADD DATAFILE`. See Section 13.1.8, "ALTER TABLESPACE Syntax".

`INITIAL_SIZE` is optional; its default value is `128M`.

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is `4G`. (Bug #29186)

When setting `EXTENT_SIZE` or `INITIAL_SIZE` (either or both), you may optionally follow the number with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (for megabytes) or `G` (for gigabytes).

INITIAL_SIZE, EXTENT_SIZE, and UNDO_BUFFER_SIZE are subject to rounding as follows:

- EXTENT_SIZE and UNDO_BUFFER_SIZE are each rounded up to the nearest whole multiple of 32K.

- INITIAL_SIZE is rounded *down* to the nearest whole multiple of 32K.

  For data files, *INITIAL_SIZE* is subject to further rounding; the result just obtained is rounded up to the nearest whole multiple of EXTENT_SIZE (after any rounding).

The rounding just described has always (since Disk Data tablespaces were introduced in MySQL 5.1.6) been performed implicitly, but beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2, this rounding is done explicitly, and a warning is issued by the MySQL Server when any such rounding is performed. The rounded values are also used by the NDB kernel for calculating INFORMATION_SCHEMA.FILES column values and other purposes. However, to avoid an unexpected result, we suggest that you always use whole multiples of 32K in specifying these options.

AUTOEXTEND_SIZE, MAX_SIZE, NODEGROUP, WAIT, and COMMENT are parsed but ignored, and so currently have no effect. These options are intended for future expansion.

The ENGINE parameter determines the storage engine which uses this tablespace, with *engine_name* being the name of the storage engine. In MySQL 5.1, *engine_name* must be one of the values NDB or NDBCLUSTER.

When CREATE TABLESPACE is used with ENGINE = NDB, a tablespace and associated data file are created on each Cluster data node. You can verify that the data files were created and obtain information about them by querying the INFORMATION_SCHEMA.FILES table. For example:

```
mysql> SELECT LOGFILE_GROUP_NAME, FILE_NAME, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE TABLESPACE_NAME = 'newts' AND FILE_TYPE = 'DATAFILE';
+--------------------+-------------+----------------+
| LOGFILE_GROUP_NAME | FILE_NAME   | EXTRA          |
+--------------------+-------------+----------------+
| lg_3               | newdata.dat | CLUSTER_NODE=3 |
| lg_3               | newdata.dat | CLUSTER_NODE=4 |
+--------------------+-------------+----------------+
2 rows in set (0.01 sec)
```

(See Section 20.26.1, "The INFORMATION_SCHEMA FILES Table".)

CREATE TABLESPACE was added in MySQL 5.1.6. In MySQL 5.1, it is useful only with Disk Data storage for MySQL Cluster. See Section 17.5.12, "MySQL Cluster Disk Data Tables".

13.1.19 CREATE TRIGGER Syntax

```
CREATE
    [DEFINER = { user | CURRENT_USER }]
    TRIGGER trigger_name
    trigger_time trigger_event
    ON tbl_name FOR EACH ROW
    trigger_body

trigger_time: { BEFORE | AFTER }

trigger_event: { INSERT | UPDATE | DELETE }
```

This statement creates a new trigger. A trigger is a named database object that is associated with a table, and that activates when a particular event occurs for the table. The trigger becomes associated with the

table named `tbl_name`, which must refer to a permanent table. You cannot associate a trigger with a `TEMPORARY` table or a view.

Trigger names exist in the schema namespace, meaning that all triggers must have unique names within a schema. Triggers in different schemas can have the same name.

This section describes `CREATE TRIGGER` syntax. For additional discussion, see Section 19.3.1, "Trigger Syntax and Examples".

`CREATE TRIGGER` requires the `TRIGGER` privilege for the table associated with the trigger. The statement might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section. If binary logging is enabled, `CREATE TRIGGER` might require the `SUPER` privilege, as described in Section 19.7, "Binary Logging of Stored Programs". (Before MySQL 5.1.6, there is no `TRIGGER` privilege and this statement requires the `SUPER` privilege in all cases.)

The `DEFINER` clause determines the security context to be used when checking access privileges at trigger activation time, as described later in this section.

`trigger_time` is the trigger action time. It can be `BEFORE` or `AFTER` to indicate that the trigger activates before or after each row to be modified.

`trigger_event` indicates the kind of operation that activates the trigger. These `trigger_event` values are permitted:

- `INSERT`: The trigger activates whenever a new row is inserted into the table; for example, through `INSERT`, `LOAD DATA`, and `REPLACE` statements.

- `UPDATE`: The trigger activates whenever a row is modified; for example, through `UPDATE` statements.

- `DELETE`: The trigger activates whenever a row is deleted from the table; for example, through `DELETE` and `REPLACE` statements. `DROP TABLE` and `TRUNCATE TABLE` statements on the table do *not* activate this trigger, because they do not use `DELETE`. Dropping a partition does not activate `DELETE` triggers, either.

The `trigger_event` does not represent a literal type of SQL statement that activates the trigger so much as it represents a type of table operation. For example, an `INSERT` trigger activates not only for `INSERT` statements but also `LOAD DATA` statements because both statements insert rows into a table.

A potentially confusing example of this is the `INSERT INTO ... ON DUPLICATE KEY UPDATE ...` syntax: a `BEFORE INSERT` trigger activates for every row, followed by either an `AFTER INSERT` trigger or both the `BEFORE UPDATE` and `AFTER UPDATE` triggers, depending on whether there was a duplicate key for the row.

> **Note**
>
> Cascaded foreign key actions do not activate triggers.

There cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. But you can have a `BEFORE UPDATE` and a `BEFORE INSERT` trigger, or a `BEFORE UPDATE` and an `AFTER UPDATE` trigger.

`trigger_body` is the statement to execute when the trigger activates. To execute multiple statements, use the `BEGIN ... END` compound statement construct. This also enables you to use the same statements that are permissible within stored routines. See Section 13.6.1, "BEGIN ... END Compound-Statement Syntax". Some statements are not permitted in triggers; see Section C.1, "Restrictions on Stored Programs".

Within the trigger body, you can refer to columns in the subject table (the table associated with the trigger) by using the aliases `OLD` and `NEW`. `OLD.col_name` refers to a column of an existing row before it is updated or deleted. `NEW.col_name` refers to the column of a new row to be inserted or an existing row after it is updated.

MySQL stores the `sql_mode` system variable setting in effect when a trigger is created, and always executes the trigger body with this setting in force, *regardless of the current server SQL mode when the trigger begins executing*.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at trigger activation time. If a `user` value is given, it should be a MySQL account specified as `'user_name'@'host_name'` (the same format used in the `GRANT` statement), `CURRENT_USER`, or `CURRENT_USER()`. The default `DEFINER` value is the user who executes the `CREATE TRIGGER` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

If you specify the `DEFINER` clause, these rules determine the valid `DEFINER` user values:

- If you do not have the `SUPER` privilege, the only permitted `user` value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.

- If you have the `SUPER` privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.

- Although it is possible to create a trigger with a nonexistent `DEFINER` account, it is not a good idea for such triggers to be activated until the account actually does exist. Otherwise, the behavior with respect to privilege checking is undefined.

Note: Prior to MySQL 5.1.6, `CREATE TRIGGER` always requires the `SUPER` privilege, so only the second of the preceding rules applies.

MySQL takes the `DEFINER` user into account when checking trigger privileges as follows:

- At `CREATE TRIGGER` time, the user who issues the statement must have the `TRIGGER` privilege. (`SUPER` prior to MySQL 5.1.6.)

- At trigger activation time, privileges are checked against the `DEFINER` user. This user must have these privileges:

  - The `TRIGGER` privilege. (`SUPER` prior to MySQL 5.1.6.)

  - The `SELECT` privilege for the subject table if references to table columns occur using `OLD.col_name` or `NEW.col_name` in the trigger body.

  - The `UPDATE` privilege for the subject table if table columns are targets of `SET NEW.col_name = value` assignments in the trigger body.

  - Whatever other privileges normally are required for the statements executed by the trigger.

For more information about trigger security, see Section 19.6, "Access Control for Stored Programs and Views".

Within a trigger body, the `CURRENT_USER()` function returns the account used to check privileges at trigger activation time. This is the `DEFINER` user, not the user whose actions caused the trigger to be activated. For information about user auditing within triggers, see Section 6.3.6, "SQL-Based MySQL Account Activity Auditing".

If you use `LOCK TABLES` to lock a table that has triggers, the tables used within the trigger are also locked, as described in Section 13.3.5.2, "LOCK TABLES and Triggers".

For additional discussion of trigger use, see Section 19.3.1, "Trigger Syntax and Examples".

13.1.20 CREATE VIEW Syntax

```
CREATE
    [OR REPLACE]
    [ALGORITHM = {UNDEFINED | MERGE | TEMPTABLE}]
    [DEFINER = { user | CURRENT_USER }]
    [SQL SECURITY { DEFINER | INVOKER }]
    VIEW view_name [(column_list)]
    AS select_statement
    [WITH [CASCADED | LOCAL] CHECK OPTION]
```

The `CREATE VIEW` statement creates a new view, or replaces an existing view if the `OR REPLACE` clause is given. If the view does not exist, `CREATE OR REPLACE VIEW` is the same as `CREATE VIEW`. If the view does exist, `CREATE OR REPLACE VIEW` is the same as `ALTER VIEW`.

The `select_statement` is a `SELECT` statement that provides the definition of the view. (Selecting from the view selects, in effect, using the `SELECT` statement.) The `select_statement` can select from base tables or other views.

The view definition is "frozen" at creation time and is not affected by subsequent changes to the definitions of the underlying tables. For example, if a view is defined as `SELECT *` on a table, new columns added to the table later do not become part of the view, and columns dropped from the table will result in an error when selecting from the view.

The `ALGORITHM` clause affects how MySQL processes the view. The `DEFINER` and `SQL SECURITY` clauses specify the security context to be used when checking access privileges at view invocation time. The `WITH CHECK OPTION` clause can be given to constrain inserts or updates to rows in tables referenced by the view. These clauses are described later in this section.

The `CREATE VIEW` statement requires the `CREATE VIEW` privilege for the view, and some privilege for each column selected by the `SELECT` statement. For columns used elsewhere in the `SELECT` statement, you must have the `SELECT` privilege. If the `OR REPLACE` clause is present, you must also have the `DROP` privilege for the view. `CREATE VIEW` might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section.

When a view is referenced, privilege checking occurs as described later in this section.

A view belongs to a database. By default, a new view is created in the default database. To create the view explicitly in a given database, use `db_name.view_name` syntax to qualify the view name with the database name:

```
mysql> CREATE VIEW test.v AS SELECT * FROM t;
```

Within a database, base tables and views share the same namespace, so a base table and a view cannot have the same name.

Columns retrieved by the `SELECT` statement can be simple references to table columns, or expressions that use functions, constant values, operators, and so forth.

A view must have unique column names with no duplicates, just like a base table. By default, the names of the columns retrieved by the `SELECT` statement are used for the view column names. To define explicit names for the view columns, the optional `column_list` clause can be given as a list of comma-separated identifiers. The number of names in `column_list` must be the same as the number of columns retrieved by the `SELECT` statement.

Note

Prior to MySQL 5.1.29, when you modify an existing view, the server saves a backup of the current view definition under the view database directory, in a subdirectory named `arc`. The backup file for a view `v` is named `v.frm-00001`. If you alter the view again, the next backup is named `v.frm-00002`. The three latest view backup definitions are stored.

Backed up view definitions are not preserved by `mysqldump`, or any other such programs, but you can retain them using a file copy operation. However, they are not needed for anything but to provide you with a backup of your previous view definition.

It is safe to remove these backup definitions, but only while `mysqld` is not running. If you delete the `arc` subdirectory or its files while `mysqld` is running, an error occurs the next time you try to alter the view:

```
mysql> ALTER VIEW v AS SELECT * FROM t;
ERROR 6 (HY000): Error on delete of '.\test\arc/v.frm-0004' (Errcode:
2)
```

Unqualified table or view names in the `SELECT` statement are interpreted with respect to the default database. A view can refer to tables or views in other databases by qualifying the table or view name with the appropriate database name.

A view can be created from many kinds of `SELECT` statements. It can refer to base tables or other views. It can use joins, `UNION`, and subqueries. The `SELECT` need not even refer to any tables.

The following example defines a view that selects two columns from another table as well as an expression calculated from those columns:

```
mysql> CREATE TABLE t (qty INT, price INT);
mysql> INSERT INTO t VALUES(3, 50);
mysql> CREATE VIEW v AS SELECT qty, price, qty*price AS value FROM t;
mysql> SELECT * FROM v;
+------+-------+-------+
| qty  | price | value |
+------+-------+-------+
|    3 |    50 |   150 |
+------+-------+-------+
```

A view definition is subject to the following restrictions:

- The `SELECT` statement cannot contain a subquery in the `FROM` clause.

- The `SELECT` statement cannot refer to system variables or user-defined variables.

- Within a stored program, the `SELECT` statement cannot refer to program parameters or local variables.

- The `SELECT` statement cannot refer to prepared statement parameters.

- Any table or view referred to in the definition must exist. After the view has been created, it is possible to drop a table or view that the definition refers to. In this case, use of the view results in an error. To check a view definition for problems of this kind, use the `CHECK TABLE` statement.

- The definition cannot refer to a `TEMPORARY` table, and you cannot create a `TEMPORARY` view.

- You cannot associate a trigger with a view.

- As of MySQL 5.1.23, aliases for column names in the `SELECT` statement are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters).

`ORDER BY` is permitted in a view definition, but it is ignored if you select from a view using a statement that has its own `ORDER BY`.

For other options or clauses in the definition, they are added to the options or clauses of the statement that references the view, but the effect is undefined. For example, if a view definition includes a `LIMIT` clause, and you select from the view using a statement that has its own `LIMIT` clause, it is undefined which limit applies. This same principle applies to options such as `ALL`, `DISTINCT`, or `SQL_SMALL_RESULT` that follow the `SELECT` keyword, and to clauses such as `INTO`, `FOR UPDATE`, `LOCK IN SHARE MODE`, and `PROCEDURE`.

If you create a view and then change the query processing environment by changing system variables, that may affect the results you get from the view:

```
mysql> CREATE VIEW v (mycol) AS SELECT 'abc';
Query OK, 0 rows affected (0.01 sec)

mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT "mycol" FROM v;
+-------+
| mycol |
+-------+
| mycol |
+-------+
1 row in set (0.01 sec)

mysql> SET sql_mode = 'ANSI_QUOTES';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT "mycol" FROM v;
+-------+
| mycol |
+-------+
| abc   |
+-------+
1 row in set (0.00 sec)
```

The `DEFINER` and `SQL SECURITY` clauses determine which MySQL account to use when checking access privileges for the view when a statement is executed that references the view. These clauses were added in MySQL 5.1.2. The valid `SQL SECURITY` characteristic values are `DEFINER` (the default) and `INVOKER`. These indicate that the required privileges must be held by the user who defined or invoked the view, respectively.

If a _user_ value is given for the `DEFINER` clause, it should be a MySQL account specified as `'user_name'@'host_name'` (the same format used in the `GRANT` statement), `CURRENT_USER`, or `CURRENT_USER()`. The default `DEFINER` value is the user who executes the `CREATE VIEW` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

If you specify the `DEFINER` clause, these rules determine the valid `DEFINER` user values:

- If you do not have the `SUPER` privilege, the only valid _user_ value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.

- If you have the `SUPER` privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.

- Although it is possible to create a view with a nonexistent `DEFINER` account, an error occurs when the view is referenced if the `SQL SECURITY` value is `DEFINER` but the definer account does not exist.

For more information about view security, see Section 19.6, "Access Control for Stored Programs and Views".

Within a view definition, `CURRENT_USER` returns the view's `DEFINER` value by default as of MySQL 5.1.12. For older versions, and for views defined with the `SQL SECURITY INVOKER` characteristic, `CURRENT_USER` returns the account for the view's invoker. For information about user auditing within views, see Section 6.3.6, "SQL-Based MySQL Account Activity Auditing".

Within a stored routine that is defined with the `SQL SECURITY DEFINER` characteristic, `CURRENT_USER` returns the routine's `DEFINER` value. This also affects a view defined within such a routine, if the view definition contains a `DEFINER` value of `CURRENT_USER`.

As of MySQL 5.1.2 (when the `DEFINER` and `SQL SECURITY` clauses were implemented), view privileges are checked like this:

- At view definition time, the view creator must have the privileges needed to use the top-level objects accessed by the view. For example, if the view definition refers to table columns, the creator must have some privilege for each column in the select list of the definition, and the `SELECT` privilege for each column used elsewhere in the definition. If the definition refers to a stored function, only the privileges needed to invoke the function can be checked. The privileges required at function invocation time can be checked only as it executes: For different invocations, different execution paths within the function might be taken.

- The user who references a view must have appropriate privileges to access it (`SELECT` to select from it, `INSERT` to insert into it, and so forth.)

- When a view has been referenced, privileges for objects accessed by the view are checked against the privileges held by the view `DEFINER` account or invoker, depending on whether the `SQL SECURITY` characteristic is `DEFINER` or `INVOKER`, respectively.

- If reference to a view causes execution of a stored function, privilege checking for statements executed within the function depend on whether the function `SQL SECURITY` characteristic is `DEFINER` or `INVOKER`. If the security characteristic is `DEFINER`, the function runs with the privileges of the `DEFINER` account. If the characteristic is `INVOKER`, the function runs with the privileges determined by the view's `SQL SECURITY` characteristic.

Prior to MySQL 5.1.2 (before the `DEFINER` and `SQL SECURITY` clauses were implemented), privileges required for objects used in a view are checked at view creation time.

Example: A view might depend on a stored function, and that function might invoke other stored routines. For example, the following view invokes a stored function `f()`:

```
CREATE VIEW v AS SELECT * FROM t WHERE t.id = f(t.name);
```

Suppose that `f()` contains a statement such as this:

```
IF name IS NULL then
  CALL p1();
ELSE
  CALL p2();
END IF;
```

The privileges required for executing statements within `f()` need to be checked when `f()` executes. This might mean that privileges are needed for `p1()` or `p2()`, depending on the execution path within `f()`.

Those privileges must be checked at runtime, and the user who must possess the privileges is determined by the `SQL SECURITY` values of the view `v` and the function `f()`.

The `DEFINER` and `SQL SECURITY` clauses for views are extensions to standard SQL. In standard SQL, views are handled using the rules for `SQL SECURITY DEFINER`. The standard says that the definer of the view, which is the same as the owner of the view's schema, gets applicable privileges on the view (for example, `SELECT`) and may grant them. MySQL has no concept of a schema "owner", so MySQL adds a clause to identify the definer. The `DEFINER` clause is an extension where the intent is to have what the standard has; that is, a permanent record of who defined the view. This is why the default `DEFINER` value is the account of the view creator.

If you invoke a view that was created before MySQL 5.1.2, it is treated as though it was created with a `SQL SECURITY DEFINER` characteristic and with a `DEFINER` value that is the same as your account. However, because the actual definer is unknown, MySQL issues a warning. To eliminate the warning, it is sufficient to re-create the view so that the view definition includes a `DEFINER` clause.

The optional `ALGORITHM` clause is a MySQL extension to standard SQL. It affects how MySQL processes the view. `ALGORITHM` takes three values: `MERGE`, `TEMPTABLE`, or `UNDEFINED`. The default algorithm is `UNDEFINED` if no `ALGORITHM` clause is present. For more information, see Section 19.5.2, "View Processing Algorithms".

Some views are updatable. That is, you can use them in statements such as `UPDATE`, `DELETE`, or `INSERT` to update the contents of the underlying table. For a view to be updatable, there must be a one-to-one relationship between the rows in the view and the rows in the underlying table. There are also certain other constructs that make a view nonupdatable.

The `WITH CHECK OPTION` clause can be given for an updatable view to prevent inserts or updates to rows except those for which the `WHERE` clause in the `select_statement` is true.

In a `WITH CHECK OPTION` clause for an updatable view, the `LOCAL` and `CASCADED` keywords determine the scope of check testing when the view is defined in terms of another view. The `LOCAL` keyword restricts the `CHECK OPTION` only to the view being defined. `CASCADED` causes the checks for underlying views to be evaluated as well. When neither keyword is given, the default is `CASCADED`.

For more information about updatable views and the `WITH CHECK OPTION` clause, see Section 19.5.3, "Updatable and Insertable Views", and Section 19.5.4, "The View WITH CHECK OPTION Clause".

13.1.21 DROP DATABASE Syntax

```
DROP {DATABASE | SCHEMA} [IF EXISTS] db_name
```

`DROP DATABASE` drops all tables in the database and deletes the database. Be *very* careful with this statement! To use `DROP DATABASE`, you need the `DROP` privilege on the database. `DROP SCHEMA` is a synonym for `DROP DATABASE`.

> **Important**
>
> When a database is dropped, user privileges on the database are *not* automatically dropped. See Section 13.7.1.3, "GRANT Syntax".

`IF EXISTS` is used to prevent an error from occurring if the database does not exist.

If the default database is dropped, the default database is unset (the `DATABASE()` function returns `NULL`).

If you use `DROP DATABASE` on a symbolically linked database, both the link and the original database are deleted.

`DROP DATABASE` returns the number of tables that were removed. This corresponds to the number of `.frm` files removed.

The `DROP DATABASE` statement removes from the given database directory those files and directories that MySQL itself may create during normal operation:

- All files with the following extensions.

`.BAK`	`.DAT`	`.HSH`	`.MRG`
`.MYD`	`.MYI`	`.TRG`	`.TRN`
`.db`	`.frm`	`.ibd`	`.ndb`
`.par`			

- The `db.opt` file, if it exists.

If other files or directories remain in the database directory after MySQL removes those just listed, the database directory cannot be removed. In this case, you must remove any remaining files or directories manually and issue the `DROP DATABASE` statement again.

Dropping a database does not remove any `TEMPORARY` tables that were created in that database. `TEMPORARY` tables are automatically removed when the session that created them ends. See Temporary Tables.

You can also drop databases with `mysqladmin`. See Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".

13.1.22 DROP EVENT Syntax

```
DROP EVENT [IF EXISTS] event_name
```

This statement drops the event named *event_name*. The event immediately ceases being active, and is deleted completely from the server.

If the event does not exist, the error `ERROR 1517 (HY000): Unknown event 'event_name'` results. You can override this and cause the statement to generate a warning for nonexistent events instead using `IF EXISTS`.

Beginning with MySQL 5.1.12, this statement requires the `EVENT` privilege for the schema to which the event to be dropped belongs. (In MySQL 5.1.11 and earlier, an event could be dropped only by its definer, or by a user having the `SUPER` privilege.)

13.1.23 DROP FUNCTION Syntax

The `DROP FUNCTION` statement is used to drop stored functions and user-defined functions (UDFs):

- For information about dropping stored functions, see Section 13.1.26, "DROP PROCEDURE and DROP FUNCTION Syntax".

- For information about dropping user-defined functions, see Section 13.7.3.2, "DROP FUNCTION Syntax".

13.1.24 DROP INDEX Syntax

```
DROP [ONLINE|OFFLINE] INDEX index_name ON tbl_name
```

`DROP INDEX` drops the index named `index_name` from the table `tbl_name`. This statement is mapped to an `ALTER TABLE` statement to drop the index. See Section 13.1.7, "ALTER TABLE Syntax".

To drop a primary key, the index name is always `PRIMARY`, which must be specified as a quoted identifier because `PRIMARY` is a reserved word:

```
DROP INDEX `PRIMARY` ON t;
```

Beginning with MySQL 5.1.17, indexes on variable-width columns of `NDBCLUSTER` tables are dropped online; that is, without any table copying. The table is not locked against access from other MySQL Cluster API nodes, although it is locked against other operations on the *same* API node for the duration of the operation. This is done automatically by the server whenever it determines that it is possible to do so; you do not have to use any special SQL syntax or server options to cause it to happen.

In standard MySQL 5.1 releases, it is not possible to override the server when it determines that an index is to be dropped without table copying. In MySQL Cluster, you can drop indexes offline (which causes the table to be locked for all API nodes in the cluster) using the `OFFLINE` keyword. The rules and limitations governing `DROP OFFLINE INDEX` and `DROP ONLINE INDEX` are the same as for `ALTER OFFLINE TABLE ... DROP INDEX` and `ALTER ONLINE TABLE ... DROP INDEX`. You cannot cause the noncopying dropping of an index that would normally be dropped offline by using the `ONLINE` keyword: If it is not possible to perform the `DROP` operation without table copying, the server ignores the `ONLINE` keyword. For more information, see Section 13.1.7.2, "ALTER TABLE Online Operations in MySQL Cluster".

> **Note**
>
> The `ONLINE` and `OFFLINE` keywords are available only in MySQL Cluster NDB 6.2.5, 6.3.2, and later MySQL Cluster releases; attempting to use these keywords in earlier MySQL Cluster releases or standard MySQL 5.1 releases results in a syntax error.

13.1.25 DROP LOGFILE GROUP Syntax

```
DROP LOGFILE GROUP logfile_group
    ENGINE [=] engine_name
```

This statement drops the log file group named `logfile_group`. The log file group must already exist or an error results. (For information on creating log file groups, see Section 13.1.14, "CREATE LOGFILE GROUP Syntax".)

> **Important**
>
> Before dropping a log file group, you must drop all tablespaces that use that log file group for `UNDO` logging.

The required `ENGINE` clause provides the name of the storage engine used by the log file group to be dropped. In MySQL 5.1, the only permitted values for `engine_name` are `NDB` and `NDBCLUSTER`.

`DROP LOGFILE GROUP` was added in MySQL 5.1.6. In MySQL 5.1, it is useful only with Disk Data storage for MySQL Cluster. See Section 17.5.12, "MySQL Cluster Disk Data Tables".

13.1.26 DROP PROCEDURE and DROP FUNCTION Syntax

```
DROP {PROCEDURE | FUNCTION} [IF EXISTS] sp_name
```

This statement is used to drop a stored procedure or function. That is, the specified routine is removed from the server. You must have the `ALTER ROUTINE` privilege for the routine. (If the `automatic_sp_privileges` system variable is enabled, that privilege and `EXECUTE` are granted automatically to the routine creator when the routine is created and dropped from the creator when the routine is dropped. See Section 19.2.2, "Stored Routines and MySQL Privileges".)

The `IF EXISTS` clause is a MySQL extension. It prevents an error from occurring if the procedure or function does not exist. A warning is produced that can be viewed with `SHOW WARNINGS`.

`DROP FUNCTION` is also used to drop user-defined functions (see Section 13.7.3.2, "DROP FUNCTION Syntax").

13.1.27 DROP SERVER Syntax

```
DROP SERVER [ IF EXISTS ] server_name
```

Drops the server definition for the server named `server_name`. The corresponding row in the `mysql.servers` table is deleted. This statement requires the `SUPER` privilege.

Dropping a server for a table does not affect any `FEDERATED` tables that used this connection information when they were created. See Section 13.1.16, "CREATE SERVER Syntax".

`DROP SERVER` does not cause an automatic commit.

In MySQL 5.1, `DROP SERVER` is written to the binary log only when using row-based logging. It is not logged when `binlog_format` is equal to `STATEMENT` or `MIXED`.

`DROP SERVER` was added in MySQL 5.1.15.

13.1.28 DROP TABLE Syntax

```
DROP [TEMPORARY] TABLE [IF EXISTS]
    tbl_name [, tbl_name] ...
    [RESTRICT | CASCADE]
```

`DROP TABLE` removes one or more tables. You must have the `DROP` privilege for each table. All table data and the table definition are *removed*, so *be careful* with this statement! If any of the tables named in the argument list do not exist, MySQL returns an error indicating by name which nonexisting tables it was unable to drop, but it also drops all of the tables in the list that do exist.

> **Important**
>
> When a table is dropped, user privileges on the table are *not* automatically dropped. See Section 13.7.1.3, "GRANT Syntax".

For a partitioned table, `DROP TABLE` permanently removes the table definition, all of its partitions, and all of the data which was stored in those partitions. It also removes the partitioning definition (`.par`) file associated with the dropped table.

Use `IF EXISTS` to prevent an error from occurring for tables that do not exist. A `NOTE` is generated for each nonexistent table when using `IF EXISTS`. See Section 13.7.5.42, "SHOW WARNINGS Syntax".

`RESTRICT` and `CASCADE` are permitted to make porting easier. In MySQL 5.1, they do nothing.

Note

`DROP TABLE` automatically commits the current active transaction, unless you use the `TEMPORARY` keyword.

The `TEMPORARY` keyword has the following effects:

- The statement drops only `TEMPORARY` tables.

- The statement does not end an ongoing transaction.

- No access rights are checked. (A `TEMPORARY` table is visible only to the session that created it, so no check is necessary.)

Using `TEMPORARY` is a good way to ensure that you do not accidentally drop a non-`TEMPORARY` table.

13.1.29 DROP TABLESPACE Syntax

```
DROP TABLESPACE tablespace_name
    ENGINE [=] engine_name
```

This statement drops a tablespace that was previously created using `CREATE TABLESPACE` (see Section 13.1.18, "CREATE TABLESPACE Syntax").

Important

The tablespace to be dropped must not contain any data files; in other words, before you can drop a tablespace, you must first drop each of its data files using `ALTER TABLESPACE ... DROP DATAFILE` (see Section 13.1.8, "ALTER TABLESPACE Syntax").

The `ENGINE` clause (required) specifies the storage engine used by the tablespace. In MySQL 5.1, the only accepted values for `engine_name` are `NDB` and `NDBCLUSTER`.

`DROP TABLESPACE` was added in MySQL 5.1.6. In MySQL 5.1, it is useful only with Disk Data storage for MySQL Cluster. See Section 17.5.12, "MySQL Cluster Disk Data Tables".

13.1.30 DROP TRIGGER Syntax

```
DROP TRIGGER [IF EXISTS] [schema_name.]trigger_name
```

This statement drops a trigger. The schema (database) name is optional. If the schema is omitted, the trigger is dropped from the default schema. `DROP TRIGGER` requires the `TRIGGER` privilege for the table associated with the trigger. (This statement requires the `SUPER` privilege prior to MySQL 5.1.6.)

Use `IF EXISTS` to prevent an error from occurring for a trigger that does not exist. A `NOTE` is generated for a nonexistent trigger when using `IF EXISTS`. See Section 13.7.5.42, "SHOW WARNINGS Syntax". The `IF EXISTS` clause was added in MySQL 5.1.14.

Triggers for a table are also dropped if you drop the table.

Note

When upgrading from a version of MySQL older than MySQL 5.0.10 to 5.0.10 or newer—including all MySQL 5.1 releases—you must drop all triggers and re-

> create them. Otherwise, `DROP TRIGGER` does not work for older triggers after the upgrade. See Section 2.13.1.1, "Changes Affecting Upgrades to 5.1", for a suggested upgrade procedure.

13.1.31 DROP VIEW Syntax

```
DROP VIEW [IF EXISTS]
    view_name [, view_name] ...
    [RESTRICT | CASCADE]
```

`DROP VIEW` removes one or more views. You must have the `DROP` privilege for each view. If any of the views named in the argument list do not exist, MySQL returns an error indicating by name which nonexisting views it was unable to drop, but it also drops all of the views in the list that do exist.

The `IF EXISTS` clause prevents an error from occurring for views that don't exist. When this clause is given, a `NOTE` is generated for each nonexistent view. See Section 13.7.5.42, "SHOW WARNINGS Syntax".

`RESTRICT` and `CASCADE`, if given, are parsed and ignored.

13.1.32 RENAME DATABASE Syntax

```
RENAME {DATABASE | SCHEMA} db_name TO new_db_name;
```

This statement was added in MySQL 5.1.7 but was found to be dangerous and was removed in MySQL 5.1.23. It was intended to enable upgrading pre-5.1 databases to use the encoding implemented in 5.1 for mapping database names to database directory names (see Section 9.2.3, "Mapping of Identifiers to File Names"). However, use of this statement could result in loss of database contents, which is why it was removed. Do not use `RENAME DATABASE` in earlier versions in which it is present.

To perform the task of upgrading database names with the new encoding, use `ALTER DATABASE db_name UPGRADE DATA DIRECTORY NAME` instead (see Section 13.1.1, "ALTER DATABASE Syntax").

13.1.33 RENAME TABLE Syntax

```
RENAME TABLE tbl_name TO new_tbl_name
    [, tbl_name2 TO new_tbl_name2] ...
```

This statement renames one or more tables. The rename operation is done atomically, which means that no other session can access any of the tables while the rename is running.

For example, a table named `old_table` can be renamed to `new_table` as shown here:

```
RENAME TABLE old_table TO new_table;
```

This statement is equivalent to the following `ALTER TABLE` statement:

```
ALTER TABLE old_table RENAME new_table;
```

If the statement renames more than one table, renaming operations are done from left to right. If you want to swap two table names, you can do so like this (assuming that `tmp_table` does not already exist):

```
RENAME TABLE old_table TO tmp_table,
             new_table TO old_table,
             tmp_table TO new_table;
```

MySQL checks the destination table name before checking whether the source table exists. For example, if `new_table` already exists and `old_table` does not, the following statement fails as shown here:

```
mysql> SHOW TABLES;
+----------------+
| Tables_in_mydb |
+----------------+
| table_a        |
+----------------+
1 row in set (0.00 sec)

mysql> RENAME TABLE table_b TO table_a;
ERROR 1050 (42S01): Table 'table_a' already exists
```

As long as two databases are on the same file system, you can use `RENAME TABLE` to move a table from one database to another:

```
RENAME TABLE current_db.tbl_name TO other_db.tbl_name;
```

You can use this method to move all tables from one database to a different one, in effect renaming the database. (MySQL 5.1.7 through 5.1.23 had a RENAME DATABASE statement, but this statement was not always safe to use, and was subsequently removed.)

If there are any triggers associated with a table which is moved to a different database using `RENAME TABLE`, then the statement fails with the error `Trigger in wrong schema`.

Foreign keys that point to the renamed table are not automatically updated. In such cases, you must drop and re-create the foreign keys in order for them to function properly.

`RENAME TABLE` also works for views, as long as you do not try to rename a view into a different database.

Any privileges granted specifically for the renamed table or view are not migrated to the new name. They must be changed manually.

When you execute `RENAME TABLE`, you cannot have any locked tables or active transactions. You must also have the `ALTER` and `DROP` privileges on the original table, and the `CREATE` and `INSERT` privileges on the new table.

If MySQL encounters any errors in a multiple-table rename, it does a reverse rename for all renamed tables to return everything to its original state.

You cannot use `RENAME TABLE` to rename a `TEMPORARY` table. However, you can use `ALTER TABLE` with temporary tables.

Like `RENAME TABLE`, `ALTER TABLE ... RENAME` can also be used to move a table to a different database. Regardless of the statement used to perform the rename, if the rename operation would move the table to a database located on a different file system, the success of the outcome is platform specific and depends on the underlying operating system calls used to move the table files.

13.1.34 TRUNCATE TABLE Syntax

```
TRUNCATE [TABLE] tbl_name
```

`TRUNCATE TABLE` empties a table completely. It requires the `DROP` privilege as of MySQL 5.1.16. (Before 5.1.16, it requires the `DELETE` privilege).

Logically, `TRUNCATE TABLE` is equivalent to a `DELETE` statement that deletes all rows, but there are practical differences under some circumstances.

For an `InnoDB` table:

- If there are no `FOREIGN KEY` constraints, `InnoDB` performs fast truncation by dropping the original table and creating an empty one with the same definition, which is much faster than deleting rows one by one.

- When you use this fast truncation technique with the `innodb_file_per_table` option enabled, the operating system can reuse the freed disk space. For users of the InnoDB Plugin, the space is reclaimed automatically, as described in Reclaiming Disk Space with TRUNCATE TABLE. If you do not have the InnoDB Plugin installed, issue the `OPTIMIZE TABLE` statement to free the disk space for the table.

- If there are any `FOREIGN KEY` constraints that reference the table, `InnoDB` processes `TRUNCATE TABLE` by deleting rows one by one, processing the constraints as it proceeds. If the `FOREIGN KEY` constraint specifies `DELETE CASCADE`, rows from the child (referenced) table are deleted, and the truncated table becomes empty. If the `FOREIGN KEY` constraint does *not* specify `CASCADE`, the `TRUNCATE TABLE` statement deletes rows one by one and stops if it encounters a parent row that is referenced by the child, returning this error:

```
ERROR 1451 (23000): Cannot delete or update a parent row: a foreign
key constraint fails (`test`.`child`, CONSTRAINT `child_ibfk_1`
FOREIGN KEY (`parent_id`) REFERENCES `parent` (`id`))
```

> **Note**
>
> In MySQL 5.5 and higher, `TRUNCATE TABLE` is not allowed for `InnoDB` tables referenced by foreign keys. For ease of upgrading, rewrite such statements to use `DELETE` instead.

- The `AUTO_INCREMENT` counter is reset to zero by `TRUNCATE TABLE`, regardless of whether there is a `FOREIGN KEY` constraint.

This is the same as a `DELETE` statement with no `WHERE` clause.

The count of rows affected by `TRUNCATE TABLE` is accurate only when it is mapped to a `DELETE` statement.

For other storage engines, `TRUNCATE TABLE` differs from `DELETE` in the following ways in MySQL 5.1:

- Truncate operations drop and re-create the table, which is much faster than deleting rows one by one, particularly for large tables.

- Truncate operations cause an implicit commit.

- Truncation operations cannot be performed if the session holds an active table lock.

- Truncation operations do not return a meaningful value for the number of deleted rows. The usual result is "0 rows affected," which should be interpreted as "no information."

- As long as the table format file `tbl_name.frm` is valid, the table can be re-created as an empty table with `TRUNCATE TABLE`, even if the data or index files have become corrupted.

- The table handler does not remember the last used `AUTO_INCREMENT` value, but starts counting from the beginning. This is true even for `MyISAM` and `InnoDB`, which normally do not reuse sequence values.

- When used with partitioned tables, `TRUNCATE TABLE` preserves the partitioning; that is, the data and index files are dropped and re-created, while the partition definitions (`.par`) file is unaffected.

- Since truncation of a table does not make any use of `DELETE`, the `TRUNCATE TABLE` statement does not invoke `ON DELETE` triggers.

As of MySQL 5.1.39, `TRUNCATE TABLE` for a table closes all handlers for the table that were opened with `HANDLER OPEN`.

Beginning with MySQL 5.1.32, `TRUNCATE TABLE` is treated for purposes of binary logging and replication as `DROP TABLE` followed by `CREATE TABLE`—that is, as DDL rather than DML. This is due to the fact that, when using `InnoDB` and other transactional storage engines where the transaction isolation level does not permit statement-based logging (`READ COMMITTED` or `READ UNCOMMITTED`), the statement was not logged and replicated when using `STATEMENT` or `MIXED` logging mode. (Bug #36763) However, it is still applied on replication slaves using `InnoDB` in the manner described previously.

13.2 Data Manipulation Statements

13.2.1 CALL Syntax

```
CALL sp_name([parameter[,...]])
CALL sp_name[()]
```

The `CALL` statement invokes a stored procedure that was defined previously with `CREATE PROCEDURE`.

As of MySQL 5.1.13, stored procedures that take no arguments can be invoked without parentheses. That is, `CALL p()` and `CALL p` are equivalent.

`CALL` can pass back values to its caller using parameters that are declared as `OUT` or `INOUT` parameters. When the procedure returns, a client program can also obtain the number of rows affected for the final statement executed within the routine: At the SQL level, call the `ROW_COUNT()` function; from the C API, call the `mysql_affected_rows()` function.

To get back a value from a procedure using an `OUT` or `INOUT` parameter, pass the parameter by means of a user variable, and then check the value of the variable after the procedure returns. (If you are calling the procedure from within another stored procedure or function, you can also pass a routine parameter or local routine variable as an `IN` or `INOUT` parameter.) For an `INOUT` parameter, initialize its value before passing it to the procedure. The following procedure has an `OUT` parameter that the procedure sets to the current server version, and an `INOUT` value that the procedure increments by one from its current value:

```
CREATE PROCEDURE p (OUT ver_param VARCHAR(25), INOUT incr_param INT)
BEGIN
  # Set value of OUT parameter
  SELECT VERSION() INTO ver_param;
  # Increment value of INOUT parameter
  SET incr_param = incr_param + 1;
END;
```

Before calling the procedure, initialize the variable to be passed as the `INOUT` parameter. After calling the procedure, the values of the two variables will have been set or modified:

```
mysql> SET @increment = 10;
mysql> CALL p(@version, @increment);
mysql> SELECT @version, @increment;
+-----------+------------+
| @version  | @increment |
+-----------+------------+
| 5.1.32-log | 11        |
+-----------+------------+
```

In prepared `CALL` statements used with `PREPARE` and `EXECUTE`, placeholder support is available in MySQL 5.1 for `IN` parameters, but not for `OUT` or `INOUT` parameters. To work around this limitation for `OUT` and `INOUT` parameters, forego the use of placeholders; instead, refer to user variables in the `CALL` statement itself and do not specify them in the `EXECUTE` statement:

```
mysql> SET @increment = 10;
mysql> PREPARE s FROM 'CALL p(@version, @increment)';
mysql> EXECUTE s;
mysql> SELECT @version, @increment;
+-----------+------------+
| @version  | @increment |
+-----------+------------+
| 5.1.32-log | 11        |
+-----------+------------+
```

To write C programs that use the `CALL` SQL statement to execute stored procedures that produce result sets, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. `CLIENT_MULTI_RESULTS` must also be enabled if `CALL` is used to execute any stored procedure that contains prepared statements. It cannot be determined when such a procedure is loaded whether those statements will produce result sets, so it is necessary to assume that they will.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`).

To process the result of a `CALL` statement executed using `mysql_query()` or `mysql_real_query()`, use a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 21.8.16, "C API Support for Multiple Statement Execution".

For programs written in a language that provides a MySQL interface, there is no native method for directly retrieving the results of `OUT` or `INOUT` parameters from `CALL` statements. To get the parameter values, pass user-defined variables to the procedure in the `CALL` statement and then execute a `SELECT` statement to produce a result set containing the variable values. To handle an `INOUT` parameter, execute a statement prior to the `CALL` that sets the corresponding user variable to the value to be passed to the procedure.

The following example illustrates the technique (without error checking) for the stored procedure `p` described earlier that has an `OUT` parameter and an `INOUT` parameter:

```
mysql_query(mysql, "SET @increment = 10");
mysql_query(mysql, "CALL p(@version, @increment)");
mysql_query(mysql, "SELECT @version, @increment");
result = mysql_store_result(mysql);
row = mysql_fetch_row(result);
mysql_free_result(result);
```

After the preceding code executes, `row[0]` and `row[1]` contain the values of `@version` and `@increment`, respectively.

13.2.2 DELETE Syntax

Single-table syntax:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE] FROM tbl_name
    [WHERE where_condition]
    [ORDER BY ...]
    [LIMIT row_count]
```

Multiple-table syntax:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE]
    tbl_name[.*] [, tbl_name[.*]] ...
    FROM table_references
    [WHERE where_condition]
```

Or:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE]
    FROM tbl_name[.*] [, tbl_name[.*]] ...
    USING table_references
    [WHERE where_condition]
```

For the single-table syntax, the DELETE statement deletes rows from `tbl_name` and returns a count of the number of deleted rows. This count can be obtained by calling the ROW_COUNT() function (see Section 12.14, "Information Functions"). The WHERE clause, if given, specifies the conditions that identify which rows to delete. With no WHERE clause, all rows are deleted. If the ORDER BY clause is specified, the rows are deleted in the order that is specified. The LIMIT clause places a limit on the number of rows that can be deleted.

For the multiple-table syntax, DELETE deletes from each `tbl_name` the rows that satisfy the conditions. In this case, ORDER BY and LIMIT cannot be used.

`where_condition` is an expression that evaluates to true for each row to be deleted. It is specified as described in Section 13.2.8, "SELECT Syntax".

You cannot delete from a table and select from the same table in a subquery.

You need the DELETE privilege on a table to delete rows from it. You need only the SELECT privilege for any columns that are only read, such as those named in the WHERE clause.

As stated, a DELETE statement with no WHERE clause deletes all rows. A faster way to do this, when you do not need to know the number of deleted rows, is to use TRUNCATE TABLE. However, within a transaction or if you have a lock on the table, TRUNCATE TABLE cannot be used whereas DELETE can. See Section 13.1.34, "TRUNCATE TABLE Syntax", and Section 13.3.5, "LOCK TABLES and UNLOCK TABLES Syntax".

If you delete the row containing the maximum value for an AUTO_INCREMENT column, the value is not reused for a MyISAM or InnoDB table. If you delete all rows in the table with DELETE FROM tbl_name (without a WHERE clause) in autocommit mode, the sequence starts over for all storage engines except InnoDB and MyISAM. There are some exceptions to this behavior for InnoDB tables, as discussed in Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB".

For MyISAM tables, you can specify an AUTO_INCREMENT secondary column in a multiple-column key. In this case, reuse of values deleted from the top of the sequence occurs even for MyISAM tables. See Section 3.6.9, "Using AUTO_INCREMENT".

The `DELETE` statement supports the following modifiers:

- If you specify `LOW_PRIORITY`, the server delays execution of the `DELETE` until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- For `MyISAM` tables, if you use the `QUICK` keyword, the storage engine does not merge index leaves during delete, which may speed up some kinds of delete operations.

- The `IGNORE` keyword causes MySQL to ignore errors during the process of deleting rows. (Errors encountered during the parsing stage are processed in the usual manner.) Errors that are ignored due to the use of `IGNORE` are returned as warnings.

The speed of delete operations may also be affected by factors discussed in Section 8.2.2.3, "Speed of DELETE Statements".

In `MyISAM` tables, deleted rows are maintained in a linked list and subsequent `INSERT` operations reuse old row positions. To reclaim unused space and reduce file sizes, use the `OPTIMIZE TABLE` statement or the `myisamchk` utility to reorganize tables. `OPTIMIZE TABLE` is easier to use, but `myisamchk` is faster. See Section 13.7.2.5, "OPTIMIZE TABLE Syntax", and Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility".

The `QUICK` modifier affects whether index leaves are merged for delete operations. `DELETE QUICK` is most useful for applications where index values for deleted rows are replaced by similar index values from rows inserted later. In this case, the holes left by deleted values are reused.

`DELETE QUICK` is not useful when deleted values lead to underfilled index blocks spanning a range of index values for which new inserts occur again. In this case, use of `QUICK` can lead to wasted space in the index that remains unreclaimed. Here is an example of such a scenario:

1. Create a table that contains an indexed `AUTO_INCREMENT` column.

2. Insert many rows into the table. Each insert results in an index value that is added to the high end of the index.

3. Delete a block of rows at the low end of the column range using `DELETE QUICK`.

In this scenario, the index blocks associated with the deleted index values become underfilled but are not merged with other index blocks due to the use of `QUICK`. They remain underfilled when new inserts occur, because new rows do not have index values in the deleted range. Furthermore, they remain underfilled even if you later use `DELETE` without `QUICK`, unless some of the deleted index values happen to lie in index blocks within or adjacent to the underfilled blocks. To reclaim unused index space under these circumstances, use `OPTIMIZE TABLE`.

If you are going to delete many rows from a table, it might be faster to use `DELETE QUICK` followed by `OPTIMIZE TABLE`. This rebuilds the index rather than performing many index block merge operations.

The MySQL-specific `LIMIT row_count` option to `DELETE` tells the server the maximum number of rows to be deleted before control is returned to the client. This can be used to ensure that a given `DELETE` statement does not take too much time. You can simply repeat the `DELETE` statement until the number of affected rows is less than the `LIMIT` value.

If the `DELETE` statement includes an `ORDER BY` clause, rows are deleted in the order specified by the clause. This is useful primarily in conjunction with `LIMIT`. For example, the following statement finds rows matching the `WHERE` clause, sorts them by `timestamp_column`, and deletes the first (oldest) one:

```
DELETE FROM somelog WHERE user = 'jcole'
ORDER BY timestamp_column LIMIT 1;
```

`ORDER BY` may also be useful in some cases to delete rows in an order required to avoid referential integrity violations.

If you are deleting many rows from a large table, you may exceed the lock table size for an `InnoDB` table. To avoid this problem, or simply to minimize the time that the table remains locked, the following strategy (which does not use `DELETE` at all) might be helpful:

1. Select the rows *not* to be deleted into an empty table that has the same structure as the original table:

```
INSERT INTO t_copy SELECT * FROM t WHERE ... ;
```

2. Use `RENAME TABLE` to atomically move the original table out of the way and rename the copy to the original name:

```
RENAME TABLE t TO t_old, t_copy TO t;
```

3. Drop the original table:

```
DROP TABLE t_old;
```

No other sessions can access the tables involved while `RENAME TABLE` executes, so the rename operation is not subject to concurrency problems. See Section 13.1.33, "RENAME TABLE Syntax".

You can specify multiple tables in a `DELETE` statement to delete rows from one or more tables depending on the particular condition in the `WHERE` clause. However, you cannot use `ORDER BY` or `LIMIT` in a multiple-table `DELETE`. The `table_references` clause lists the tables involved in the join. Its syntax is described in Section 13.2.8.2, "JOIN Syntax".

For the first multiple-table syntax, only matching rows from the tables listed before the `FROM` clause are deleted. For the second multiple-table syntax, only matching rows from the tables listed in the `FROM` clause (before the `USING` clause) are deleted. The effect is that you can delete rows from many tables at the same time and have additional tables that are used only for searching:

```
DELETE t1, t2 FROM t1 INNER JOIN t2 INNER JOIN t3
WHERE t1.id=t2.id AND t2.id=t3.id;
```

Or:

```
DELETE FROM t1, t2 USING t1 INNER JOIN t2 INNER JOIN t3
WHERE t1.id=t2.id AND t2.id=t3.id;
```

These statements use all three tables when searching for rows to delete, but delete matching rows only from tables `t1` and `t2`.

The preceding examples use `INNER JOIN`, but multiple-table `DELETE` statements can use other types of join permitted in `SELECT` statements, such as `LEFT JOIN`. For example, to delete rows that exist in `t1` that have no match in `t2`, use a `LEFT JOIN`:

```
DELETE t1 FROM t1 LEFT JOIN t2 ON t1.id=t2.id WHERE t2.id IS NULL;
```

The syntax permits `.*` after each `tbl_name` for compatibility with `Access`.

If you use a multiple-table `DELETE` statement involving `InnoDB` tables for which there are foreign key constraints, the MySQL optimizer might process tables in an order that differs from that of their parent/child relationship. In this case, the statement fails and rolls back. Instead, you should delete from a single table and rely on the `ON DELETE` capabilities that `InnoDB` provides to cause the other tables to be modified accordingly.

> **Note**
>
> If you declare an alias for a table, you must use the alias when referring to the table:
>
> ```
> DELETE t1 FROM test AS t1, test2 WHERE ...
> ```

Table aliases in a multiple-table `DELETE` should be declared only in the `table_references` part of the statement.

Correct:

```
DELETE a1, a2 FROM t1 AS a1 INNER JOIN t2 AS a2
WHERE a1.id=a2.id;

DELETE FROM a1, a2 USING t1 AS a1 INNER JOIN t2 AS a2
WHERE a1.id=a2.id;
```

Incorrect:

```
DELETE t1 AS a1, t2 AS a2 FROM t1 INNER JOIN t2
WHERE a1.id=a2.id;

DELETE FROM t1 AS a1, t2 AS a2 USING t1 INNER JOIN t2
WHERE a1.id=a2.id;
```

Declaration of aliases other than in the `table_references` part of the statement should be avoided because that can lead to ambiguous statements that have unexpected results such as deleting rows from the wrong table. This is such a statement:

```
DELETE t1 AS a2 FROM t1 AS a1 INNER JOIN t2 AS a2;
```

As of MySQL 5.1.23, alias declarations outside the `table_references` part of the statement are disallowed for the `USING` variant of multiple-table `DELETE` syntax. (In MySQL 5.5, alias declarations outside `table_references` are disallowed for all multiple-table `DELETE` statements.)

For alias references in the list of tables from which to delete rows in a multiple-table delete, the default database is used unless one is specified explicitly. For example, if the default database is `db1`, the following statement does not work because the unqualified alias reference `a2` is interpreted as having a database of `db1`:

```
DELETE a1, a2 FROM db1.t1 AS a1 INNER JOIN db2.t2 AS a2
WHERE a1.id=a2.id;
```

To correctly match an alias that refers to a table outside the default database, you must explicitly qualify the reference with the name of the proper database:

```
DELETE a1, db2.a2 FROM db1.t1 AS a1 INNER JOIN db2.t2 AS a2
WHERE a1.id=a2.id;
```

13.2.3 DO Syntax

```
DO expr [, expr] ...
```

DO executes the expressions but does not return any results. In most respects, DO is shorthand for SELECT expr, ..., but has the advantage that it is slightly faster when you do not care about the result.

DO is useful primarily with functions that have side effects, such as RELEASE_LOCK().

Example: This SELECT statement pauses, but also produces a result set:

```
mysql> SELECT SLEEP(5);
+----------+
| SLEEP(5) |
+----------+
|        0 |
+----------+
1 row in set (5.02 sec)
```

DO, on the other hand, pauses without producing a result set.:

```
mysql> DO SLEEP(5);
Query OK, 0 rows affected (4.99 sec)
```

This could be useful, for example in a stored function or trigger, which prohibit statements that produce result sets.

DO only executes expressions. It cannot be used in all cases where SELECT can be used. For example, DO id FROM t1 is invalid because it references a table.

13.2.4 HANDLER Syntax

```
HANDLER tbl_name OPEN [ [AS] alias]

HANDLER tbl_name READ index_name { = | <= | >= | < | > } (value1,value2,...)
    [ WHERE where_condition ] [LIMIT ... ]
HANDLER tbl_name READ index_name { FIRST | NEXT | PREV | LAST }
    [ WHERE where_condition ] [LIMIT ... ]
HANDLER tbl_name READ { FIRST | NEXT }
    [ WHERE where_condition ] [LIMIT ... ]

HANDLER tbl_name CLOSE
```

The HANDLER statement provides direct access to table storage engine interfaces. It is available for InnoDB and MyISAM tables.

The HANDLER ... OPEN statement opens a table, making it accessible using subsequent HANDLER ... READ statements. This table object is not shared by other sessions and is not closed until the session calls HANDLER ... CLOSE or the session terminates.

If you open the table using an alias, further references to the open table with other HANDLER statements must use the alias rather than the table name. If you do not use an alias, but open the table using a table name qualified by the database name, further references must use the unqualified table name. For example, for a table opened using mydb.mytable, further references must use mytable.

The first HANDLER ... READ syntax fetches a row where the index specified satisfies the given values and the WHERE condition is met. If you have a multiple-column index, specify the index column values as a

comma-separated list. Either specify values for all the columns in the index, or specify values for a leftmost prefix of the index columns. Suppose that an index `my_idx` includes three columns named `col_a`, `col_b`, and `col_c`, in that order. The `HANDLER` statement can specify values for all three columns in the index, or for the columns in a leftmost prefix. For example:

```
HANDLER ... READ my_idx = (col_a_val,col_b_val,col_c_val) ...
HANDLER ... READ my_idx = (col_a_val,col_b_val) ...
HANDLER ... READ my_idx = (col_a_val) ...
```

To employ the `HANDLER` interface to refer to a table's `PRIMARY KEY`, use the quoted identifier `` `PRIMARY` ``:

```
HANDLER tbl_name READ `PRIMARY` ...
```

The second `HANDLER ... READ` syntax fetches a row from the table in index order that matches the `WHERE` condition.

The third `HANDLER ... READ` syntax fetches a row from the table in natural row order that matches the `WHERE` condition. It is faster than `HANDLER tbl_name READ index_name` when a full table scan is desired. Natural row order is the order in which rows are stored in a `MyISAM` table data file. This statement works for `InnoDB` tables as well, but there is no such concept because there is no separate data file.

Without a `LIMIT` clause, all forms of `HANDLER ... READ` fetch a single row if one is available. To return a specific number of rows, include a `LIMIT` clause. It has the same syntax as for the `SELECT` statement. See Section 13.2.8, "SELECT Syntax".

`HANDLER ... CLOSE` closes a table that was opened with `HANDLER ... OPEN`.

There are several reasons to use the `HANDLER` interface instead of normal `SELECT` statements:

- `HANDLER` is faster than `SELECT`:

  - A designated storage engine handler object is allocated for the `HANDLER ... OPEN`. The object is reused for subsequent `HANDLER` statements for that table; it need not be reinitialized for each one.

  - There is less parsing involved.

  - There is no optimizer or query-checking overhead.

  - The handler interface does not have to provide a consistent look of the data (for example, dirty reads are permitted), so the storage engine can use optimizations that `SELECT` does not normally permit.

- `HANDLER` makes it easier to port to MySQL applications that use a low-level `ISAM`-like interface.

- `HANDLER` enables you to traverse a database in a manner that is difficult (or even impossible) to accomplish with `SELECT`. The `HANDLER` interface is a more natural way to look at data when working with applications that provide an interactive user interface to the database.

`HANDLER` is a somewhat low-level statement. For example, it does not provide consistency. That is, `HANDLER ... OPEN` does *not* take a snapshot of the table, and does *not* lock the table. This means that after a `HANDLER ... OPEN` statement is issued, table data can be modified (by the current session or other sessions) and these modifications might be only partially visible to `HANDLER ... NEXT` or `HANDLER ... PREV` scans.

An open handler can be closed and marked for reopen, in which case the handler loses its position in the table. This occurs when both of the following circumstances are true:

- Any session executes `FLUSH TABLES` or DDL statements on the handler's table.

- The session in which the handler is open executes non-`HANDLER` statements that use tables.

As of MySQL 5.1.39, `TRUNCATE TABLE` for a table closes all handlers for the table that were opened with `HANDLER OPEN`.

`HANDLER` is not supported with partitioned tables.

13.2.5 INSERT Syntax

```
INSERT [LOW_PRIORITY | DELAYED | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name [(col_name,...)]
    {VALUES | VALUE} ({expr | DEFAULT},...),(...),...
    [ ON DUPLICATE KEY UPDATE
      col_name=expr
        [, col_name=expr] ... ]
```

Or:

```
INSERT [LOW_PRIORITY | DELAYED | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name
    SET col_name={expr | DEFAULT}, ...
    [ ON DUPLICATE KEY UPDATE
      col_name=expr
        [, col_name=expr] ... ]
```

Or:

```
INSERT [LOW_PRIORITY | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name [(col_name,...)]
    SELECT ...
    [ ON DUPLICATE KEY UPDATE
      col_name=expr
        [, col_name=expr] ... ]
```

`INSERT` inserts new rows into an existing table. The `INSERT ... VALUES` and `INSERT ... SET` forms of the statement insert rows based on explicitly specified values. The `INSERT ... SELECT` form inserts rows selected from another table or tables. `INSERT ... SELECT` is discussed further in Section 13.2.5.1, "INSERT ... SELECT Syntax".

You can use `REPLACE` instead of `INSERT` to overwrite old rows. `REPLACE` is the counterpart to `INSERT IGNORE` in the treatment of new rows that contain unique key values that duplicate old rows: The new rows are used to replace the old rows rather than being discarded. See Section 13.2.7, "REPLACE Syntax".

`tbl_name` is the table into which rows should be inserted. The columns for which the statement provides values can be specified as follows:

- You can provide a comma-separated list of column names following the table name. In this case, a value for each named column must be provided by the `VALUES` list or the `SELECT` statement.

- If you do not specify a list of column names for `INSERT ... VALUES` or `INSERT ... SELECT`, values for every column in the table must be provided by the `VALUES` list or the `SELECT` statement. If you do not know the order of the columns in the table, use `DESCRIBE tbl_name` to find out.

- The `SET` clause indicates the column names explicitly.

Column values can be given in several ways:

- If you are not running in strict SQL mode, any column not explicitly given a value is set to its default (explicit or implicit) value. For example, if you specify a column list that does not name all the columns in the table, unnamed columns are set to their default values. Default value assignment is described in Section 11.6, "Data Type Default Values". See also Section 1.8.3.3, "Constraints on Invalid Data".

  If you want an `INSERT` statement to generate an error unless you explicitly specify values for all columns that do not have a default value, you should use strict mode. See Section 5.1.7, "Server SQL Modes".

- Use the keyword `DEFAULT` to set a column explicitly to its default value. This makes it easier to write `INSERT` statements that assign values to all but a few columns, because it enables you to avoid writing an incomplete `VALUES` list that does not include a value for each column in the table. Otherwise, you would have to write out the list of column names corresponding to each value in the `VALUES` list.

  You can also use `DEFAULT(col_name)` as a more general form that can be used in expressions to produce a given column's default value.

- If both the column list and the `VALUES` list are empty, `INSERT` creates a row with each column set to its default value:

```
INSERT INTO tbl_name () VALUES();
```

  In strict mode, an error occurs if any column doesn't have a default value. Otherwise, MySQL uses the implicit default value for any column that does not have an explicitly defined default.

- You can specify an expression `expr` to provide a column value. This might involve type conversion if the type of the expression does not match the type of the column, and conversion of a given value can result in different inserted values depending on the data type. For example, inserting the string `'1999.0e-2'` into an `INT`, `FLOAT`, `DECIMAL(10,6)`, or `YEAR` column results in the values `1999`, `19.9921`, `19.992100`, and `1999` being inserted, respectively. The reason the value stored in the `INT` and `YEAR` columns is `1999` is that the string-to-integer conversion looks only at as much of the initial part of the string as may be considered a valid integer or year. For the floating-point and fixed-point columns, the string-to-floating-point conversion considers the entire string a valid floating-point value.

  An expression `expr` can refer to any column that was set earlier in a value list. For example, you can do this because the value for `col2` refers to `col1`, which has previously been assigned:

```
INSERT INTO tbl_name (col1,col2) VALUES(15,col1*2);
```

  But the following is not legal, because the value for `col1` refers to `col2`, which is assigned after `col1`:

```
INSERT INTO tbl_name (col1,col2) VALUES(col2*2,15);
```

  One exception involves columns that contain `AUTO_INCREMENT` values. Because the `AUTO_INCREMENT` value is generated after other value assignments, any reference to an `AUTO_INCREMENT` column in the assignment returns a `0`.

`INSERT` statements that use `VALUES` syntax can insert multiple rows. To do this, include multiple lists of column values, each enclosed within parentheses and separated by commas. Example:

```
INSERT INTO tbl_name (a,b,c) VALUES(1,2,3),(4,5,6),(7,8,9);
```

The values list for each row must be enclosed within parentheses. The following statement is illegal because the number of values in the list does not match the number of column names:

```
INSERT INTO tbl_name (a,b,c) VALUES(1,2,3,4,5,6,7,8,9);
```

`VALUE` is a synonym for `VALUES` in this context. Neither implies anything about the number of values lists, and either may be used whether there is a single values list or multiple lists.

The affected-rows value for an `INSERT` can be obtained using the `ROW_COUNT()` function (see Section 12.14, "Information Functions"), or the `mysql_affected_rows()` C API function (see Section 21.8.7.1, "mysql_affected_rows()").

If you use an `INSERT ... VALUES` statement with multiple value lists or `INSERT ... SELECT`, the statement returns an information string in this format:

```
Records: 100 Duplicates: 0 Warnings: 0
```

`Records` indicates the number of rows processed by the statement. (This is not necessarily the number of rows actually inserted because `Duplicates` can be nonzero.) `Duplicates` indicates the number of rows that could not be inserted because they would duplicate some existing unique index value. `Warnings` indicates the number of attempts to insert column values that were problematic in some way. Warnings can occur under any of the following conditions:

- Inserting `NULL` into a column that has been declared `NOT NULL`. For multiple-row `INSERT` statements or `INSERT INTO ... SELECT` statements, the column is set to the implicit default value for the column data type. This is `0` for numeric types, the empty string (`''`) for string types, and the "zero" value for date and time types. `INSERT INTO ... SELECT` statements are handled the same way as multiple-row inserts because the server does not examine the result set from the `SELECT` to see whether it returns a single row. (For a single-row `INSERT`, no warning occurs when `NULL` is inserted into a `NOT NULL` column. Instead, the statement fails with an error.)

- Setting a numeric column to a value that lies outside the column's range. The value is clipped to the closest endpoint of the range.

- Assigning a value such as `'10.34 a'` to a numeric column. The trailing nonnumeric text is stripped off and the remaining numeric part is inserted. If the string value has no leading numeric part, the column is set to `0`.

- Inserting a string into a string column (`CHAR`, `VARCHAR`, `TEXT`, or `BLOB`) that exceeds the column's maximum length. The value is truncated to the column's maximum length.

- Inserting a value into a date or time column that is illegal for the data type. The column is set to the appropriate zero value for the type.

If you are using the C API, the information string can be obtained by invoking the `mysql_info()` function. See Section 21.8.7.35, "mysql_info()".

If `INSERT` inserts a row into a table that has an `AUTO_INCREMENT` column, you can find the value used for that column by using the SQL `LAST_INSERT_ID()` function. From within the C API, use the `mysql_insert_id()` function. However, you should note that the two functions do not always behave identically. The behavior of `INSERT` statements with respect to `AUTO_INCREMENT` columns is discussed further in Section 12.14, "Information Functions", and Section 21.8.7.37, "mysql_insert_id()".

The `INSERT` statement supports the following modifiers:

- If you use the `DELAYED` keyword, the server puts the row or rows to be inserted into a buffer, and the client issuing the `INSERT DELAYED` statement can then continue immediately. If the table is in use, the

server holds the rows. When the table is free, the server begins inserting rows, checking periodically to see whether there are any new read requests for the table. If there are, the delayed row queue is suspended until the table becomes free again. See Section 13.2.5.2, "INSERT DELAYED Syntax".

`DELAYED` is ignored with `INSERT ... SELECT` or `INSERT ... ON DUPLICATE KEY UPDATE`.

Beginning with MySQL 5.1.19, `DELAYED` is also disregarded for an `INSERT` that uses functions accessing tables or triggers, or that is called from a function or a trigger.

- If you use the `LOW_PRIORITY` keyword, execution of the `INSERT` is delayed until no other clients are reading from the table. This includes other clients that began reading while existing clients are reading, and while the `INSERT LOW_PRIORITY` statement is waiting. It is possible, therefore, for a client that issues an `INSERT LOW_PRIORITY` statement to wait for a very long time (or even forever) in a read-heavy environment. (This is in contrast to `INSERT DELAYED`, which lets the client continue at once.)

> **Note**
>
> `LOW_PRIORITY` should normally not be used with `MyISAM` tables because doing so disables concurrent inserts. See Section 8.11.3, "Concurrent Inserts".

  If you specify `HIGH_PRIORITY`, it overrides the effect of the `--low-priority-updates` option if the server was started with that option. It also causes concurrent inserts not to be used. See Section 8.11.3, "Concurrent Inserts".

  `LOW_PRIORITY` and `HIGH_PRIORITY` affect only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- If you use the `IGNORE` keyword, errors that occur while executing the `INSERT` statement are ignored. For example, without `IGNORE`, a row that duplicates an existing `UNIQUE` index or `PRIMARY KEY` value in the table causes a duplicate-key error and the statement is aborted. With `IGNORE`, the row is discarded and no error occurs. Ignored errors may generate warnings instead, although duplicate-key errors do not.

  `IGNORE` has a similar effect on inserts into partitioned tables where no partition matching a given value is found. Without `IGNORE`, such `INSERT` statements are aborted with an error; however, when `INSERT IGNORE` is used, the insert operation fails silently for the row containing the unmatched value, but any rows that are matched are inserted. For an example, see Section 18.2.2, "LIST Partitioning".

  Data conversions that would trigger errors abort the statement if `IGNORE` is not specified. With `IGNORE`, invalid values are adjusted to the closest values and inserted; warnings are produced but the statement does not abort. You can determine with the `mysql_info()` C API function how many rows were actually inserted into the table.

- If you specify `ON DUPLICATE KEY UPDATE`, and a row is inserted that would cause a duplicate value in a `UNIQUE` index or `PRIMARY KEY`, an `UPDATE` of the old row is performed. The affected-rows value per row is 1 if the row is inserted as a new row and 2 if an existing row is updated. See Section 13.2.5.3, "INSERT ... ON DUPLICATE KEY UPDATE Syntax".

Inserting into a table requires the `INSERT` privilege for the table. If the `ON DUPLICATE KEY UPDATE` clause is used and a duplicate key causes an `UPDATE` to be performed instead, the statement requires the `UPDATE` privilege for the columns to be updated. For columns that are read but not modified you need only the `SELECT` privilege (such as for a column referenced only on the right hand side of an `col_name=expr` assignment in an `ON DUPLICATE KEY UPDATE` clause).

An `INSERT`statement that acts on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines

such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. See Section 18.5.4, "Partitioning and Table-Level Locking", for more information.

13.2.5.1 INSERT ... SELECT Syntax

```
INSERT [LOW_PRIORITY | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name [(col_name,...)]
    SELECT ...
    [ ON DUPLICATE KEY UPDATE col_name=expr, ... ]
```

With `INSERT ... SELECT`, you can quickly insert many rows into a table from one or many tables. For example:

```
INSERT INTO tbl_temp2 (fld_id)
  SELECT tbl_temp1.fld_order_id
  FROM tbl_temp1 WHERE tbl_temp1.fld_order_id > 100;
```

The following conditions hold for a `INSERT ... SELECT` statements:

- Specify `IGNORE` to ignore rows that would cause duplicate-key violations.

- `DELAYED` is ignored with `INSERT ... SELECT`.

- The target table of the `INSERT` statement may appear in the `FROM` clause of the `SELECT` part of the query. (This was not possible in some older versions of MySQL.) However, you cannot insert into a table and select from the same table in a subquery.

  When selecting from and inserting into a table at the same time, MySQL creates a temporary table to hold the rows from the `SELECT` and then inserts those rows into the target table. However, it remains true that you cannot use `INSERT INTO t ... SELECT ... FROM t` when `t` is a `TEMPORARY` table, because `TEMPORARY` tables cannot be referred to twice in the same statement (see Section B.5.6.2, "TEMPORARY Table Problems").

- `AUTO_INCREMENT` columns work as usual.

- To ensure that the binary log can be used to re-create the original tables, MySQL does not permit concurrent inserts for `INSERT ... SELECT` statements.

- To avoid ambiguous column reference problems when the `SELECT` and the `INSERT` refer to the same table, provide a unique alias for each table used in the `SELECT` part, and qualify column names in that part with the appropriate alias.

In the values part of `ON DUPLICATE KEY UPDATE`, you can refer to columns in other tables, as long as you do not use `GROUP BY` in the `SELECT` part. One side effect is that you must qualify nonunique column names in the values part.

The order in which rows are returned by a `SELECT` statement with no `ORDER BY` clause is not determined. This means that, when using replication, there is no guarantee that such a `SELECT` returns rows in the same order on the master and the slave; this can lead to inconsistencies between them. To prevent this from occurring, you should always write `INSERT ... SELECT` statements that are to be replicated as `INSERT ... SELECT ... ORDER BY column`. The choice of `column` does not matter as long as the same order for returning the rows is enforced on both the master and the slave. See also Section 16.4.1.16, "Replication and LIMIT".

An `INSERT ... SELECT` statement that acts on partitioned tables using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the source and target tables. This does not

occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. See Section 18.5.4, "Partitioning and Table-Level Locking", for more information.

13.2.5.2 INSERT DELAYED Syntax

```
INSERT DELAYED ...
```

The `DELAYED` option for the `INSERT` statement is a MySQL extension to standard SQL that is very useful if you have clients that cannot or need not wait for the `INSERT` to complete. This is a common situation when you use MySQL for logging and you also periodically run `SELECT` and `UPDATE` statements that take a long time to complete.

When a client uses `INSERT DELAYED`, it gets an okay from the server at once, and the row is queued to be inserted when the table is not in use by any other thread.

Another major benefit of using `INSERT DELAYED` is that inserts from many clients are bundled together and written in one block. This is much faster than performing many separate inserts.

Note that `INSERT DELAYED` is slower than a normal `INSERT` if the table is not otherwise in use. There is also the additional overhead for the server to handle a separate thread for each table for which there are delayed rows. This means that you should use `INSERT DELAYED` only when you are really sure that you need it.

The queued rows are held only in memory until they are inserted into the table. This means that if you terminate `mysqld` forcibly (for example, with `kill -9`) or if `mysqld` dies unexpectedly, *any queued rows that have not been written to disk are lost*.

There are some constraints on the use of `DELAYED`:

- `INSERT DELAYED` works only with `MyISAM`, `MEMORY`, `ARCHIVE`, and (as of MySQL 5.1.19) `BLACKHOLE` tables. For engines that do not support `DELAYED`, an error occurs.

- An error occurs for `INSERT DELAYED` if used with a table that has been locked with `LOCK TABLES` because the insert must be handled by a separate thread, not by the session that holds the lock.

- For `MyISAM` tables, if there are no free blocks in the middle of the data file, concurrent `SELECT` and `INSERT` statements are supported. Under these circumstances, you very seldom need to use `INSERT DELAYED` with `MyISAM`.

- `INSERT DELAYED` should be used only for `INSERT` statements that specify value lists. The server ignores `DELAYED` for `INSERT ... SELECT` or `INSERT ... ON DUPLICATE KEY UPDATE` statements.

- Because the `INSERT DELAYED` statement returns immediately, before the rows are inserted, you cannot use `LAST_INSERT_ID()` to get the `AUTO_INCREMENT` value that the statement might generate.

- `DELAYED` rows are not visible to `SELECT` statements until they actually have been inserted.

- `INSERT DELAYED` is treated as a normal `INSERT` if the statement inserts multiple rows and binary logging is enabled and the global logging format is to use statement-based logging (`binlog_format` is set to `STATEMENT`). This restriction does not apply to row-based binary logging.

- `DELAYED` is ignored on slave replication servers, so that `INSERT DELAYED` is treated as a normal `INSERT` on slaves. This is because `DELAYED` could cause the slave to have different data than the master.

- Pending `INSERT DELAYED` statements are lost if a table is write locked and `ALTER TABLE` is used to modify the table structure.

- `INSERT DELAYED` is not supported for views.

- `INSERT DELAYED` is not supported for partitioned tables.

The following describes in detail what happens when you use the `DELAYED` option to `INSERT` or `REPLACE`. In this description, the "thread" is the thread that received an `INSERT DELAYED` statement and "handler" is the thread that handles all `INSERT DELAYED` statements for a particular table.

- When a thread executes a `DELAYED` statement for a table, a handler thread is created to process all `DELAYED` statements for the table, if no such handler already exists.

- The thread checks whether the handler has previously acquired a `DELAYED` lock; if not, it tells the handler thread to do so. The `DELAYED` lock can be obtained even if other threads have a `READ` or `WRITE` lock on the table. However, the handler waits for all `ALTER TABLE` locks or `FLUSH TABLES` statements to finish, to ensure that the table structure is up to date.

- The thread executes the `INSERT` statement, but instead of writing the row to the table, it puts a copy of the final row into a queue that is managed by the handler thread. Any syntax errors are noticed by the thread and reported to the client program.

- The client cannot obtain from the server the number of duplicate rows or the `AUTO_INCREMENT` value for the resulting row, because the `INSERT` returns before the insert operation has been completed. (If you use the C API, the `mysql_info()` function does not return anything meaningful, for the same reason.)

- The binary log is updated by the handler thread when the row is inserted into the table. In case of multiple-row inserts, the binary log is updated when the first row is inserted.

- Each time that `delayed_insert_limit` rows are written, the handler checks whether any `SELECT` statements are still pending. If so, it permits these to execute before continuing.

- When the handler has no more rows in its queue, the table is unlocked. If no new `INSERT DELAYED` statements are received within `delayed_insert_timeout` seconds, the handler terminates.

- If more than `delayed_queue_size` rows are pending in a specific handler queue, the thread requesting `INSERT DELAYED` waits until there is room in the queue. This is done to ensure that `mysqld` does not use all memory for the delayed memory queue.

- The handler thread shows up in the MySQL process list with `delayed_insert` in the `Command` column. It is killed if you execute a `FLUSH TABLES` statement or kill it with `KILL` *`thread_id`*. However, before exiting, it first stores all queued rows into the table. During this time it does not accept any new `INSERT` statements from other threads. If you execute an `INSERT DELAYED` statement after this, a new handler thread is created.

  Note that this means that `INSERT DELAYED` statements have higher priority than normal `INSERT` statements if there is an `INSERT DELAYED` handler running. Other update statements have to wait until the `INSERT DELAYED` queue is empty, someone terminates the handler thread (with `KILL` *`thread_id`*), or someone executes a `FLUSH TABLES`.

- The following status variables provide information about `INSERT DELAYED` statements.

Status Variable	Meaning
`Delayed_insert_threads`	Number of handler threads
`Delayed_writes`	Number of rows written with `INSERT DELAYED`

Status Variable	Meaning
`Not_flushed_delayed_rows`	Number of rows waiting to be written

You can view these variables by issuing a `SHOW STATUS` statement or by executing a `mysqladmin extended-status` command.

13.2.5.3 INSERT ... ON DUPLICATE KEY UPDATE Syntax

If you specify `ON DUPLICATE KEY UPDATE`, and a row is inserted that would cause a duplicate value in a `UNIQUE` index or `PRIMARY KEY`, MySQL performs an `UPDATE` of the old row. For example, if column `a` is declared as `UNIQUE` and contains the value `1`, the following two statements have similar effect:

```
INSERT INTO table (a,b,c) VALUES (1,2,3)
  ON DUPLICATE KEY UPDATE c=c+1;

UPDATE table SET c=c+1 WHERE a=1;
```

(The effects are not identical for an `InnoDB` table where `a` is an auto-increment column. With an auto-increment column, an `INSERT` statement increases the auto-increment value but `UPDATE` does not.)

The `ON DUPLICATE KEY UPDATE` clause can contain multiple column assignments, separated by commas.

With `ON DUPLICATE KEY UPDATE`, the affected-rows value per row is 1 if the row is inserted as a new row, and 2 if an existing row is updated.

If column `b` is also unique, the `INSERT` is equivalent to this `UPDATE` statement instead:

```
UPDATE table SET c=c+1 WHERE a=1 OR b=2 LIMIT 1;
```

If `a=1 OR b=2` matches several rows, only *one* row is updated. In general, you should try to avoid using an `ON DUPLICATE KEY UPDATE` clause on tables with multiple unique indexes.

You can use the `VALUES(col_name)` function in the `UPDATE` clause to refer to column values from the `INSERT` portion of the `INSERT ... ON DUPLICATE KEY UPDATE` statement. In other words, `VALUES(col_name)` in the `ON DUPLICATE KEY UPDATE` clause refers to the value of `col_name` that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The `VALUES()` function is meaningful only in `INSERT ... UPDATE` statements and returns `NULL` otherwise. Example:

```
INSERT INTO table (a,b,c) VALUES (1,2,3),(4,5,6)
  ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
```

That statement is identical to the following two statements:

```
INSERT INTO table (a,b,c) VALUES (1,2,3)
  ON DUPLICATE KEY UPDATE c=3;
INSERT INTO table (a,b,c) VALUES (4,5,6)
  ON DUPLICATE KEY UPDATE c=9;
```

If a table contains an `AUTO_INCREMENT` column and `INSERT ... ON DUPLICATE KEY UPDATE` inserts or updates a row, the `LAST_INSERT_ID()` function returns the `AUTO_INCREMENT` value. Exception: For updates, `LAST_INSERT_ID()` is not meaningful prior to MySQL 5.1.12. However, you can work around this by using `LAST_INSERT_ID(expr)`. Suppose that `id` is the `AUTO_INCREMENT` column. To make `LAST_INSERT_ID()` meaningful for updates, insert rows as follows:

```
INSERT INTO table (a,b,c) VALUES (1,2,3)
  ON DUPLICATE KEY UPDATE id=LAST_INSERT_ID(id), c=3;
```

The `DELAYED` option is ignored when you use `ON DUPLICATE KEY UPDATE`.

An `INSERT ... ON DUPLICATE KEY UPDATE` on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. See Section 18.5.4, "Partitioning and Table-Level Locking", for more information.

13.2.6 LOAD DATA INFILE Syntax

```
LOAD DATA [LOW_PRIORITY | CONCURRENT] [LOCAL] INFILE 'file_name'
    [REPLACE | IGNORE]
    INTO TABLE tbl_name
    [CHARACTER SET charset_name]
    [{FIELDS | COLUMNS}
        [TERMINATED BY 'string']
        [[OPTIONALLY] ENCLOSED BY 'char']
        [ESCAPED BY 'char']
    ]
    [LINES
        [STARTING BY 'string']
        [TERMINATED BY 'string']
    ]
    [IGNORE number LINES]
    [(col_name_or_user_var,...)]
    [SET col_name = expr,...]
```

The `LOAD DATA INFILE` statement reads rows from a text file into a table at a very high speed. `LOAD DATA INFILE` is the complement of `SELECT ... INTO OUTFILE`. (See Section 13.2.8.1, "SELECT ... INTO Syntax".) To write data from a table to a file, use `SELECT ... INTO OUTFILE`. To read the file back into a table, use `LOAD DATA INFILE`. The syntax of the `FIELDS` and `LINES` clauses is the same for both statements. Both clauses are optional, but `FIELDS` must precede `LINES` if both are specified.

You can also load data files by using the `mysqlimport` utility; it operates by sending a `LOAD DATA INFILE` statement to the server. The `--local` option causes `mysqlimport` to read data files from the client host. You can specify the `--compress` option to get better performance over slow networks if the client and server support the compressed protocol. See Section 4.5.5, "`mysqlimport` — A Data Import Program".

For more information about the efficiency of `INSERT` versus `LOAD DATA INFILE` and speeding up `LOAD DATA INFILE`, see Section 8.2.2.1, "Speed of INSERT Statements".

The file name must be given as a literal string. On Windows, specify backslashes in path names as forward slashes or doubled backslashes. As of MySQL 5.1.6, the `character_set_filesystem` system variable controls the interpretation of the file name.

The server uses the character set indicated by the `character_set_database` system variable to interpret the information in the file. `SET NAMES` and the setting of `character_set_client` do not affect interpretation of input. If the contents of the input file use a character set that differs from the default, it is usually preferable to specify the character set of the file by using the `CHARACTER SET` clause, which is available as of MySQL 5.1.17. A character set of `binary` specifies "no conversion."

`LOAD DATA INFILE` interprets all fields in the file as having the same character set, regardless of the data types of the columns into which field values are loaded. For proper interpretation of file contents, you must ensure that it was written with the correct character set. For example, if you write a data file with `mysqldump -T` or by issuing a `SELECT ... INTO OUTFILE` statement in `mysql`, be sure to use a `--`

`default-character-set` option so that output is written in the character set to be used when the file is loaded with `LOAD DATA INFILE`.

> **Note**
>
> It is not possible to load data files that use the `ucs2` character set.

If you use `LOW_PRIORITY`, execution of the `LOAD DATA` statement is delayed until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

If you specify `CONCURRENT` with a `MyISAM` table that satisfies the condition for concurrent inserts (that is, it contains no free blocks in the middle), other threads can retrieve data from the table while `LOAD DATA` is executing. This option affects the performance of `LOAD DATA` a bit, even if no other thread is using the table at the same time.

With row-based replication, `CONCURRENT` is replicated regardless of MySQL version. With statement-based replication `CONCURRENT` is not replicated prior to MySQL 5.1.43 (see Bug #34628). For more information, see Section 16.4.1.17, "Replication and LOAD DATA INFILE".

> **Note**
>
> Prior to MySQL 5.1.23, `LOAD DATA` performed very poorly when importing into partitioned tables. The statement now uses buffering to improve performance; however, the buffer uses 130KB memory per partition to achieve this. (Bug #26527)

The `LOCAL` keyword affects expected location of the file and error handling, as described later. `LOCAL` works only if your server and your client both have been configured to permit it. For example, if `mysqld` was started with `--local-infile=0`, `LOCAL` does not work. See Section 6.1.6, "Security Issues with LOAD DATA LOCAL".

The `LOCAL` keyword affects where the file is expected to be found:

- If `LOCAL` is specified, the file is read by the client program on the client host and sent to the server. The file can be given as a full path name to specify its exact location. If given as a relative path name, the name is interpreted relative to the directory in which the client program was started.

  When using `LOCAL` with `LOAD DATA`, a copy of the file is created in the server's temporary directory. This is *not* the directory determined by the value of `tmpdir` or `slave_load_tmpdir`, but rather the operating system's temporary directory, and is not configurable in the MySQL Server. (Typically the system temporary directory is `/tmp` on Linux systems and `C:\WINDOWS\TEMP` on Windows.) Lack of sufficient space for the copy in this directory can cause the `LOAD DATA LOCAL` statement to fail.

- If `LOCAL` is not specified, the file must be located on the server host and is read directly by the server. The server uses the following rules to locate the file:

  - If the file name is an absolute path name, the server uses it as given.

  - If the file name is a relative path name with one or more leading components, the server searches for the file relative to the server's data directory.

  - If a file name with no leading components is given, the server looks for the file in the database directory of the default database.

In the non-`LOCAL` case, these rules mean that a file named as `./myfile.txt` is read from the server's data directory, whereas the file named as `myfile.txt` is read from the database directory of the default

database. For example, if `db1` is the default database, the following `LOAD DATA` statement reads the file `data.txt` from the database directory for `db1`, even though the statement explicitly loads the file into a table in the `db2` database:

```
LOAD DATA INFILE 'data.txt' INTO TABLE db2.my_table;
```

Note

A regression in MySQL 5.1.40 caused the database referenced in a fully qualified table name to be ignored by `LOAD DATA` when using replication with either `STATEMENT` or `MIXED` as the binary logging format; this could lead to problems if the table was not in the current database. As a workaround, you can specify the correct database with the `USE` statement prior to executing `LOAD DATA`. If necessary, you can reset the default database with a second `USE` statement following the `LOAD DATA` statement.

This issue was fixed in MySQL 5.1.41. (Bug #48297)

For security reasons, when reading text files located on the server, the files must either reside in the database directory or be readable by all. Also, to use `LOAD DATA INFILE` on server files, you must have the `FILE` privilege. See Section 6.2.1, "Privileges Provided by MySQL". For non-`LOCAL` load operations, if the `secure_file_priv` system variable is set to a nonempty directory name, the file to be loaded must be located in that directory.

Using `LOCAL` is a bit slower than letting the server access the files directly, because the contents of the file must be sent over the connection by the client to the server. On the other hand, you do not need the `FILE` privilege to load local files.

`LOCAL` also affects error handling:

- With `LOAD DATA INFILE`, data-interpretation and duplicate-key errors terminate the operation.

- With `LOAD DATA LOCAL INFILE`, data-interpretation and duplicate-key errors become warnings and the operation continues because the server has no way to stop transmission of the file in the middle of the operation. For duplicate-key errors, this is the same as if `IGNORE` is specified. `IGNORE` is explained further later in this section.

The `REPLACE` and `IGNORE` keywords control handling of input rows that duplicate existing rows on unique key values:

- If you specify `REPLACE`, input rows replace existing rows. In other words, rows that have the same value for a primary key or unique index as an existing row. See Section 13.2.7, "REPLACE Syntax".

- If you specify `IGNORE`, rows that duplicate an existing row on a unique key value are discarded.

- If you do not specify either option, the behavior depends on whether the `LOCAL` keyword is specified. Without `LOCAL`, an error occurs when a duplicate key value is found, and the rest of the text file is ignored. With `LOCAL`, the default behavior is the same as if `IGNORE` is specified; this is because the server has no way to stop transmission of the file in the middle of the operation.

To ignore foreign key constraints during the load operation, issue a `SET foreign_key_checks = 0` statement before executing `LOAD DATA`.

If you use `LOAD DATA INFILE` on an empty `MyISAM` table, all nonunique indexes are created in a separate batch (as for `REPAIR TABLE`). Normally, this makes `LOAD DATA INFILE` much faster when

you have many indexes. In some extreme cases, you can create the indexes even faster by turning them off with `ALTER TABLE ... DISABLE KEYS` before loading the file into the table and using `ALTER TABLE ... ENABLE KEYS` to re-create the indexes after loading the file. See Section 8.2.2.1, "Speed of INSERT Statements".

For both the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements, the syntax of the `FIELDS` and `LINES` clauses is the same. Both clauses are optional, but `FIELDS` must precede `LINES` if both are specified.

If you specify a `FIELDS` clause, each of its subclauses (`TERMINATED BY`, `[OPTIONALLY] ENCLOSED BY`, and `ESCAPED BY`) is also optional, except that you must specify at least one of them.

If you specify no `FIELDS` or `LINES` clause, the defaults are the same as if you had written this:

```
FIELDS TERMINATED BY '\t' ENCLOSED BY '' ESCAPED BY '\\'
LINES TERMINATED BY '\n' STARTING BY ''
```

(Backslash is the MySQL escape character within strings in SQL statements, so to specify a literal backslash, you must specify two backslashes for the value to be interpreted as a single backslash. The escape sequences `'\t'` and `'\n'` specify tab and newline characters, respectively.)

In other words, the defaults cause `LOAD DATA INFILE` to act as follows when reading input:

* Look for line boundaries at newlines.

* Do not skip over any line prefix.

* Break lines into fields at tabs.

* Do not expect fields to be enclosed within any quoting characters.

* Interpret characters preceded by the escape character "\" as escape sequences. For example, "\t", "\n", and "\\" signify tab, newline, and backslash, respectively. See the discussion of `FIELDS ESCAPED BY` later for the full list of escape sequences.

Conversely, the defaults cause `SELECT ... INTO OUTFILE` to act as follows when writing output:

* Write tabs between fields.

* Do not enclose fields within any quoting characters.

* Use "\" to escape instances of tab, newline, or "\" that occur within field values.

* Write newlines at the ends of lines.

Note

If you have generated the text file on a Windows system, you might have to use `LINES TERMINATED BY '\r\n'` to read the file properly, because Windows programs typically use two characters as a line terminator. Some programs, such as WordPad, might use `\r` as a line terminator when writing files. To read such files, use `LINES TERMINATED BY '\r'`.

If all the lines you want to read in have a common prefix that you want to ignore, you can use `LINES STARTING BY 'prefix_string'` to skip over the prefix, *and anything before it*. If a line does not include the prefix, the entire line is skipped. Suppose that you issue the following statement:

```
LOAD DATA INFILE '/tmp/test.txt' INTO TABLE test
  FIELDS TERMINATED BY ','  LINES STARTING BY 'xxx';
```

If the data file looks like this:

```
xxx"abc",1
something xxx"def",2
"ghi",3
```

The resulting rows will be `("abc",1)` and `("def",2)`. The third row in the file is skipped because it does not contain the prefix.

The `IGNORE number LINES` option can be used to ignore lines at the start of the file. For example, you can use `IGNORE 1 LINES` to skip over an initial header line containing column names:

```
LOAD DATA INFILE '/tmp/test.txt' INTO TABLE test IGNORE 1 LINES;
```

When you use `SELECT ... INTO OUTFILE` in tandem with `LOAD DATA INFILE` to write data from a database into a file and then read the file back into the database later, the field- and line-handling options for both statements must match. Otherwise, `LOAD DATA INFILE` will not interpret the contents of the file properly. Suppose that you use `SELECT ... INTO OUTFILE` to write a file with fields delimited by commas:

```
SELECT * INTO OUTFILE 'data.txt'
  FIELDS TERMINATED BY ','
  FROM table2;
```

To read the comma-delimited file back in, the correct statement would be:

```
LOAD DATA INFILE 'data.txt' INTO TABLE table2
  FIELDS TERMINATED BY ',';
```

If instead you tried to read in the file with the statement shown following, it wouldn't work because it instructs `LOAD DATA INFILE` to look for tabs between fields:

```
LOAD DATA INFILE 'data.txt' INTO TABLE table2
  FIELDS TERMINATED BY '\t';
```

The likely result is that each input line would be interpreted as a single field.

`LOAD DATA INFILE` can be used to read files obtained from external sources. For example, many programs can export data in comma-separated values (CSV) format, such that lines have fields separated by commas and enclosed within double quotation marks, with an initial line of column names. If the lines in such a file are terminated by carriage return/newline pairs, the statement shown here illustrates the field- and line-handling options you would use to load the file:

```
LOAD DATA INFILE 'data.txt' INTO TABLE tbl_name
  FIELDS TERMINATED BY ',' ENCLOSED BY '"'
  LINES TERMINATED BY '\r\n'
  IGNORE 1 LINES;
```

If the input values are not necessarily enclosed within quotation marks, use `OPTIONALLY` before the `ENCLOSED BY` keywords.

Any of the field- or line-handling options can specify an empty string (`''`). If not empty, the `FIELDS [OPTIONALLY] ENCLOSED BY` and `FIELDS ESCAPED BY` values must be a single character. The `FIELDS TERMINATED BY`, `LINES STARTING BY`, and `LINES TERMINATED BY` values can be more than one character. For example, to write lines that are terminated by carriage return/linefeed pairs, or to read a file containing such lines, specify a `LINES TERMINATED BY '\r\n'` clause.

To read a file containing jokes that are separated by lines consisting of `%%`, you can do this

```
CREATE TABLE jokes
  (a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
  joke TEXT NOT NULL);
LOAD DATA INFILE '/tmp/jokes.txt' INTO TABLE jokes
  FIELDS TERMINATED BY ''
  LINES TERMINATED BY '\n%%\n' (joke);
```

`FIELDS [OPTIONALLY] ENCLOSED BY` controls quoting of fields. For output (`SELECT ... INTO OUTFILE`), if you omit the word `OPTIONALLY`, all fields are enclosed by the `ENCLOSED BY` character. An example of such output (using a comma as the field delimiter) is shown here:

```
"1","a string","100.20"
"2","a string containing a , comma","102.20"
"3","a string containing a \" quote","102.20"
"4","a string containing a \", quote and comma","102.20"
```

If you specify `OPTIONALLY`, the `ENCLOSED BY` character is used only to enclose values from columns that have a string data type (such as `CHAR`, `BINARY`, `TEXT`, or `ENUM`):

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a \" quote",102.20
4,"a string containing a \", quote and comma",102.20
```

Occurrences of the `ENCLOSED BY` character within a field value are escaped by prefixing them with the `ESCAPED BY` character. Also note that if you specify an empty `ESCAPED BY` value, it is possible to inadvertently generate output that cannot be read properly by `LOAD DATA INFILE`. For example, the preceding output just shown would appear as follows if the escape character is empty. Observe that the second field in the fourth line contains a comma following the quote, which (erroneously) appears to terminate the field:

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a " quote",102.20
4,"a string containing a ", quote and comma",102.20
```

For input, the `ENCLOSED BY` character, if present, is stripped from the ends of field values. (This is true regardless of whether `OPTIONALLY` is specified; `OPTIONALLY` has no effect on input interpretation.) Occurrences of the `ENCLOSED BY` character preceded by the `ESCAPED BY` character are interpreted as part of the current field value.

If the field begins with the `ENCLOSED BY` character, instances of that character are recognized as terminating a field value only if followed by the field or line `TERMINATED BY` sequence. To avoid ambiguity, occurrences of the `ENCLOSED BY` character within a field value can be doubled and are interpreted as a single instance of the character. For example, if `ENCLOSED BY '"'` is specified, quotation marks are handled as shown here:

```
"The ""BIG"" boss"  -> The "BIG" boss
The "BIG" boss      -> The "BIG" boss
The ""BIG"" boss    -> The ""BIG"" boss
```

`FIELDS ESCAPED BY` controls how to read or write special characters:

- For input, if the `FIELDS ESCAPED BY` character is not empty, occurrences of that character are stripped and the following character is taken literally as part of a field value. Some two-character sequences that are exceptions, where the first character is the escape character. These sequences are shown in the following table (using "\" for the escape character). The rules for `NULL` handling are described later in this section.

Character	Escape Sequence
\0	An ASCII NUL (`X'00'`) character
\b	A backspace character
\n	A newline (linefeed) character
\r	A carriage return character
\t	A tab character.
\Z	ASCII 26 (Control+Z)
\N	NULL

For more information about "\"-escape syntax, see Section 9.1.1, "String Literals".

If the `FIELDS ESCAPED BY` character is empty, escape-sequence interpretation does not occur.

- For output, if the `FIELDS ESCAPED BY` character is not empty, it is used to prefix the following characters on output:

  - The `FIELDS ESCAPED BY` character

  - The `FIELDS [OPTIONALLY] ENCLOSED BY` character

  - The first character of the `FIELDS TERMINATED BY` and `LINES TERMINATED BY` values

  - ASCII `0` (what is actually written following the escape character is ASCII "0", not a zero-valued byte)

  If the `FIELDS ESCAPED BY` character is empty, no characters are escaped and `NULL` is output as `NULL`, not `\N`. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

In certain cases, field- and line-handling options interact:

- If `LINES TERMINATED BY` is an empty string and `FIELDS TERMINATED BY` is nonempty, lines are also terminated with `FIELDS TERMINATED BY`.

- If the `FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` values are both empty (`''`), a fixed-row (nondelimited) format is used. With fixed-row format, no delimiters are used between fields (but you can still have a line terminator). Instead, column values are read and written using a field width wide enough to hold all values in the field. For `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT`, and `BIGINT`, the field widths are 4, 6, 8, 11, and 20, respectively, no matter what the declared display width is.

  `LINES TERMINATED BY` is still used to separate lines. If a line does not contain all fields, the rest of the columns are set to their default values. If you do not have a line terminator, you should set this to `''`. In this case, the text file must contain all fields for each row.

Fixed-row format also affects handling of `NULL` values, as described later.

> **Note**
>
> Fixed-size format does not work if you are using a multibyte character set.

Handling of `NULL` values varies according to the `FIELDS` and `LINES` options in use:

- For the default `FIELDS` and `LINES` values, `NULL` is written as a field value of `\N` for output, and a field value of `\N` is read as `NULL` for input (assuming that the `ESCAPED BY` character is "\").

- If `FIELDS ENCLOSED BY` is not empty, a field containing the literal word `NULL` as its value is read as a `NULL` value. This differs from the word `NULL` enclosed within `FIELDS ENCLOSED BY` characters, which is read as the string `'NULL'`.

- If `FIELDS ESCAPED BY` is empty, `NULL` is written as the word `NULL`.

- With fixed-row format (which is used when `FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` are both empty), `NULL` is written as an empty string. This causes both `NULL` values and empty strings in the table to be indistinguishable when written to the file because both are written as empty strings. If you need to be able to tell the two apart when reading the file back in, you should not use fixed-row format.

An attempt to load `NULL` into a `NOT NULL` column causes assignment of the implicit default value for the column's data type and a warning, or an error in strict SQL mode. Implicit default values are discussed in Section 11.6, "Data Type Default Values".

Some cases are not supported by `LOAD DATA INFILE`:

- Fixed-size rows (`FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` both empty) and `BLOB` or `TEXT` columns.

- If you specify one separator that is the same as or a prefix of another, `LOAD DATA INFILE` cannot interpret the input properly. For example, the following `FIELDS` clause would cause problems:

```
FIELDS TERMINATED BY '"' ENCLOSED BY '"'
```

- If `FIELDS ESCAPED BY` is empty, a field value that contains an occurrence of `FIELDS ENCLOSED BY` or `LINES TERMINATED BY` followed by the `FIELDS TERMINATED BY` value causes `LOAD DATA INFILE` to stop reading a field or line too early. This happens because `LOAD DATA INFILE` cannot properly determine where the field or line value ends.

The following example loads all columns of the `persondata` table:

```
LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata;
```

By default, when no column list is provided at the end of the `LOAD DATA INFILE` statement, input lines are expected to contain a field for each table column. If you want to load only some of a table's columns, specify a column list:

```
LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata (col1,col2,...);
```

You must also specify a column list if the order of the fields in the input file differs from the order of the columns in the table. Otherwise, MySQL cannot tell how to match input fields with table columns.

The column list can contain either column names or user variables. With user variables, the SET clause enables you to perform transformations on their values before assigning the result to columns.

User variables in the SET clause can be used in several ways. The following example uses the first input column directly for the value of `t1.column1`, and assigns the second input column to a user variable that is subjected to a division operation before being used for the value of `t1.column2`:

```
LOAD DATA INFILE 'file.txt'
  INTO TABLE t1
  (column1, @var1)
  SET column2 = @var1/100;
```

The SET clause can be used to supply values not derived from the input file. The following statement sets `column3` to the current date and time:

```
LOAD DATA INFILE 'file.txt'
  INTO TABLE t1
  (column1, column2)
  SET column3 = CURRENT_TIMESTAMP;
```

You can also discard an input value by assigning it to a user variable and not assigning the variable to a table column:

```
LOAD DATA INFILE 'file.txt'
  INTO TABLE t1
  (column1, @dummy, column2, @dummy, column3);
```

Use of the column/variable list and SET clause is subject to the following restrictions:

- Assignments in the SET clause should have only column names on the left hand side of assignment operators.

- You can use subqueries in the right hand side of SET assignments. A subquery that returns a value to be assigned to a column may be a scalar subquery only. Also, you cannot use a subquery to select from the table that is being loaded.

- Lines ignored by an IGNORE clause are not processed for the column/variable list or SET clause.

- User variables cannot be used when loading data with fixed-row format because user variables do not have a display width.

When processing an input line, LOAD DATA splits it into fields and uses the values according to the column/variable list and the SET clause, if they are present. Then the resulting row is inserted into the table. If there are BEFORE INSERT or AFTER INSERT triggers for the table, they are activated before or after inserting the row, respectively.

If an input line has too many fields, the extra fields are ignored and the number of warnings is incremented.

If an input line has too few fields, the table columns for which input fields are missing are set to their default values. Default value assignment is described in Section 11.6, "Data Type Default Values".

An empty field value is interpreted different from a missing field:

- For string types, the column is set to the empty string.

- For numeric types, the column is set to 0.

- For date and time types, the column is set to the appropriate "zero" value for the type. See Section 11.3, "Date and Time Types".

These are the same values that result if you assign an empty string explicitly to a string, numeric, or date or time type explicitly in an `INSERT` or `UPDATE` statement.

Treatment of empty or incorrect field values differs from that just described if the SQL mode is set to a restrictive value. For example, if `sql_mode` is set to `TRADITIONAL`, conversion of an empty value or a value such as `'x'` for a numeric column results in an error, not conversion to 0. (With `LOCAL` or `IGNORE`, warnings occur rather than errors, even with a restrictive `sql_mode` value, and the row is inserted using the same closest-value behavior used for nonrestrictive SQL modes. This occurs because the server has no way to stop transmission of the file in the middle of the operation.)

`TIMESTAMP` columns are set to the current date and time only if there is a `NULL` value for the column (that is, `\N`) and the column is not declared to permit `NULL` values, or if the `TIMESTAMP` column's default value is the current timestamp and it is omitted from the field list when a field list is specified.

`LOAD DATA INFILE` regards all input as strings, so you cannot use numeric values for `ENUM` or `SET` columns the way you can with `INSERT` statements. All `ENUM` and `SET` values must be specified as strings.

`BIT` values cannot be loaded using binary notation (for example, `b'011010'`). To work around this, specify the values as regular integers and use the `SET` clause to convert them so that MySQL performs a numeric type conversion and loads them into the `BIT` column properly:

```
shell> cat /tmp/bit_test.txt
2
127
shell> mysql test
mysql> LOAD DATA INFILE '/tmp/bit_test.txt'
    -> INTO TABLE bit_test (@var1) SET b = CAST(@var1 AS UNSIGNED);
Query OK, 2 rows affected (0.00 sec)
Records: 2  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT BIN(b+0) FROM bit_test;
+----------+
| bin(b+0) |
+----------+
| 10       |
| 1111111  |
+----------+
2 rows in set (0.00 sec)
```

On Unix, if you need `LOAD DATA` to read from a pipe, you can use the following technique (the example loads a listing of the `/` directory into the table `db1.t1`):

```
mkfifo /mysql/data/db1/ls.dat
chmod 666 /mysql/data/db1/ls.dat
find / -ls > /mysql/data/db1/ls.dat &
mysql -e "LOAD DATA INFILE 'ls.dat' INTO TABLE t1" db1
```

Here you must run the command that generates the data to be loaded and the `mysql` commands either on separate terminals, or run the data generation process in the background (as shown in the preceding example). If you do not do this, the pipe will block until data is read by the `mysql` process.

When the `LOAD DATA INFILE` statement finishes, it returns an information string in the following format:

```
Records: 1  Deleted: 0  Skipped: 0  Warnings: 0
```

Warnings occur under the same circumstances as when values are inserted using the `INSERT` statement (see Section 13.2.5, "INSERT Syntax"), except that `LOAD DATA INFILE` also generates warnings when there are too few or too many fields in the input row.

You can use `SHOW WARNINGS` to get a list of the first `max_error_count` warnings as information about what went wrong. See Section 13.7.5.42, "SHOW WARNINGS Syntax".

If you are using the C API, you can get information about the statement by calling the `mysql_info()` function. See Section 21.8.7.35, "mysql_info()".

For partitioned tables using storage engines that employ table locks, such as `MyISAM`, any locks caused by `LOAD DATA` perform locks on all partitions of the table. This does not apply to tables using storage engines which employ row-level locking, such as `InnoDB`. For more information, see Section 18.5.4, "Partitioning and Table-Level Locking".

13.2.7 REPLACE Syntax

```
REPLACE [LOW_PRIORITY | DELAYED]
    [INTO] tbl_name [(col_name,...)]
    {VALUES | VALUE} ({expr | DEFAULT},...),(...),...
```

Or:

```
REPLACE [LOW_PRIORITY | DELAYED]
    [INTO] tbl_name
    SET col_name={expr | DEFAULT}, ...
```

Or:

```
REPLACE [LOW_PRIORITY | DELAYED]
    [INTO] tbl_name [(col_name,...)]
    SELECT ...
```

`REPLACE` works exactly like `INSERT`, except that if an old row in the table has the same value as a new row for a `PRIMARY KEY` or a `UNIQUE` index, the old row is deleted before the new row is inserted. See Section 13.2.5, "INSERT Syntax".

`REPLACE` is a MySQL extension to the SQL standard. It either inserts, or *deletes* and inserts. For another MySQL extension to standard SQL—that either inserts or *updates*—see Section 13.2.5.3, "INSERT ... ON DUPLICATE KEY UPDATE Syntax".

> **Note**
>
> `REPLACE` makes sense only if a table has a `PRIMARY KEY` or `UNIQUE` index. Otherwise, it becomes equivalent to `INSERT`, because there is no index to be used to determine whether a new row duplicates another.

Values for all columns are taken from the values specified in the `REPLACE` statement. Any missing columns are set to their default values, just as happens for `INSERT`. You cannot refer to values from the current row and use them in the new row. If you use an assignment such as `SET col_name = col_name + 1`, the reference to the column name on the right hand side is treated as `DEFAULT(col_name)`, so the assignment is equivalent to `SET col_name = DEFAULT(col_name) + 1`.

To use `REPLACE`, you must have both the `INSERT` and `DELETE` privileges for the table.

The `REPLACE` statement returns a count to indicate the number of rows affected. This is the sum of the rows deleted and inserted. If the count is 1 for a single-row `REPLACE`, a row was inserted and no rows were deleted. If the count is greater than 1, one or more old rows were deleted before the new row was inserted. It is possible for a single row to replace more than one old row if the table contains multiple unique indexes and the new row duplicates values for different old rows in different unique indexes.

The affected-rows count makes it easy to determine whether `REPLACE` only added a row or whether it also replaced any rows: Check whether the count is 1 (added) or greater (replaced).

If you are using the C API, the affected-rows count can be obtained using the `mysql_affected_rows()` function.

You cannot replace into a table and select from the same table in a subquery.

MySQL uses the following algorithm for `REPLACE` (and `LOAD DATA ... REPLACE`):

1. Try to insert the new row into the table

2. While the insertion fails because a duplicate-key error occurs for a primary key or unique index:

    a. Delete from the table the conflicting row that has the duplicate key value

    b. Try again to insert the new row into the table

It is possible that in the case of a duplicate-key error, a storage engine may perform the `REPLACE` as an update rather than a delete plus insert, but the semantics are the same. There are no user-visible effects other than a possible difference in how the storage engine increments `Handler_xxx` status variables.

When modifying an existing table that is not partitioned to accommodate partitioning, or, when modifying the partitioning of an already partitioned table, you may consider altering the table's primary key (see Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys"). You should be aware that, if you do this, the results of `REPLACE` statements may be affected, just as they would be if you modified the primary key of a nonpartitioned table. Consider the table created by the following `CREATE TABLE` statement:

```
CREATE TABLE test (
  id INT UNSIGNED NOT NULL AUTO_INCREMENT,
  data VARCHAR(64) DEFAULT NULL,
  ts TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
  PRIMARY KEY (id)
);
```

When we create this table and run the statements shown in the mysql client, the result is as follows:

```
mysql> REPLACE INTO test VALUES (1, 'Old', '2014-08-20 18:47:00');
Query OK, 1 row affected (0.04 sec)

mysql> REPLACE INTO test VALUES (1, 'New', '2014-08-20 18:47:42');
Query OK, 2 rows affected (0.04 sec)

mysql> SELECT * FROM test;
+----+------+---------------------+
| id | data | ts                  |
+----+------+---------------------+
|  1 | New  | 2014-08-20 18:47:42 |
+----+------+---------------------+
```

```
1 row in set (0.00 sec)
```

Now we create a second table almost identical to the first, except that the primary key now covers 2 columns, as shown here (emphasized text):

```
CREATE TABLE test2 (
  id INT UNSIGNED NOT NULL AUTO_INCREMENT,
  data VARCHAR(64) DEFAULT NULL,
  ts TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
  PRIMARY KEY (id, ts)
);
```

When we run on `test2` the same two `REPLACE` statements as we did on the original `test` table, we obtain a different result:

```
mysql> REPLACE INTO test2 VALUES (1, 'Old', '2014-08-20 18:47:00');
Query OK, 1 row affected (0.05 sec)

mysql> REPLACE INTO test2 VALUES (1, 'New', '2014-08-20 18:47:42');
Query OK, 1 row affected (0.06 sec)

mysql> SELECT * FROM test2;
+----+------+---------------------+
| id | data | ts                  |
+----+------+---------------------+
|  1 | Old  | 2014-08-20 18:47:00 |
|  1 | New  | 2014-08-20 18:47:42 |
+----+------+---------------------+
2 rows in set (0.00 sec)
```

This is due to the fact that, when run on `test2`, both the `id` and `ts` column values must match those of an existing row for the row to be replaced; otherwise, a row is inserted.

A `REPLACE` statement that acts on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. See Section 18.5.4, "Partitioning and Table-Level Locking", for more information.

13.2.8 SELECT Syntax

```
SELECT
    [ALL | DISTINCT | DISTINCTROW ]
      [HIGH_PRIORITY]
      [STRAIGHT_JOIN]
      [SQL_SMALL_RESULT] [SQL_BIG_RESULT] [SQL_BUFFER_RESULT]
      [SQL_CACHE | SQL_NO_CACHE] [SQL_CALC_FOUND_ROWS]
    select_expr [, select_expr ...]
    [FROM table_references
    [WHERE where_condition]
    [GROUP BY {col_name | expr | position}
      [ASC | DESC], ... [WITH ROLLUP]]
    [HAVING where_condition]
    [ORDER BY {col_name | expr | position}
      [ASC | DESC], ...]
    [LIMIT {[offset,] row_count | row_count OFFSET offset}]
    [PROCEDURE procedure_name(argument_list)]
    [INTO OUTFILE 'file_name'
        [CHARACTER SET charset_name]
        export_options
      | INTO DUMPFILE 'file_name'
```

```
      | INTO var_name [, var_name]]
  [FOR UPDATE | LOCK IN SHARE MODE]]
```

SELECT is used to retrieve rows selected from one or more tables, and can include UNION statements and subqueries. See Section 13.2.8.3, "UNION Syntax", and Section 13.2.9, "Subquery Syntax".

The most commonly used clauses of SELECT statements are these:

- Each `select_expr` indicates a column that you want to retrieve. There must be at least one `select_expr`.

- `table_references` indicates the table or tables from which to retrieve rows. Its syntax is described in Section 13.2.8.2, "JOIN Syntax".

- The WHERE clause, if given, indicates the condition or conditions that rows must satisfy to be selected. `where_condition` is an expression that evaluates to true for each row to be selected. The statement selects all rows if there is no WHERE clause.

  In the WHERE expression, you can use any of the functions and operators that MySQL supports, except for aggregate (summary) functions. See Section 9.5, "Expression Syntax", and Chapter 12, *Functions and Operators*.

SELECT can also be used to retrieve rows computed without reference to any table.

For example:

```
mysql> SELECT 1 + 1;
        -> 2
```

You are permitted to specify DUAL as a dummy table name in situations where no tables are referenced:

```
mysql> SELECT 1 + 1 FROM DUAL;
        -> 2
```

DUAL is purely for the convenience of people who require that all SELECT statements should have FROM and possibly other clauses. MySQL may ignore the clauses. MySQL does not require FROM DUAL if no tables are referenced.

In general, clauses used must be given in exactly the order shown in the syntax description. For example, a HAVING clause must come after any GROUP BY clause and before any ORDER BY clause. The exception is that the INTO clause can appear either as shown in the syntax description or immediately following the `select_expr` list. For more information about INTO, see Section 13.2.8.1, "SELECT ... INTO Syntax".

The list of `select_expr` terms comprises the select list that indicates which columns to retrieve. Terms specify a column or expression or can use *-shorthand:

- A select list consisting only of a single unqualified * can be used as shorthand to select all columns from all tables:

```
SELECT * FROM t1 INNER JOIN t2 ...
```

- `tbl_name.*` can be used as a qualified shorthand to select all columns from the named table:

```
SELECT t1.*, t2.* FROM t1 INNER JOIN t2 ...
```

- Use of an unqualified `*` with other items in the select list may produce a parse error. To avoid this problem, use a qualified `tbl_name.*` reference

```
SELECT AVG(score), t1.* FROM t1 ...
```

The following list provides additional information about other `SELECT` clauses:

- A `select_expr` can be given an alias using `AS alias_name`. The alias is used as the expression's column name and can be used in `GROUP BY`, `ORDER BY`, or `HAVING` clauses. For example:

```
SELECT CONCAT(last_name,', ',first_name) AS full_name
  FROM mytable ORDER BY full_name;
```

The `AS` keyword is optional when aliasing a `select_expr` with an identifier. The preceding example could have been written like this:

```
SELECT CONCAT(last_name,', ',first_name) full_name
  FROM mytable ORDER BY full_name;
```

However, because the `AS` is optional, a subtle problem can occur if you forget the comma between two `select_expr` expressions: MySQL interprets the second as an alias name. For example, in the following statement, `columnb` is treated as an alias name:

```
SELECT columna columnb FROM mytable;
```

For this reason, it is good practice to be in the habit of using `AS` explicitly when specifying column aliases.

It is not permissible to refer to a column alias in a `WHERE` clause, because the column value might not yet be determined when the `WHERE` clause is executed. See Section B.5.4.4, "Problems with Column Aliases".

- The `FROM table_references` clause indicates the table or tables from which to retrieve rows. If you name more than one table, you are performing a join. For information on join syntax, see Section 13.2.8.2, "JOIN Syntax". For each table specified, you can optionally specify an alias.

```
tbl_name [[AS] alias] [index_hint]
```

The use of index hints provides the optimizer with information about how to choose indexes during query processing. For a description of the syntax for specifying these hints, see Section 8.9.3, "Index Hints".

You can use `SET max_seeks_for_key=value` as an alternative way to force MySQL to prefer key scans instead of table scans. See Section 5.1.4, "Server System Variables".

- You can refer to a table within the default database as `tbl_name`, or as `db_name.tbl_name` to specify a database explicitly. You can refer to a column as `col_name`, `tbl_name.col_name`, or `db_name.tbl_name.col_name`. You need not specify a `tbl_name` or `db_name.tbl_name` prefix for a column reference unless the reference would be ambiguous. See Section 9.2.1, "Identifier Qualifiers", for examples of ambiguity that require the more explicit column reference forms.

- A table reference can be aliased using `tbl_name AS alias_name` or `tbl_name alias_name`:

```
SELECT t1.name, t2.salary FROM employee AS t1, info AS t2
  WHERE t1.name = t2.name;
```

```
SELECT t1.name, t2.salary FROM employee t1, info t2
  WHERE t1.name = t2.name;
```

- Columns selected for output can be referred to in `ORDER BY` and `GROUP BY` clauses using column names, column aliases, or column positions. Column positions are integers and begin with 1:

```
SELECT college, region, seed FROM tournament
  ORDER BY region, seed;

SELECT college, region AS r, seed AS s FROM tournament
  ORDER BY r, s;

SELECT college, region, seed FROM tournament
  ORDER BY 2, 3;
```

To sort in reverse order, add the `DESC` (descending) keyword to the name of the column in the `ORDER BY` clause that you are sorting by. The default is ascending order; this can be specified explicitly using the `ASC` keyword.

If `ORDER BY` occurs within a subquery and also is applied in the outer query, the outermost `ORDER BY` takes precedence. For example, results for the following statement are sorted in descending order, not ascending order:

```
(SELECT ... ORDER BY a) ORDER BY a DESC;
```

Use of column positions is deprecated because the syntax has been removed from the SQL standard.

- If you use `GROUP BY`, output rows are sorted according to the `GROUP BY` columns as if you had an `ORDER BY` for the same columns. To avoid the overhead of sorting that `GROUP BY` produces, add `ORDER BY NULL`:

```
SELECT a, COUNT(b) FROM test_table GROUP BY a ORDER BY NULL;
```

- MySQL extends the `GROUP BY` clause so that you can also specify `ASC` and `DESC` after columns named in the clause:

```
SELECT a, COUNT(b) FROM test_table GROUP BY a DESC;
```

- MySQL extends the use of `GROUP BY` to permit selecting fields that are not mentioned in the `GROUP BY` clause. If you are not getting the results that you expect from your query, please read the description of `GROUP BY` found in Section 12.17, "Aggregate (GROUP BY) Functions".

- `GROUP BY` permits a `WITH ROLLUP` modifier. See Section 12.17.2, "GROUP BY Modifiers".

- The `HAVING` clause is applied nearly last, just before items are sent to the client, with no optimization. (`LIMIT` is applied after `HAVING`.)

The SQL standard requires that `HAVING` must reference only columns in the `GROUP BY` clause or columns used in aggregate functions. However, MySQL supports an extension to this behavior, and permits `HAVING` to refer to columns in the `SELECT` list and columns in outer subqueries as well.

If the `HAVING` clause refers to a column that is ambiguous, a warning occurs. In the following statement, `col2` is ambiguous because it is used as both an alias and a column name:

```
SELECT COUNT(col1) AS col2 FROM t GROUP BY col2 HAVING col2 = 2;
```

Preference is given to standard SQL behavior, so if a `HAVING` column name is used both in `GROUP BY` and as an aliased column in the output column list, preference is given to the column in the `GROUP BY` column.

- Do not use `HAVING` for items that should be in the `WHERE` clause. For example, do not write the following:

```
SELECT col_name FROM tbl_name HAVING col_name > 0;
```

Write this instead:

```
SELECT col_name FROM tbl_name WHERE col_name > 0;
```

- The `HAVING` clause can refer to aggregate functions, which the `WHERE` clause cannot:

```
SELECT user, MAX(salary) FROM users
  GROUP BY user HAVING MAX(salary) > 10;
```

(This did not work in some older versions of MySQL.)

- MySQL permits duplicate column names. That is, there can be more than one `select_expr` with the same name. This is an extension to standard SQL. Because MySQL also permits `GROUP BY` and `HAVING` to refer to `select_expr` values, this can result in an ambiguity:

```
SELECT 12 AS a, a FROM t GROUP BY a;
```

In that statement, both columns have the name `a`. To ensure that the correct column is used for grouping, use different names for each `select_expr`.

- MySQL resolves unqualified column or alias references in `ORDER BY` clauses by searching in the `select_expr` values, then in the columns of the tables in the `FROM` clause. For `GROUP BY` or `HAVING` clauses, it searches the `FROM` clause before searching in the `select_expr` values. (For `GROUP BY` and `HAVING`, this differs from the pre-MySQL 5.0 behavior that used the same rules as for `ORDER BY`.)

- The `LIMIT` clause can be used to constrain the number of rows returned by the `SELECT` statement. `LIMIT` takes one or two numeric arguments, which must both be nonnegative integer constants (except when using prepared statements).

With two arguments, the first argument specifies the offset of the first row to return, and the second specifies the maximum number of rows to return. The offset of the initial row is 0 (not 1):

```
SELECT * FROM tbl LIMIT 5,10;  # Retrieve rows 6-15
```

To retrieve all rows from a certain offset up to the end of the result set, you can use some large number for the second parameter. This statement retrieves all rows from the 96th row to the last:

```
SELECT * FROM tbl LIMIT 95,18446744073709551615;
```

With one argument, the value specifies the number of rows to return from the beginning of the result set:

```
SELECT * FROM tbl LIMIT 5;     # Retrieve first 5 rows
```

In other words, `LIMIT row_count` is equivalent to `LIMIT 0, row_count`.

For prepared statements, you can use placeholders. The following statements will return one row from the `tbl` table:

```
SET @a=1;
PREPARE STMT FROM 'SELECT * FROM tbl LIMIT ?';
EXECUTE STMT USING @a;
```

The following statements will return the second to sixth row from the `tbl` table:

```
SET @skip=1; SET @numrows=5;
PREPARE STMT FROM 'SELECT * FROM tbl LIMIT ?, ?';
EXECUTE STMT USING @skip, @numrows;
```

For compatibility with PostgreSQL, MySQL also supports the `LIMIT row_count OFFSET offset` syntax.

If `LIMIT` occurs within a subquery and also is applied in the outer query, the outermost `LIMIT` takes precedence. For example, the following statement produces two rows, not one:

```
(SELECT ... LIMIT 1) LIMIT 2;
```

- A `PROCEDURE` clause names a procedure that should process the data in the result set. For an example, see Section 8.4.2.4, "Using PROCEDURE ANALYSE", which describes `ANALYSE`, a procedure that can be used to obtain suggestions for optimal column data types that may help reduce table sizes.

  A `PROCEDURE` clause is not permitted in a `UNION` statement.

- The `SELECT ... INTO` form of `SELECT` enables the query result to be written to a file or stored in variables. For more information, see Section 13.2.8.1, "SELECT ... INTO Syntax".

- If you use `FOR UPDATE` with a storage engine that uses page or row locks, rows examined by the query are write-locked until the end of the current transaction. Using `LOCK IN SHARE MODE` sets a shared lock that permits other transactions to read the examined rows but not to update or delete them. See Section 14.6.4.5, "SELECT ... FOR UPDATE and SELECT ... LOCK IN SHARE MODE Locking Reads".

Following the `SELECT` keyword, you can use a number of options that affect the operation of the statement. `HIGH_PRIORITY`, `STRAIGHT_JOIN`, and options beginning with `SQL_` are MySQL extensions to standard SQL.

- The `ALL` and `DISTINCT` options specify whether duplicate rows should be returned. `ALL` (the default) specifies that all matching rows should be returned, including duplicates. `DISTINCT` specifies removal of duplicate rows from the result set. It is an error to specify both options. `DISTINCTROW` is a synonym for `DISTINCT`.

- `HIGH_PRIORITY` gives the `SELECT` higher priority than a statement that updates a table. You should use this only for queries that are very fast and must be done at once. A `SELECT HIGH_PRIORITY` query that is issued while the table is locked for reading runs even if there is an update statement waiting for the table to be free. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

  `HIGH_PRIORITY` cannot be used with `SELECT` statements that are part of a `UNION`.

- `STRAIGHT_JOIN` forces the optimizer to join the tables in the order in which they are listed in the `FROM` clause. You can use this to speed up a query if the optimizer joins the tables in nonoptimal order.

STRAIGHT_JOIN also can be used in the `table_references` list. See Section 13.2.8.2, "JOIN Syntax".

STRAIGHT_JOIN does not apply to any table that the optimizer treats as a `const` or `system` table. Such a table produces a single row, is read during the optimization phase of query execution, and references to its columns are replaced with the appropriate column values before query execution proceeds. These tables will appear first in the query plan displayed by EXPLAIN. See Section 8.8.1, "Optimizing Queries with EXPLAIN". This exception may not apply to `const` or `system` tables that are used on the NULL-complemented side of an outer join (that is, the right-side table of a LEFT JOIN or the left-side table of a RIGHT JOIN.

- SQL_BIG_RESULT or SQL_SMALL_RESULT can be used with GROUP BY or DISTINCT to tell the optimizer that the result set has many rows or is small, respectively. For SQL_BIG_RESULT, MySQL directly uses disk-based temporary tables if needed, and prefers sorting to using a temporary table with a key on the GROUP BY elements. For SQL_SMALL_RESULT, MySQL uses fast temporary tables to store the resulting table instead of using sorting. This should not normally be needed.

- SQL_BUFFER_RESULT forces the result to be put into a temporary table. This helps MySQL free the table locks early and helps in cases where it takes a long time to send the result set to the client. This option can be used only for top-level SELECT statements, not for subqueries or following UNION.

- SQL_CALC_FOUND_ROWS tells MySQL to calculate how many rows there would be in the result set, disregarding any LIMIT clause. The number of rows can then be retrieved with SELECT FOUND_ROWS(). See Section 12.14, "Information Functions".

- The SQL_CACHE and SQL_NO_CACHE options affect caching of query results in the query cache (see Section 8.10.3, "The MySQL Query Cache"). SQL_CACHE tells MySQL to store the result in the query cache if it is cacheable and the value of the `query_cache_type` system variable is 2 or DEMAND. With SQL_NO_CACHE, the server does not use the query cache. It neither checks the query cache to see whether the result is already cached, nor does it cache the query result. (Due to a limitation in the parser, a space character must precede and follow the SQL_NO_CACHE keyword; a nonspace such as a newline causes the server to check the query cache to see whether the result is already cached.)

  For a query that uses UNION, subqueries, or views, the following rules apply:

  - SQL_NO_CACHE applies if it appears in any SELECT in the query.

  - For a cacheable query, SQL_CACHE applies if it appears in the first SELECT of the query, or in the first SELECT of a view referred to by the query.

A SELECT from a partitioned table using a storage engine such as MyISAM that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. See Section 18.5.4, "Partitioning and Table-Level Locking", for more information.

13.2.8.1 SELECT ... INTO Syntax

The SELECT ... INTO form of SELECT enables a query result to be stored in variables or written to a file:

- SELECT ... INTO `var_list` selects column values and stores them into variables.

- SELECT ... INTO OUTFILE writes the selected rows to a file. Column and line terminators can be specified to produce a specific output format.

- SELECT ... INTO DUMPFILE writes a single row to a file without any formatting.

The `SELECT` syntax description (see Section 13.2.8, "SELECT Syntax") shows the `INTO` clause near the end of the statement. It is also possible to use `INTO` immediately following the *select_expr* list.

An `INTO` clause should not be used in a nested `SELECT` because such a `SELECT` must return its result to the outer context.

The `INTO` clause can name a list of one or more variables, which can be user-defined variables, stored procedure or function parameters, or stored program local variables. (Within a prepared `SELECT ... INTO OUTFILE` statement, only user-defined variables are permitted;see Section 13.6.4.2, "Local Variable Scope and Resolution".)

The selected values are assigned to the variables. The number of variables must match the number of columns. The query should return a single row. If the query returns no rows, a warning with error code 1329 occurs (`No data`), and the variable values remain unchanged. If the query returns multiple rows, error 1172 occurs (`Result consisted of more than one row`). If it is possible that the statement may retrieve multiple rows, you can use `LIMIT 1` to limit the result set to a single row.

```
SELECT id, data INTO @x, @y FROM test.t1 LIMIT 1;
```

User variable names are not case sensitive. See Section 9.4, "User-Defined Variables".

The `SELECT ... INTO OUTFILE 'file_name'` form of `SELECT` writes the selected rows to a file. The file is created on the server host, so you must have the `FILE` privilege to use this syntax. *file_name* cannot be an existing file, which among other things prevents files such as `/etc/passwd` and database tables from being destroyed. As of MySQL 5.1.6, the `character_set_filesystem` system variable controls the interpretation of the file name.

The `SELECT ... INTO OUTFILE` statement is intended primarily to let you very quickly dump a table to a text file on the server machine. If you want to create the resulting file on some other host than the server host, you normally cannot use `SELECT ... INTO OUTFILE` since there is no way to write a path to the file relative to the server host's file system.

However, if the MySQL client software is installed on the remote machine, you can instead use a client command such as `mysql -e "SELECT ..." > file_name` to generate the file on the client host.

It is also possible to create the resulting file on a different host other than the server host, if the location of the file on the remote host can be accessed using a network-mapped path on the server's file system. In this case, the presence of `mysql` (or some other MySQL client program) is not required on the target host.

`SELECT ... INTO OUTFILE` is the complement of `LOAD DATA INFILE`. Column values are written converted to the character set specified in the `CHARACTER SET` clause, which is available as of MySQL 5.1.38. Prior to 5.1.38 or if no such clause is present, values are dumped using the `binary` character set. In effect, there is no character set conversion. If a result set contains columns in several character sets, the output data file will as well and you may not be able to reload the file correctly.

The syntax for the *export_options* part of the statement consists of the same `FIELDS` and `LINES` clauses that are used with the `LOAD DATA INFILE` statement. See Section 13.2.6, "LOAD DATA INFILE Syntax", for information about the `FIELDS` and `LINES` clauses, including their default values and permissible values.

`FIELDS ESCAPED BY` controls how to write special characters. If the `FIELDS ESCAPED BY` character is not empty, it is used when necessary to avoid ambiguity as a prefix that precedes following characters on output:

- The `FIELDS ESCAPED BY` character

- The `FIELDS [OPTIONALLY] ENCLOSED BY` character

- The first character of the `FIELDS TERMINATED BY` and `LINES TERMINATED BY` values

- ASCII `NUL` (the zero-valued byte; what is actually written following the escape character is ASCII "`0`", not a zero-valued byte)

The `FIELDS TERMINATED BY`, `ENCLOSED BY`, `ESCAPED BY`, or `LINES TERMINATED BY` characters *must* be escaped so that you can read the file back in reliably. ASCII `NUL` is escaped to make it easier to view with some pagers.

The resulting file does not have to conform to SQL syntax, so nothing else need be escaped.

If the `FIELDS ESCAPED BY` character is empty, no characters are escaped and `NULL` is output as `NULL`, not `\N`. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

Here is an example that produces a file in the comma-separated values (CSV) format used by many programs:

```
SELECT a,b,a+b INTO OUTFILE '/tmp/result.txt'
  FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"'
  LINES TERMINATED BY '\n'
  FROM test_table;
```

If you use `INTO DUMPFILE` instead of `INTO OUTFILE`, MySQL writes only one row into the file, without any column or line termination and without performing any escape processing. This is useful if you want to store a `BLOB` value in a file.

> **Note**
>
> Any file created by `INTO OUTFILE` or `INTO DUMPFILE` is writable by all users on the server host. The reason for this is that the MySQL server cannot create a file that is owned by anyone other than the user under whose account it is running. (You should *never* run `mysqld` as `root` for this and other reasons.) The file thus must be world-writable so that you can manipulate its contents.
>
> If the `secure_file_priv` system variable is set to a nonempty directory name, the file to be written must be located in that directory.

In the context of `SELECT ... INTO` statements that occur as part of events executed by the Event Scheduler, diagnostics messages (not only errors, but also warnings) are written to the error log, and, on Windows, to the application event log. For additional information, see Section 19.4.5, "Event Scheduler Status".

13.2.8.2 JOIN Syntax

MySQL supports the following `JOIN` syntaxes for the `table_references` part of `SELECT` statements and multiple-table `DELETE` and `UPDATE` statements:

```
table_references:
    escaped_table_reference [, escaped_table_reference] ...

escaped_table_reference:
    table_reference
  | { OJ table_reference }

table_reference:
    table_factor
  | join_table
```

```
table_factor:
    tbl_name [[AS] alias] [index_hint_list]
  | table_subquery [AS] alias
  | ( table_references )

join_table:
    table_reference [INNER | CROSS] JOIN table_factor [join_condition]
  | table_reference STRAIGHT_JOIN table_factor
  | table_reference STRAIGHT_JOIN table_factor ON conditional_expr
  | table_reference {LEFT|RIGHT} [OUTER] JOIN table_reference join_condition
  | table_reference NATURAL [{LEFT|RIGHT} [OUTER]] JOIN table_factor

join_condition:
    ON conditional_expr
  | USING (column_list)

index_hint_list:
    index_hint [, index_hint] ...

index_hint:
    USE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] ([index_list])
  | IGNORE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)
  | FORCE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)

index_list:
    index_name [, index_name] ...
```

A table reference is also known as a join expression.

The syntax of `table_factor` is extended in comparison with the SQL Standard. The latter accepts only `table_reference`, not a list of them inside a pair of parentheses.

This is a conservative extension if we consider each comma in a list of `table_reference` items as equivalent to an inner join. For example:

```
SELECT * FROM t1 LEFT JOIN (t2, t3, t4)
                 ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

is equivalent to:

```
SELECT * FROM t1 LEFT JOIN (t2 CROSS JOIN t3 CROSS JOIN t4)
                 ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

In MySQL, `JOIN`, `CROSS JOIN`, and `INNER JOIN` are syntactic equivalents (they can replace each other). In standard SQL, they are not equivalent. `INNER JOIN` is used with an `ON` clause, `CROSS JOIN` is used otherwise.

In general, parentheses can be ignored in join expressions containing only inner join operations. MySQL also supports nested joins (see Section 8.2.1.9, "Nested Join Optimization").

Index hints can be specified to affect how the MySQL optimizer makes use of indexes. For more information, see Section 8.9.3, "Index Hints".

The following list describes general factors to take into account when writing joins.

• A table reference can be aliased using `tbl_name AS alias_name` or `tbl_name alias_name`:

```
SELECT t1.name, t2.salary
  FROM employee AS t1 INNER JOIN info AS t2 ON t1.name = t2.name;

SELECT t1.name, t2.salary
  FROM employee t1 INNER JOIN info t2 ON t1.name = t2.name;
```

- A `table_subquery` is also known as a subquery in the `FROM` clause. Such subqueries *must* include an alias to give the subquery result a table name. A trivial example follows; see also Section 13.2.9.8, "Subqueries in the FROM Clause".

```
SELECT * FROM (SELECT 1, 2, 3) AS t1;
```

- `INNER JOIN` and `,` (comma) are semantically equivalent in the absence of a join condition: both produce a Cartesian product between the specified tables (that is, each and every row in the first table is joined to each and every row in the second table).

  However, the precedence of the comma operator is less than that of `INNER JOIN`, `CROSS JOIN`, `LEFT JOIN`, and so on. If you mix comma joins with the other join types when there is a join condition, an error of the form `Unknown column 'col_name' in 'on clause'` may occur. Information about dealing with this problem is given later in this section.

- The `conditional_expr` used with `ON` is any conditional expression of the form that can be used in a `WHERE` clause. Generally, you should use the `ON` clause for conditions that specify how to join tables, and the `WHERE` clause to restrict which rows you want in the result set.

- If there is no matching row for the right table in the `ON` or `USING` part in a `LEFT JOIN`, a row with all columns set to `NULL` is used for the right table. You can use this fact to find rows in a table that have no counterpart in another table:

```
SELECT left_tbl.*
  FROM left_tbl LEFT JOIN right_tbl ON left_tbl.id = right_tbl.id
  WHERE right_tbl.id IS NULL;
```

  This example finds all rows in `left_tbl` with an `id` value that is not present in `right_tbl` (that is, all rows in `left_tbl` with no corresponding row in `right_tbl`). This assumes that `right_tbl.id` is declared `NOT NULL`. See Section 8.2.1.7, "LEFT JOIN and RIGHT JOIN Optimization".

- The `USING(column_list)` clause names a list of columns that must exist in both tables. If tables `a` and `b` both contain columns `c1`, `c2`, and `c3`, the following join compares corresponding columns from the two tables:

```
a LEFT JOIN b USING (c1,c2,c3)
```

- The `NATURAL [LEFT] JOIN` of two tables is defined to be semantically equivalent to an `INNER JOIN` or a `LEFT JOIN` with a `USING` clause that names all columns that exist in both tables.

- `RIGHT JOIN` works analogously to `LEFT JOIN`. To keep code portable across databases, it is recommended that you use `LEFT JOIN` instead of `RIGHT JOIN`.

- The `{ OJ ... }` syntax shown in the join syntax description exists only for compatibility with ODBC. The curly braces in the syntax should be written literally; they are not metasyntax as used elsewhere in syntax descriptions.

```
SELECT left_tbl.*
    FROM { OJ left_tbl LEFT OUTER JOIN right_tbl ON left_tbl.id = right_tbl.id }
    WHERE right_tbl.id IS NULL;
```

As of MySQL 5.1.24, you can use other types of joins within `{ OJ ... }`, such as `INNER JOIN` or `RIGHT OUTER JOIN`. This helps with compatibility with some third-party applications, but is not official ODBC syntax.

A consequence of this change is that the parser does not permit nested `{ OJ ... }` constructs (which are not legal ODBC syntax, anyway). Queries that use such constructs should be rewritten. For example, this query is now produces an error:

```
SELECT * FROM
    {OJ
        {OJ a LEFT OUTER JOIN b ON a.a1=b.a1}
        LEFT OUTER JOIN c ON b.b1 = c.b1};
```

That can be replaced by any of the following rewrites:

```
SELECT * FROM
    {OJ a LEFT OUTER JOIN b
            LEFT OUTER JOIN c ON b.b1 = c.b1 ON a.a1=b.a1};

SELECT * FROM
    {OJ a LEFT OUTER JOIN b ON a.a1=b.a1
            LEFT OUTER JOIN c ON b.b1 = c.b1};

SELECT * FROM
    a LEFT OUTER JOIN b ON a.a1=b.a1 LEFT OUTER JOIN c ON b.b1 = c.b1;
```

The first two are legal according to ODBC, and you nest the joins inside a single `{ OJ ...}` clause. The third is standard SQL syntax, without ODBC decoration. It can be used with parentheses to emphasize the evaluation order:

```
SELECT * FROM
    ((a LEFT OUTER JOIN b ON a.a1=b.a1)
            LEFT OUTER JOIN c ON b.b1 = c.b1);
```

- `STRAIGHT_JOIN` is similar to `JOIN`, except that the left table is always read before the right table. This can be used for those (few) cases for which the join optimizer puts the tables in the wrong order.

Some join examples:

```
SELECT * FROM table1, table2;

SELECT * FROM table1 INNER JOIN table2 ON table1.id=table2.id;

SELECT * FROM table1 LEFT JOIN table2 ON table1.id=table2.id;

SELECT * FROM table1 LEFT JOIN table2 USING (id);

SELECT * FROM table1 LEFT JOIN table2 ON table1.id=table2.id
  LEFT JOIN table3 ON table2.id=table3.id;
```

Join Processing Changes in MySQL 5.0.12

> **Note**
>
> Natural joins and joins with `USING`, including outer join variants, are processed according to the SQL:2003 standard. The goal was to align the syntax and semantics of MySQL with respect to `NATURAL JOIN` and `JOIN ... USING` according to SQL:2003. However, these changes in join processing can result in

> different output columns for some joins. Also, some queries that appeared to work correctly in older versions (prior to 5.0.12) must be rewritten to comply with the standard.

These changes have five main aspects:

- The way that MySQL determines the result columns of `NATURAL` or `USING` join operations (and thus the result of the entire `FROM` clause).

- Expansion of `SELECT *` and `SELECT tbl_name.*` into a list of selected columns.

- Resolution of column names in `NATURAL` or `USING` joins.

- Transformation of `NATURAL` or `USING` joins into `JOIN ... ON`.

- Resolution of column names in the `ON` condition of a `JOIN ... ON`.

The following list provides more detail about several effects of current join processing versus join processing in older versions. The term "previously" means "prior to MySQL 5.0.12."

- The columns of a `NATURAL` join or a `USING` join may be different from previously. Specifically, redundant output columns no longer appear, and the order of columns for `SELECT *` expansion may be different from before.

  Consider this set of statements:

  ```
  CREATE TABLE t1 (i INT, j INT);
  CREATE TABLE t2 (k INT, j INT);
  INSERT INTO t1 VALUES(1,1);
  INSERT INTO t2 VALUES(1,1);
  SELECT * FROM t1 NATURAL JOIN t2;
  SELECT * FROM t1 JOIN t2 USING (j);
  ```

  Previously, the statements produced this output:

  ```
  +------+------+------+------+
  | i    | j    | k    | j    |
  +------+------+------+------+
  |    1 |    1 |    1 |    1 |
  +------+------+------+------+
  +------+------+------+------+
  | i    | j    | k    | j    |
  +------+------+------+------+
  |    1 |    1 |    1 |    1 |
  +------+------+------+------+
  ```

  In the first `SELECT` statement, column `j` appears in both tables and thus becomes a join column, so, according to standard SQL, it should appear only once in the output, not twice. Similarly, in the second SELECT statement, column `j` is named in the `USING` clause and should appear only once in the output, not twice. But in both cases, the redundant column is not eliminated. Also, the order of the columns is not correct according to standard SQL.

  Now the statements produce this output:

  ```
  +------+------+------+
  | j    | i    | k    |
  +------+------+------+
  |    1 |    1 |    1 |
  +------+------+------+
  ```

```
+------+------+------+
| j    | i    | k    |
+------+------+------+
|    1 |    1 |    1 |
+------+------+------+
```

The redundant column is eliminated and the column order is correct according to standard SQL:

- First, coalesced common columns of the two joined tables, in the order in which they occur in the first table

- Second, columns unique to the first table, in order in which they occur in that table

- Third, columns unique to the second table, in order in which they occur in that table

The single result column that replaces two common columns is defined using the coalesce operation. That is, for two `t1.a` and `t2.a` the resulting single join column `a` is defined as `a = COALESCE(t1.a, t2.a)`, where:

```
COALESCE(x, y) = (CASE WHEN V1 IS NOT NULL THEN V1 ELSE V2 END)
```

If the join operation is any other join, the result columns of the join consists of the concatenation of all columns of the joined tables. This is the same as previously.

A consequence of the definition of coalesced columns is that, for outer joins, the coalesced column contains the value of the non-`NULL` column if one of the two columns is always `NULL`. If neither or both columns are `NULL`, both common columns have the same value, so it doesn't matter which one is chosen as the value of the coalesced column. A simple way to interpret this is to consider that a coalesced column of an outer join is represented by the common column of the inner table of a `JOIN`. Suppose that the tables `t1(a,b)` and `t2(a,c)` have the following contents:

```
t1     t2
----   ----
1 x    2 z
2 y    3 w
```

Then:

```
mysql> SELECT * FROM t1 NATURAL LEFT JOIN t2;
+------+------+------+
| a    | b    | c    |
+------+------+------+
|    1 | x    | NULL |
|    2 | y    | z    |
+------+------+------+
```

Here column `a` contains the values of `t1.a`.

```
mysql> SELECT * FROM t1 NATURAL RIGHT JOIN t2;
+------+------+------+
| a    | c    | b    |
+------+------+------+
|    2 | z    | y    |
|    3 | w    | NULL |
+------+------+------+
```

Here column `a` contains the values of `t2.a`.

Compare these results to the otherwise equivalent queries with `JOIN ... ON`:

```
mysql> SELECT * FROM t1 LEFT JOIN t2 ON (t1.a = t2.a);
+------+------+------+------+
| a    | b    | a    | c    |
+------+------+------+------+
|    1 | x    | NULL | NULL |
|    2 | y    |    2 | z    |
+------+------+------+------+
```

```
mysql> SELECT * FROM t1 RIGHT JOIN t2 ON (t1.a = t2.a);
+------+------+------+------+
| a    | b    | a    | c    |
+------+------+------+------+
|    2 | y    |    2 | z    |
| NULL | NULL |    3 | w    |
+------+------+------+------+
```

- Previously, a `USING` clause could be rewritten as an `ON` clause that compares corresponding columns. For example, the following two clauses were semantically identical:

```
a LEFT JOIN b USING (c1,c2,c3)
a LEFT JOIN b ON a.c1=b.c1 AND a.c2=b.c2 AND a.c3=b.c3
```

Now the two clauses no longer are quite the same:

- With respect to determining which rows satisfy the join condition, both joins remain semantically identical.

- With respect to determining which columns to display for `SELECT *` expansion, the two joins are not semantically identical. The `USING` join selects the coalesced value of corresponding columns, whereas the `ON` join selects all columns from all tables. For the preceding `USING` join, `SELECT *` selects these values:

```
COALESCE(a.c1,b.c1), COALESCE(a.c2,b.c2), COALESCE(a.c3,b.c3)
```

For the `ON` join, `SELECT *` selects these values:

```
a.c1, a.c2, a.c3, b.c1, b.c2, b.c3
```

With an inner join, `COALESCE(a.c1,b.c1)` is the same as either `a.c1` or `b.c1` because both columns will have the same value. With an outer join (such as `LEFT JOIN`), one of the two columns can be `NULL`. That column will be omitted from the result.

- The evaluation of multi-way natural joins differs in a very important way that affects the result of `NATURAL` or `USING` joins and that can require query rewriting. Suppose that you have three tables `t1(a,b)`, `t2(c,b)`, and `t3(a,c)` that each have one row: `t1(1,2)`, `t2(10,2)`, and `t3(7,10)`. Suppose also that you have this `NATURAL JOIN` on the three tables:

```
SELECT ... FROM t1 NATURAL JOIN t2 NATURAL JOIN t3;
```

Previously, the left operand of the second join was considered to be `t2`, whereas it should be the nested join `(t1 NATURAL JOIN t2)`. As a result, the columns of `t3` are checked for common columns only

in `t2`, and, if `t3` has common columns with `t1`, these columns are not used as equi-join columns. Thus, previously, the preceding query was transformed to the following equi-join:

```
SELECT ... FROM t1, t2, t3
  WHERE t1.b = t2.b AND t2.c = t3.c;
```

That join is missing one more equi-join predicate `(t1.a = t3.a)`. As a result, it produces one row, not the empty result that it should. The correct equivalent query is this:

```
SELECT ... FROM t1, t2, t3
  WHERE t1.b = t2.b AND t2.c = t3.c AND t1.a = t3.a;
```

If you require the same query result in current versions of MySQL as in older versions, rewrite the natural join as the first equi-join.

- Previously, the comma operator (`,`) and `JOIN` both had the same precedence, so the join expression `t1, t2 JOIN t3` was interpreted as `((t1, t2) JOIN t3)`. Now `JOIN` has higher precedence, so the expression is interpreted as `(t1, (t2 JOIN t3))`. This change affects statements that use an `ON` clause, because that clause can refer only to columns in the operands of the join, and the change in precedence changes interpretation of what those operands are.

  Example:

  ```
  CREATE TABLE t1 (i1 INT, j1 INT);
  CREATE TABLE t2 (i2 INT, j2 INT);
  CREATE TABLE t3 (i3 INT, j3 INT);
  INSERT INTO t1 VALUES(1,1);
  INSERT INTO t2 VALUES(1,1);
  INSERT INTO t3 VALUES(1,1);
  SELECT * FROM t1, t2 JOIN t3 ON (t1.i1 = t3.i3);
  ```

  Previously, the `SELECT` was legal due to the implicit grouping of `t1,t2` as `(t1,t2)`. Now the `JOIN` takes precedence, so the operands for the `ON` clause are `t2` and `t3`. Because `t1.i1` is not a column in either of the operands, the result is an `Unknown column 't1.i1' in 'on clause'` error. To allow the join to be processed, group the first two tables explicitly with parentheses so that the operands for the `ON` clause are `(t1,t2)` and `t3`:

  ```
  SELECT * FROM (t1, t2) JOIN t3 ON (t1.i1 = t3.i3);
  ```

  Alternatively, avoid the use of the comma operator and use `JOIN` instead:

  ```
  SELECT * FROM t1 JOIN t2 JOIN t3 ON (t1.i1 = t3.i3);
  ```

  This change also applies to statements that mix the comma operator with `INNER JOIN`, `CROSS JOIN`, `LEFT JOIN`, and `RIGHT JOIN`, all of which now have higher precedence than the comma operator.

- Previously, the `ON` clause could refer to columns in tables named to its right. Now an `ON` clause can refer only to its operands.

  Example:

  ```
  CREATE TABLE t1 (i1 INT);
  CREATE TABLE t2 (i2 INT);
  CREATE TABLE t3 (i3 INT);
  SELECT * FROM t1 JOIN t2 ON (i1 = i3) JOIN t3;
  ```

Previously, the `SELECT` statement was legal. Now the statement fails with an `Unknown column 'i3'` `in 'on clause'` error because `i3` is a column in `t3`, which is not an operand of the `ON` clause. The statement should be rewritten as follows:

```
SELECT * FROM t1 JOIN t2 JOIN t3 ON (i1 = i3);
```

- Resolution of column names in `NATURAL` or `USING` joins is different than previously. For column names that are outside the `FROM` clause, MySQL now handles a superset of the queries compared to previously. That is, in cases when MySQL formerly issued an error that some column is ambiguous, the query now is handled correctly. This is due to the fact that MySQL now treats the common columns of `NATURAL` or `USING` joins as a single column, so when a query refers to such columns, the query compiler does not consider them as ambiguous.

  Example:

  ```
  SELECT * FROM t1 NATURAL JOIN t2 WHERE b > 1;
  ```

  Previously, this query would produce an error `ERROR 1052 (23000): Column 'b' in where` `clause is ambiguous`. Now the query produces the correct result:

  ```
  +------+------+------+
  | b    | c    | y    |
  +------+------+------+
  |    4 |    2 |    3 |
  +------+------+------+
  ```

  One extension of MySQL compared to the SQL:2003 standard is that MySQL enables you to qualify the common (coalesced) columns of `NATURAL` or `USING` joins (just as previously), while the standard disallows that.

13.2.8.3 UNION Syntax

```
SELECT ...
UNION [ALL | DISTINCT] SELECT ...
[UNION [ALL | DISTINCT] SELECT ...]
```

`UNION` is used to combine the result from multiple `SELECT` statements into a single result set.

The column names from the first `SELECT` statement are used as the column names for the results returned. Selected columns listed in corresponding positions of each `SELECT` statement should have the same data type. (For example, the first column selected by the first statement should have the same type as the first column selected by the other statements.)

If the data types of corresponding `SELECT` columns do not match, the types and lengths of the columns in the `UNION` result take into account the values retrieved by all of the `SELECT` statements. For example, consider the following:

```
mysql> SELECT REPEAT('a',1) UNION SELECT REPEAT('b',10);
+---------------+
| REPEAT('a',1) |
+---------------+
| a             |
| bbbbbbbbbb    |
+---------------+
```

(In some earlier versions of MySQL, only the type and length from the first `SELECT` would have been used and the second row would have been truncated to a length of 1.)

The `SELECT` statements are normal select statements, but with the following restrictions:

- Only the last `SELECT` statement can use `INTO OUTFILE`. (However, the entire `UNION` result is written to the file.)

- `HIGH_PRIORITY` cannot be used with `SELECT` statements that are part of a `UNION`. If you specify it for the first `SELECT`, it has no effect. If you specify it for any subsequent `SELECT` statements, a syntax error results.

The default behavior for `UNION` is that duplicate rows are removed from the result. The optional `DISTINCT` keyword has no effect other than the default because it also specifies duplicate-row removal. With the optional `ALL` keyword, duplicate-row removal does not occur and the result includes all matching rows from all the `SELECT` statements.

You can mix `UNION ALL` and `UNION DISTINCT` in the same query. Mixed `UNION` types are treated such that a `DISTINCT` union overrides any `ALL` union to its left. A `DISTINCT` union can be produced explicitly by using `UNION DISTINCT` or implicitly by using `UNION` with no following `DISTINCT` or `ALL` keyword.

To apply `ORDER BY` or `LIMIT` to an individual `SELECT`, place the clause inside the parentheses that enclose the `SELECT`:

```
(SELECT a FROM t1 WHERE a=10 AND B=1 ORDER BY a LIMIT 10)
UNION
(SELECT a FROM t2 WHERE a=11 AND B=2 ORDER BY a LIMIT 10);
```

However, use of `ORDER BY` for individual `SELECT` statements implies nothing about the order in which the rows appear in the final result because `UNION` by default produces an unordered set of rows. Therefore, the use of `ORDER BY` in this context is typically in conjunction with `LIMIT`, so that it is used to determine the subset of the selected rows to retrieve for the `SELECT`, even though it does not necessarily affect the order of those rows in the final `UNION` result. If `ORDER BY` appears without `LIMIT` in a `SELECT`, it is optimized away because it will have no effect anyway.

To use an `ORDER BY` or `LIMIT` clause to sort or limit the entire `UNION` result, parenthesize the individual `SELECT` statements and place the `ORDER BY` or `LIMIT` after the last one. The following example uses both clauses:

```
(SELECT a FROM t1 WHERE a=10 AND B=1)
UNION
(SELECT a FROM t2 WHERE a=11 AND B=2)
ORDER BY a LIMIT 10;
```

A statement without parentheses is equivalent to one parenthesized as just shown.

This kind of `ORDER BY` cannot use column references that include a table name (that is, names in `tbl_name.col_name` format). Instead, provide a column alias in the first `SELECT` statement and refer to the alias in the `ORDER BY`. (Alternatively, refer to the column in the `ORDER BY` using its column position. However, use of column positions is deprecated.)

Also, if a column to be sorted is aliased, the `ORDER BY` clause *must* refer to the alias, not the column name. The first of the following statements will work, but the second will fail with an `Unknown column 'a' in 'order clause'` error:

```
(SELECT a AS b FROM t) UNION (SELECT ...) ORDER BY b;
(SELECT a AS b FROM t) UNION (SELECT ...) ORDER BY a;
```

To cause rows in a UNION result to consist of the sets of rows retrieved by each SELECT one after the other, select an additional column in each SELECT to use as a sort column and add an ORDER BY following the last SELECT:

```
(SELECT 1 AS sort_col, col1a, col1b, ... FROM t1)
UNION
(SELECT 2, col2a, col2b, ... FROM t2) ORDER BY sort_col;
```

To additionally maintain sort order within individual SELECT results, add a secondary column to the ORDER BY clause:

```
(SELECT 1 AS sort_col, col1a, col1b, ... FROM t1)
UNION
(SELECT 2, col2a, col2b, ... FROM t2) ORDER BY sort_col, col1a;
```

Use of an additional column also enables you to determine which SELECT each row comes from. Extra columns can provide other identifying information as well, such as a string that indicates a table name.

13.2.9 Subquery Syntax

A subquery is a SELECT statement within another statement.

All subquery forms and operations that the SQL standard requires are supported, as well as a few features that are MySQL-specific.

Here is an example of a subquery:

```
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

In this example, SELECT * FROM t1 ... is the *outer query* (or *outer statement*), and (SELECT column1 FROM t2) is the *subquery*. We say that the subquery is *nested* within the outer query, and in fact it is possible to nest subqueries within other subqueries, to a considerable depth. A subquery must always appear within parentheses.

The main advantages of subqueries are:

• They allow queries that are *structured* so that it is possible to isolate each part of a statement.

• They provide alternative ways to perform operations that would otherwise require complex joins and unions.

• Many people find subqueries more readable than complex joins or unions. Indeed, it was the innovation of subqueries that gave people the original idea of calling the early SQL "Structured Query Language."

Here is an example statement that shows the major points about subquery syntax as specified by the SQL standard and supported in MySQL:

```
DELETE FROM t1
WHERE s11 > ANY
 (SELECT COUNT(*) /* no hint */ FROM t2
  WHERE NOT EXISTS
    (SELECT * FROM t3
```

```
    WHERE ROW(5*t2.s1,77)=
      (SELECT 50,11*s1 FROM t4 UNION SELECT 50,77 FROM
        (SELECT * FROM t5) AS t5)));
```

A subquery can return a scalar (a single value), a single row, a single column, or a table (one or more rows of one or more columns). These are called scalar, column, row, and table subqueries. Subqueries that return a particular kind of result often can be used only in certain contexts, as described in the following sections.

There are few restrictions on the type of statements in which subqueries can be used. A subquery can contain many of the keywords or clauses that an ordinary SELECT can contain: DISTINCT, GROUP BY, ORDER BY, LIMIT, joins, index hints, UNION constructs, comments, functions, and so on.

A subquery's outer statement can be any one of: SELECT, INSERT, UPDATE, DELETE, SET, or DO.

In MySQL, you cannot modify a table and select from the same table in a subquery. This applies to statements such as DELETE, INSERT, REPLACE, UPDATE, and (because subqueries can be used in the SET clause) LOAD DATA INFILE.

For information about how the optimizer handles subqueries, see Section 8.2.1.14, "Optimizing Subqueries with EXISTS Strategy". For a discussion of restrictions on subquery use, including performance issues for certain forms of subquery syntax, see Section C.3, "Restrictions on Subqueries".

13.2.9.1 The Subquery as Scalar Operand

In its simplest form, a subquery is a scalar subquery that returns a single value. A scalar subquery is a simple operand, and you can use it almost anywhere a single column value or literal is legal, and you can expect it to have those characteristics that all operands have: a data type, a length, an indication that it can be NULL, and so on. For example:

```
CREATE TABLE t1 (s1 INT, s2 CHAR(5) NOT NULL);
INSERT INTO t1 VALUES(100, 'abcde');
SELECT (SELECT s2 FROM t1);
```

The subquery in this SELECT returns a single value ('abcde') that has a data type of CHAR, a length of 5, a character set and collation equal to the defaults in effect at CREATE TABLE time, and an indication that the value in the column can be NULL. Nullability of the value selected by a scalar subquery is not copied because if the subquery result is empty, the result is NULL. For the subquery just shown, if t1 were empty, the result would be NULL even though s2 is NOT NULL.

There are a few contexts in which a scalar subquery cannot be used. If a statement permits only a literal value, you cannot use a subquery. For example, LIMIT requires literal integer arguments, and LOAD DATA INFILE requires a literal string file name. You cannot use subqueries to supply these values.

When you see examples in the following sections that contain the rather spartan construct (SELECT column1 FROM t1), imagine that your own code contains much more diverse and complex constructions.

Suppose that we make two tables:

```
CREATE TABLE t1 (s1 INT);
INSERT INTO t1 VALUES (1);
CREATE TABLE t2 (s1 INT);
INSERT INTO t2 VALUES (2);
```

Then perform a SELECT:

```
SELECT (SELECT s1 FROM t2) FROM t1;
```

The result is 2 because there is a row in t2 containing a column s1 that has a value of 2.

A scalar subquery can be part of an expression, but remember the parentheses, even if the subquery is an operand that provides an argument for a function. For example:

```
SELECT UPPER((SELECT s1 FROM t1)) FROM t2;
```

13.2.9.2 Comparisons Using Subqueries

The most common use of a subquery is in the form:

```
non_subquery_operand comparison_operator (subquery)
```

Where *comparison_operator* is one of these operators:

```
=   >   <   >=   <=   <>   !=   <=>
```

For example:

```
... WHERE 'a' = (SELECT column1 FROM t1)
```

MySQL also permits this construct:

```
non_subquery_operand LIKE (subquery)
```

At one time the only legal place for a subquery was on the right side of a comparison, and you might still find some old DBMSs that insist on this.

Here is an example of a common-form subquery comparison that you cannot do with a join. It finds all the rows in table t1 for which the column1 value is equal to a maximum value in table t2:

```
SELECT * FROM t1
  WHERE column1 = (SELECT MAX(column2) FROM t2);
```

Here is another example, which again is impossible with a join because it involves aggregating for one of the tables. It finds all rows in table t1 containing a value that occurs twice in a given column:

```
SELECT * FROM t1 AS t
  WHERE 2 = (SELECT COUNT(*) FROM t1 WHERE t1.id = t.id);
```

For a comparison of the subquery to a scalar, the subquery must return a scalar. For a comparison of the subquery to a row constructor, the subquery must be a row subquery that returns a row with the same number of values as the row constructor. See Section 13.2.9.5, "Row Subqueries".

13.2.9.3 Subqueries with ANY, IN, or SOME

Syntax:

```
operand comparison_operator ANY (subquery)
operand IN (subquery)
operand comparison_operator SOME (subquery)
```

Where `comparison_operator` is one of these operators:

```
=  >  <  >=  <=  <>  !=
```

The `ANY` keyword, which must follow a comparison operator, means "return `TRUE` if the comparison is `TRUE` for `ANY` of the values in the column that the subquery returns." For example:

```
SELECT s1 FROM t1 WHERE s1 > ANY (SELECT s1 FROM t2);
```

Suppose that there is a row in table `t1` containing `(10)`. The expression is `TRUE` if table `t2` contains `(21,14,7)` because there is a value `7` in `t2` that is less than `10`. The expression is `FALSE` if table `t2` contains `(20,10)`, or if table `t2` is empty. The expression is *unknown* (that is, `NULL`) if table `t2` contains `(NULL,NULL,NULL)`.

When used with a subquery, the word `IN` is an alias for `= ANY`. Thus, these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 = ANY (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 IN    (SELECT s1 FROM t2);
```

`IN` and `= ANY` are not synonyms when used with an expression list. `IN` can take an expression list, but `= ANY` cannot. See Section 12.3.2, "Comparison Functions and Operators".

`NOT IN` is not an alias for `<> ANY`, but for `<> ALL`. See Section 13.2.9.4, "Subqueries with ALL".

The word `SOME` is an alias for `ANY`. Thus, these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 <> ANY  (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 <> SOME (SELECT s1 FROM t2);
```

Use of the word `SOME` is rare, but this example shows why it might be useful. To most people, the English phrase "a is not equal to any b" means "there is no b which is equal to a," but that is not what is meant by the SQL syntax. The syntax means "there is some b to which a is not equal." Using `<> SOME` instead helps ensure that everyone understands the true meaning of the query.

13.2.9.4 Subqueries with ALL

Syntax:

```
operand comparison_operator ALL (subquery)
```

The word `ALL`, which must follow a comparison operator, means "return `TRUE` if the comparison is `TRUE` for `ALL` of the values in the column that the subquery returns." For example:

```
SELECT s1 FROM t1 WHERE s1 > ALL (SELECT s1 FROM t2);
```

Suppose that there is a row in table `t1` containing `(10)`. The expression is `TRUE` if table `t2` contains `(-5,0,+5)` because `10` is greater than all three values in `t2`. The expression is `FALSE` if table `t2` contains `(12,6,NULL,-100)` because there is a single value `12` in table `t2` that is greater than `10`. The expression is *unknown* (that is, `NULL`) if table `t2` contains `(0,NULL,1)`.

Finally, the expression is `TRUE` if table `t2` is empty. So, the following expression is `TRUE` when table `t2` is empty:

```
SELECT * FROM t1 WHERE 1 > ALL (SELECT s1 FROM t2);
```

But this expression is `NULL` when table `t2` is empty:

```
SELECT * FROM t1 WHERE 1 > (SELECT s1 FROM t2);
```

In addition, the following expression is `NULL` when table `t2` is empty:

```
SELECT * FROM t1 WHERE 1 > ALL (SELECT MAX(s1) FROM t2);
```

In general, *tables containing* `NULL` *values* and *empty tables* are "edge cases." When writing subqueries, always consider whether you have taken those two possibilities into account.

`NOT IN` is an alias for `<> ALL`. Thus, these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 <> ALL (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 NOT IN (SELECT s1 FROM t2);
```

13.2.9.5 Row Subqueries

Scalar or column subqueries return a single value or a column of values. A *row subquery* is a subquery variant that returns a single row and can thus return more than one column value. Legal operators for row subquery comparisons are:

```
=  >  <  >=  <=  <>  !=  <=>
```

Here are two examples:

```
SELECT * FROM t1
  WHERE (col1,col2) = (SELECT col3, col4 FROM t2 WHERE id = 10);
SELECT * FROM t1
  WHERE ROW(col1,col2) = (SELECT col3, col4 FROM t2 WHERE id = 10);
```

For both queries, if the table `t2` contains a single row with `id = 10`, the subquery returns a single row. If this row has `col3` and `col4` values equal to the `col1` and `col2` values of any rows in `t1`, the `WHERE` expression is `TRUE` and each query returns those `t1` rows. If the `t2` row `col3` and `col4` values are not equal the `col1` and `col2` values of any `t1` row, the expression is `FALSE` and the query returns an empty result set. The expression is *unknown* (that is, `NULL`) if the subquery produces no rows. An error occurs if the subquery produces multiple rows because a row subquery can return at most one row.

For information about how each operator works for row comparisons, see Section 12.3.2, "Comparison Functions and Operators".

The expressions `(1,2)` and `ROW(1,2)` are sometimes called *row constructors*. The two are equivalent. The row constructor and the row returned by the subquery must contain the same number of values.

A row constructor is used for comparisons with subqueries that return two or more columns. When a subquery returns a single column, this is regarded as a scalar value and not as a row, so a row constructor cannot be used with a subquery that does not return at least two columns. Thus, the following query fails with a syntax error:

```
SELECT * FROM t1 WHERE ROW(1) = (SELECT column1 FROM t2)
```

Row constructors are legal in other contexts. For example, the following two statements are semantically equivalent:

```
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

Prior to MySQL 5.1.12, only the second of the preceding two expressions could be optimized.

The following query answers the request, "find all rows in table `t1` that also exist in table `t2`":

```
SELECT column1,column2,column3
  FROM t1
  WHERE (column1,column2,column3) IN
         (SELECT column1,column2,column3 FROM t2);
```

For more information about the optimizer and row constructors, see Section 8.2.1.16, "Row Constructor Expression Optimization"

13.2.9.6 Subqueries with EXISTS or NOT EXISTS

If a subquery returns any rows at all, `EXISTS subquery` is `TRUE`, and `NOT EXISTS subquery` is `FALSE`. For example:

```
SELECT column1 FROM t1 WHERE EXISTS (SELECT * FROM t2);
```

Traditionally, an `EXISTS` subquery starts with `SELECT *`, but it could begin with `SELECT 5` or `SELECT column1` or anything at all. MySQL ignores the `SELECT` list in such a subquery, so it makes no difference.

For the preceding example, if `t2` contains any rows, even rows with nothing but `NULL` values, the `EXISTS` condition is `TRUE`. This is actually an unlikely example because a `[NOT] EXISTS` subquery almost always contains correlations. Here are some more realistic examples:

- What kind of store is present in one or more cities?

```
SELECT DISTINCT store_type FROM stores
  WHERE EXISTS (SELECT * FROM cities_stores
                WHERE cities_stores.store_type = stores.store_type);
```

- What kind of store is present in no cities?

```
SELECT DISTINCT store_type FROM stores
  WHERE NOT EXISTS (SELECT * FROM cities_stores
                    WHERE cities_stores.store_type = stores.store_type);
```

- What kind of store is present in all cities?

```
SELECT DISTINCT store_type FROM stores s1
  WHERE NOT EXISTS (
    SELECT * FROM cities WHERE NOT EXISTS (
      SELECT * FROM cities_stores
       WHERE cities_stores.city = cities.city
       AND cities_stores.store_type = stores.store_type));
```

The last example is a double-nested `NOT EXISTS` query. That is, it has a `NOT EXISTS` clause within a `NOT EXISTS` clause. Formally, it answers the question "does a city exist with a store that is not in `Stores`"? But it is easier to say that a nested `NOT EXISTS` answers the question "is x `TRUE` for all y?"

13.2.9.7 Correlated Subqueries

A *correlated subquery* is a subquery that contains a reference to a table that also appears in the outer query. For example:

```
SELECT * FROM t1
  WHERE column1 = ANY (SELECT column1 FROM t2
                       WHERE t2.column2 = t1.column2);
```

Notice that the subquery contains a reference to a column of `t1`, even though the subquery's `FROM` clause does not mention a table `t1`. So, MySQL looks outside the subquery, and finds `t1` in the outer query.

Suppose that table `t1` contains a row where `column1 = 5` and `column2 = 6`; meanwhile, table `t2` contains a row where `column1 = 5` and `column2 = 7`. The simple expression `... WHERE column1 = ANY (SELECT column1 FROM t2)` would be `TRUE`, but in this example, the `WHERE` clause within the subquery is `FALSE` (because `(5,6)` is not equal to `(5,7)`), so the expression as a whole is `FALSE`.

Scoping rule: MySQL evaluates from inside to outside. For example:

```
SELECT column1 FROM t1 AS x
  WHERE x.column1 = (SELECT column1 FROM t2 AS x
    WHERE x.column1 = (SELECT column1 FROM t3
      WHERE x.column2 = t3.column1));
```

In this statement, `x.column2` must be a column in table `t2` because `SELECT column1 FROM t2 AS x ...` renames `t2`. It is not a column in table `t1` because `SELECT column1 FROM t1 ...` is an outer query that is *farther out*.

For subqueries in `HAVING` or `ORDER BY` clauses, MySQL also looks for column names in the outer select list.

For certain cases, a correlated subquery is optimized. For example:

```
val IN (SELECT key_val FROM tbl_name WHERE correlated_condition)
```

Otherwise, they are inefficient and likely to be slow. Rewriting the query as a join might improve performance.

Aggregate functions in correlated subqueries may contain outer references, provided the function contains nothing but outer references, and provided the function is not contained in another function or expression.

13.2.9.8 Subqueries in the FROM Clause

Subqueries are legal in a `SELECT` statement's `FROM` clause. The actual syntax is:

```
SELECT ... FROM (subquery) [AS] name ...
```

The `[AS] name` clause is mandatory, because every table in a `FROM` clause must have a name. Any columns in the `subquery` select list must have unique names.

For the sake of illustration, assume that you have this table:

```
CREATE TABLE t1 (s1 INT, s2 CHAR(5), s3 FLOAT);
```

Here is how to use a subquery in the FROM clause, using the example table:

```
INSERT INTO t1 VALUES (1,'1',1.0);
INSERT INTO t1 VALUES (2,'2',2.0);
SELECT sb1,sb2,sb3
  FROM (SELECT s1 AS sb1, s2 AS sb2, s3*2 AS sb3 FROM t1) AS sb
  WHERE sb1 > 1;
```

Result: 2, '2', 4.0.

Here is another example: Suppose that you want to know the average of a set of sums for a grouped table. This does not work:

```
SELECT AVG(SUM(column1)) FROM t1 GROUP BY column1;
```

However, this query provides the desired information:

```
SELECT AVG(sum_column1)
  FROM (SELECT SUM(column1) AS sum_column1
        FROM t1 GROUP BY column1) AS t1;
```

Notice that the column name used within the subquery (sum_column1) is recognized in the outer query.

Subqueries in the FROM clause can return a scalar, column, row, or table. Subqueries in the FROM clause cannot be correlated subqueries, unless used within the ON clause of a JOIN operation.

Subqueries in the FROM clause are executed even for the EXPLAIN statement (that is, derived temporary tables are materialized). This occurs because upper-level queries need information about all tables during the optimization phase, and the table represented by a subquery in the FROM clause is unavailable unless the subquery is executed.

It is possible under certain circumstances to modify table data using EXPLAIN SELECT. This can occur if the outer query accesses any tables and an inner query invokes a stored function that changes one or more rows of a table. Suppose that there are two tables t1 and t2 in database d1, created as shown here:

```
mysql> CREATE DATABASE d1;
Query OK, 1 row affected (0.00 sec)

mysql> USE d1;
Database changed

mysql> CREATE TABLE t1 (c1 INT);
Query OK, 0 rows affected (0.15 sec)

mysql> CREATE TABLE t2 (c1 INT);
Query OK, 0 rows affected (0.08 sec)
```

Now we create a stored function f1 which modifies t2:

```
mysql> DELIMITER //
mysql> CREATE FUNCTION f1(p1 INT) RETURNS INT
mysql>   BEGIN
mysql>     INSERT INTO t2 VALUES (p1);
mysql>     RETURN p1;
```

```
mysql>   END //
Query OK, 0 rows affected (0.01 sec)

mysql> DELIMITER ;
```

Referencing the function directly in an EXPLAIN SELECT does not have any effect on t2, as shown here:

```
mysql> SELECT * FROM t2;
Empty set (0.00 sec)

mysql> EXPLAIN SELECT f1(5);
+----+-------------+-------+------+---------------+------+---------+------+------+---------------+
| id | select_type | table | type | possible_keys | key  | key_len | ref  | rows | Extra         |
+----+-------------+-------+------+---------------+------+---------+------+------+---------------+
|  1 | SIMPLE      | NULL  | NULL | NULL          | NULL | NULL    | NULL | NULL | No tables used |
+----+-------------+-------+------+---------------+------+---------+------+------+---------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM t2;
Empty set (0.00 sec)
```

This is because the SELECT statement did not reference any tables, as can be seen in the table and Extra columns of the output. This is also true of the following nested SELECT:

```
mysql> EXPLAIN SELECT NOW() AS a1, (SELECT f1(5)) AS a2;
+----+-------------+-------+------+---------------+------+---------+------+------+---------------+
| id | select_type | table | type | possible_keys | key  | key_len | ref  | rows | Extra         |
+----+-------------+-------+------+---------------+------+---------+------+------+---------------+
|  1 | PRIMARY     | NULL  | NULL | NULL          | NULL | NULL    | NULL | NULL | No tables used |
+----+-------------+-------+------+---------------+------+---------+------+------+---------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+-------+------+----------------------------------------+
| Level | Code | Message                                |
+-------+------+----------------------------------------+
| Note  | 1249 | Select 2 was reduced during optimization |
+-------+------+----------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM t2;
Empty set (0.00 sec)
```

However, if the outer SELECT references any tables, the optimizer executes the statement in the subquery as well:

```
mysql> EXPLAIN SELECT * FROM t1 AS a1, (SELECT f1(5)) AS a2;
+----+-------------+-------------+--------+---------------+------+---------+------+------+------------------
| id | select_type | table       | type   | possible_keys | key  | key_len | ref  | rows | Extra
+----+-------------+-------------+--------+---------------+------+---------+------+------+------------------
|  1 | PRIMARY     | a1          | system | NULL          | NULL | NULL    | NULL |    0 | const row not fou
|  1 | PRIMARY     | <derived2>  | system | NULL          | NULL | NULL    | NULL |    1 |
|  2 | DERIVED     | NULL        | NULL   | NULL          | NULL | NULL    | NULL | NULL | No tables used
+----+-------------+-------------+--------+---------------+------+---------+------+------+------------------
3 rows in set (0.00 sec)

mysql> SELECT * FROM t2;
+------+
| c1   |
+------+
|    5 |
+------+
1 row in set (0.00 sec)
```

This also means that an `EXPLAIN SELECT` statement such as the one shown here may take a long time to execute because the `BENCHMARK()` function is executed once for each row in `t1`:

```
EXPLAIN SELECT * FROM t1 AS a1, (SELECT BENCHMARK(1000000, MD5(NOW())));
```

13.2.9.9 Subquery Errors

There are some errors that apply only to subqueries. This section describes them.

- Unsupported subquery syntax:

```
ERROR 1235 (ER_NOT_SUPPORTED_YET)
SQLSTATE = 42000
Message = "This version of MySQL doesn't yet support
'LIMIT & IN/ALL/ANY/SOME subquery'"
```

This means that MySQL does not support statements of the following form:

```
SELECT * FROM t1 WHERE s1 IN (SELECT s2 FROM t2 ORDER BY s1 LIMIT 1)
```

- Incorrect number of columns from subquery:

```
ERROR 1241 (ER_OPERAND_COL)
SQLSTATE = 21000
Message = "Operand should contain 1 column(s)"
```

This error occurs in cases like this:

```
SELECT (SELECT column1, column2 FROM t2) FROM t1;
```

You may use a subquery that returns multiple columns, if the purpose is row comparison. In other contexts, the subquery must be a scalar operand. See Section 13.2.9.5, "Row Subqueries".

- Incorrect number of rows from subquery:

```
ERROR 1242 (ER_SUBSELECT_NO_1_ROW)
SQLSTATE = 21000
Message = "Subquery returns more than 1 row"
```

This error occurs for statements where the subquery must return at most one row but returns multiple rows. Consider the following example:

```
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

If `SELECT column1 FROM t2` returns just one row, the previous query will work. If the subquery returns more than one row, error 1242 will occur. In that case, the query should be rewritten as:

```
SELECT * FROM t1 WHERE column1 = ANY (SELECT column1 FROM t2);
```

- Incorrectly used table in subquery:

```
Error 1093 (ER_UPDATE_TABLE_USED)
SQLSTATE = HY000
Message = "You can't specify target table 'x'
```

```
for update in FROM clause"
```

This error occurs in cases such as the following, which attempts to modify a table and select from the same table in the subquery:

```
UPDATE t1 SET column2 = (SELECT MAX(column1) FROM t1);
```

You can use a subquery for assignment within an UPDATE statement because subqueries are legal in UPDATE and DELETE statements as well as in SELECT statements. However, you cannot use the same table (in this case, table t1) for both the subquery FROM clause and the update target.

For transactional storage engines, the failure of a subquery causes the entire statement to fail. For nontransactional storage engines, data modifications made before the error was encountered are preserved.

13.2.9.10 Optimizing Subqueries

Development is ongoing, so no optimization tip is reliable for the long term. The following list provides some interesting tricks that you might want to play with:

- Use subquery clauses that affect the number or order of the rows in the subquery. For example:

```
SELECT * FROM t1 WHERE t1.column1 IN
  (SELECT column1 FROM t2 ORDER BY column1);
SELECT * FROM t1 WHERE t1.column1 IN
  (SELECT DISTINCT column1 FROM t2);
SELECT * FROM t1 WHERE EXISTS
  (SELECT * FROM t2 LIMIT 1);
```

- Replace a join with a subquery. For example, try this:

```
SELECT DISTINCT column1 FROM t1 WHERE t1.column1 IN (
  SELECT column1 FROM t2);
```

Instead of this:

```
SELECT DISTINCT t1.column1 FROM t1, t2
  WHERE t1.column1 = t2.column1;
```

- Some subqueries can be transformed to joins for compatibility with older versions of MySQL that do not support subqueries. However, in some cases, converting a subquery to a join may improve performance. See Section 13.2.9.11, "Rewriting Subqueries as Joins".

- Move clauses from outside to inside the subquery. For example, use this query:

```
SELECT * FROM t1
  WHERE s1 IN (SELECT s1 FROM t1 UNION ALL SELECT s1 FROM t2);
```

Instead of this query:

```
SELECT * FROM t1
  WHERE s1 IN (SELECT s1 FROM t1) OR s1 IN (SELECT s1 FROM t2);
```

For another example, use this query:

```
SELECT (SELECT column1 + 5 FROM t1) FROM t2;
```

Instead of this query:

```
SELECT (SELECT column1 FROM t1) + 5 FROM t2;
```

- Use a row subquery instead of a correlated subquery. For example, use this query:

```
SELECT * FROM t1
  WHERE (column1,column2) IN (SELECT column1,column2 FROM t2);
```

Instead of this query:

```
SELECT * FROM t1
  WHERE EXISTS (SELECT * FROM t2 WHERE t2.column1=t1.column1
                AND t2.column2=t1.column2);
```

- Use `NOT (a = ANY (...))` rather than `a <> ALL (...)`.

- Use `x = ANY (table containing (1,2))` rather than `x=1 OR x=2`.

- Use `= ANY` rather than `EXISTS`.

- For uncorrelated subqueries that always return one row, `IN` is always slower than `=`. For example, use this query:

```
SELECT * FROM t1
  WHERE t1.col_name = (SELECT a FROM t2 WHERE b = some_const);
```

Instead of this query:

```
SELECT * FROM t1
  WHERE t1.col_name IN (SELECT a FROM t2 WHERE b = some_const);
```

These tricks might cause programs to go faster or slower. Using MySQL facilities like the `BENCHMARK()` function, you can get an idea about what helps in your own situation. See Section 12.14, "Information Functions".

Some optimizations that MySQL itself makes are:

- MySQL executes uncorrelated subqueries only once. Use `EXPLAIN` to make sure that a given subquery really is uncorrelated.

- MySQL rewrites `IN`, `ALL`, `ANY`, and `SOME` subqueries in an attempt to take advantage of the possibility that the select-list columns in the subquery are indexed.

- MySQL replaces subqueries of the following form with an index-lookup function, which `EXPLAIN` describes as a special join type (`unique_subquery` or `index_subquery`):

```
... IN (SELECT indexed_column FROM single_table ...)
```

- MySQL enhances expressions of the following form with an expression involving `MIN()` or `MAX()`, unless `NULL` values or empty sets are involved:

```
value {ALL|ANY|SOME} {> | < | >= | <=} (uncorrelated subquery)
```

For example, this `WHERE` clause:

```
WHERE 5 > ALL (SELECT x FROM t)
```

might be treated by the optimizer like this:

```
WHERE 5 > (SELECT MAX(x) FROM t)
```

See also MySQL Internals: How MySQL Transforms Subqueries.

13.2.9.11 Rewriting Subqueries as Joins

Sometimes there are other ways to test membership in a set of values than by using a subquery. Also, on some occasions, it is not only possible to rewrite a query without a subquery, but it can be more efficient to make use of some of these techniques rather than to use subqueries. One of these is the `IN()` construct:

For example, this query:

```
SELECT * FROM t1 WHERE id IN (SELECT id FROM t2);
```

Can be rewritten as:

```
SELECT DISTINCT t1.* FROM t1, t2 WHERE t1.id=t2.id;
```

The queries:

```
SELECT * FROM t1 WHERE id NOT IN (SELECT id FROM t2);
SELECT * FROM t1 WHERE NOT EXISTS (SELECT id FROM t2 WHERE t1.id=t2.id);
```

Can be rewritten as:

```
SELECT table1.*
  FROM table1 LEFT JOIN table2 ON table1.id=table2.id
  WHERE table2.id IS NULL;
```

A `LEFT [OUTER] JOIN` can be faster than an equivalent subquery because the server might be able to optimize it better—a fact that is not specific to MySQL Server alone. Prior to SQL-92, outer joins did not exist, so subqueries were the only way to do certain things. Today, MySQL Server and many other modern database systems offer a wide range of outer join types.

MySQL Server supports multiple-table `DELETE` statements that can be used to efficiently delete rows based on information from one table or even from many tables at the same time. Multiple-table `UPDATE` statements are also supported. See Section 13.2.2, "DELETE Syntax", and Section 13.2.10, "UPDATE Syntax".

13.2.10 UPDATE Syntax

Single-table syntax:

```
UPDATE [LOW_PRIORITY] [IGNORE] table_reference
    SET col_name1={expr1|DEFAULT} [, col_name2={expr2|DEFAULT}] ...
    [WHERE where_condition]
    [ORDER BY ...]
```

```
    [LIMIT row_count]
```

Multiple-table syntax:

```
UPDATE [LOW_PRIORITY] [IGNORE] table_references
    SET col_name1={expr1|DEFAULT} [, col_name2={expr2|DEFAULT}] ...
    [WHERE where_condition]
```

For the single-table syntax, the `UPDATE` statement updates columns of existing rows in the named table with new values. The `SET` clause indicates which columns to modify and the values they should be given. Each value can be given as an expression, or the keyword `DEFAULT` to set a column explicitly to its default value. The `WHERE` clause, if given, specifies the conditions that identify which rows to update. With no `WHERE` clause, all rows are updated. If the `ORDER BY` clause is specified, the rows are updated in the order that is specified. The `LIMIT` clause places a limit on the number of rows that can be updated.

For the multiple-table syntax, `UPDATE` updates rows in each table named in `table_references` that satisfy the conditions. Each matching row is updated once, even if it matches the conditions multiple times. For multiple-table syntax, `ORDER BY` and `LIMIT` cannot be used.

`where_condition` is an expression that evaluates to true for each row to be updated. For expression syntax, see Section 9.5, "Expression Syntax".

`table_references` and `where_condition` are specified as described in Section 13.2.8, "SELECT Syntax".

You need the `UPDATE` privilege only for columns referenced in an `UPDATE` that are actually updated. You need only the `SELECT` privilege for any columns that are read but not modified.

The `UPDATE` statement supports the following modifiers:

- With the `LOW_PRIORITY` keyword, execution of the `UPDATE` is delayed until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- With the `IGNORE` keyword, the update statement does not abort even if errors occur during the update. Rows for which duplicate-key conflicts occur on a unique key value are not updated. Rows updated to values that would cause data conversion errors are updated to the closest valid values instead.

If you access a column from the table to be updated in an expression, `UPDATE` uses the current value of the column. For example, the following statement sets `col1` to one more than its current value:

```
UPDATE t1 SET col1 = col1 + 1;
```

The second assignment in the following statement sets `col2` to the current (updated) `col1` value, not the original `col1` value. The result is that `col1` and `col2` have the same value. This behavior differs from standard SQL.

```
UPDATE t1 SET col1 = col1 + 1, col2 = col1;
```

Single-table `UPDATE` assignments are generally evaluated from left to right. For multiple-table updates, there is no guarantee that assignments are carried out in any particular order.

If you set a column to the value it currently has, MySQL notices this and does not update it.

If you update a column that has been declared `NOT NULL` by setting to `NULL`, an error occurs if strict SQL mode is enabled; otherwise, the column is set to the implicit default value for the column data type and the

warning count is incremented. The implicit default value is `0` for numeric types, the empty string (`' '`) for string types, and the "zero" value for date and time types. See Section 11.6, "Data Type Default Values".

`UPDATE` returns the number of rows that were actually changed. The `mysql_info()` C API function returns the number of rows that were matched and updated and the number of warnings that occurred during the `UPDATE`.

You can use `LIMIT` `row_count` to restrict the scope of the `UPDATE`. A `LIMIT` clause is a rows-matched restriction. The statement stops as soon as it has found `row_count` rows that satisfy the `WHERE` clause, whether or not they actually were changed.

If an `UPDATE` statement includes an `ORDER BY` clause, the rows are updated in the order specified by the clause. This can be useful in certain situations that might otherwise result in an error. Suppose that a table `t` contains a column `id` that has a unique index. The following statement could fail with a duplicate-key error, depending on the order in which rows are updated:

```
UPDATE t SET id = id + 1;
```

For example, if the table contains 1 and 2 in the `id` column and 1 is updated to 2 before 2 is updated to 3, an error occurs. To avoid this problem, add an `ORDER BY` clause to cause the rows with larger `id` values to be updated before those with smaller values:

```
UPDATE t SET id = id + 1 ORDER BY id DESC;
```

You can also perform `UPDATE` operations covering multiple tables. However, you cannot use `ORDER BY` or `LIMIT` with a multiple-table `UPDATE`. The `table_references` clause lists the tables involved in the join. Its syntax is described in Section 13.2.8.2, "JOIN Syntax". Here is an example:

```
UPDATE items,month SET items.price=month.price
WHERE items.id=month.id;
```

The preceding example shows an inner join that uses the comma operator, but multiple-table `UPDATE` statements can use any type of join permitted in `SELECT` statements, such as `LEFT JOIN`.

If you use a multiple-table `UPDATE` statement involving `InnoDB` tables for which there are foreign key constraints, the MySQL optimizer might process tables in an order that differs from that of their parent/child relationship. In this case, the statement fails and rolls back. Instead, update a single table and rely on the `ON UPDATE` capabilities that `InnoDB` provides to cause the other tables to be modified accordingly. See Section 14.6.6.6, "InnoDB and FOREIGN KEY Constraints".

You cannot update a table and select from the same table in a subquery.

Index hints (see Section 8.9.3, "Index Hints") are accepted but ignored for `UPDATE` statements.

An `UPDATE` on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. See Section 18.5.4, "Partitioning and Table-Level Locking", for more information.

13.3 MySQL Transactional and Locking Statements

MySQL supports local transactions (within a given client session) through statements such as `SET autocommit`, `START TRANSACTION`, `COMMIT`, and `ROLLBACK`. See Section 13.3.1, "START TRANSACTION, COMMIT, and ROLLBACK Syntax". XA transaction support enables MySQL to participate in distributed transactions as well. See Section 13.3.7, "XA Transactions".

13.3.1 START TRANSACTION, COMMIT, and ROLLBACK Syntax

```
START TRANSACTION [WITH CONSISTENT SNAPSHOT]
BEGIN [WORK]
COMMIT [WORK] [AND [NO] CHAIN] [[NO] RELEASE]
ROLLBACK [WORK] [AND [NO] CHAIN] [[NO] RELEASE]
SET autocommit = {0 | 1}
```

These statements provide control over use of transactions:

- START TRANSACTION or BEGIN start a new transaction.

- COMMIT commits the current transaction, making its changes permanent.

- ROLLBACK rolls back the current transaction, canceling its changes.

- SET autocommit disables or enables the default autocommit mode for the current session.

By default, MySQL runs with autocommit mode enabled. This means that as soon as you execute a statement that updates (modifies) a table, MySQL stores the update on disk to make it permanent. The change cannot be rolled back.

To disable autocommit mode implicitly for a single series of statements, use the START TRANSACTION statement:

```
START TRANSACTION;
SELECT @A:=SUM(salary) FROM table1 WHERE type=1;
UPDATE table2 SET summary=@A WHERE type=1;
COMMIT;
```

With START TRANSACTION, autocommit remains disabled until you end the transaction with COMMIT or ROLLBACK. The autocommit mode then reverts to its previous state.

You can also begin a transaction like this:

```
START TRANSACTION WITH CONSISTENT SNAPSHOT;
```

The WITH CONSISTENT SNAPSHOT option starts a consistent read for storage engines that are capable of it. This applies only to InnoDB. The effect is the same as issuing a START TRANSACTION followed by a SELECT from any InnoDB table. See Section 14.6.4.4, "Consistent Nonlocking Reads". The WITH CONSISTENT SNAPSHOT option does not change the current transaction isolation level, so it provides a consistent snapshot only if the current isolation level is one that permits a consistent read. The only isolation level that permits a consistent read is REPEATABLE READ. For all other isolation levels, the WITH CONSISTENT SNAPSHOT clause is ignored.

> ⚠️ **Important**
>
> Many APIs used for writing MySQL client applications (such as JDBC) provide their own methods for starting transactions that can (and sometimes should) be used instead of sending a START TRANSACTION statement from the client. See Chapter 21, *Connectors and APIs*, or the documentation for your API, for more information.

To disable autocommit mode explicitly, use the following statement:

```
SET autocommit=0;
```

After disabling autocommit mode by setting the `autocommit` variable to zero, changes to transaction-safe tables (such as those for `InnoDB` or `NDBCLUSTER`) are not made permanent immediately. You must use `COMMIT` to store your changes to disk or `ROLLBACK` to ignore the changes.

`autocommit` is a session variable and must be set for each session. To disable autocommit mode for each new connection, see the description of the `autocommit` system variable at Section 5.1.4, "Server System Variables".

`BEGIN` and `BEGIN WORK` are supported as aliases of `START TRANSACTION` for initiating a transaction. `START TRANSACTION` is standard SQL syntax and is the recommended way to start an ad-hoc transaction.

The `BEGIN` statement differs from the use of the `BEGIN` keyword that starts a `BEGIN ... END` compound statement. The latter does not begin a transaction. See Section 13.6.1, "BEGIN ... END Compound-Statement Syntax".

> **Note**
>
> Within all stored programs (stored procedures and functions, triggers, and events), the parser treats `BEGIN [WORK]` as the beginning of a `BEGIN ... END` block. Begin a transaction in this context with `START TRANSACTION` instead.

The optional `WORK` keyword is supported for `COMMIT` and `ROLLBACK`, as are the `CHAIN` and `RELEASE` clauses. `CHAIN` and `RELEASE` can be used for additional control over transaction completion. The value of the `completion_type` system variable determines the default completion behavior. See Section 5.1.4, "Server System Variables".

The `AND CHAIN` clause causes a new transaction to begin as soon as the current one ends, and the new transaction has the same isolation level as the just-terminated transaction. The `RELEASE` clause causes the server to disconnect the current client session after terminating the current transaction. Including the `NO` keyword suppresses `CHAIN` or `RELEASE` completion, which can be useful if the `completion_type` system variable is set to cause chaining or release completion by default.

Beginning a transaction causes any pending transaction to be committed. See Section 13.3.3, "Statements That Cause an Implicit Commit", for more information.

Beginning a transaction also causes table locks acquired with `LOCK TABLES` to be released, as though you had executed `UNLOCK TABLES`. Beginning a transaction does not release a global read lock acquired with `FLUSH TABLES WITH READ LOCK`.

For best results, transactions should be performed using only tables managed by a single transaction-safe storage engine. Otherwise, the following problems can occur:

- If you use tables from more than one transaction-safe storage engine (such as `InnoDB`), and the transaction isolation level is not `SERIALIZABLE`, it is possible that when one transaction commits, another ongoing transaction that uses the same tables will see only some of the changes made by the first transaction. That is, the atomicity of transactions is not guaranteed with mixed engines and inconsistencies can result. (If mixed-engine transactions are infrequent, you can use `SET TRANSACTION ISOLATION LEVEL` to set the isolation level to `SERIALIZABLE` on a per-transaction basis as necessary.)

- If you use tables that are not transaction-safe within a transaction, changes to those tables are stored at once, regardless of the status of autocommit mode.

- If you issue a `ROLLBACK` statement after updating a nontransactional table within a transaction, an `ER_WARNING_NOT_COMPLETE_ROLLBACK` warning occurs. Changes to transaction-safe tables are rolled back, but not changes to nontransaction-safe tables.

Each transaction is stored in the binary log in one chunk, upon `COMMIT`. Transactions that are rolled back are not logged. (**Exception**: Modifications to nontransactional tables cannot be rolled back. If a transaction that is rolled back includes modifications to nontransactional tables, the entire transaction is logged with a `ROLLBACK` statement at the end to ensure that modifications to the nontransactional tables are replicated.) See Section 5.4.4, "The Binary Log".

You can change the isolation level for transactions with the `SET TRANSACTION` statement. See Section 13.3.6, "SET TRANSACTION Syntax".

Rolling back can be a slow operation that may occur implicitly without the user having explicitly asked for it (for example, when an error occurs). Because of this, `SHOW PROCESSLIST` displays `Rolling back` in the `State` column for the session, not only for explicit rollbacks performed with the `ROLLBACK` statement but also for implicit rollbacks.

> **Note**
>
> Beginning with MySQL 5.1.36, `BEGIN`, `COMMIT`, and `ROLLBACK` are no longer affected by `--replicate-do-db` or `--replicate-ignore-db` rules. (Bug #43263)

13.3.2 Statements That Cannot Be Rolled Back

Some statements cannot be rolled back. In general, these include data definition language (DDL) statements, such as those that create or drop databases, those that create, drop, or alter tables or stored routines.

You should design your transactions not to include such statements. If you issue a statement early in a transaction that cannot be rolled back, and then another statement later fails, the full effect of the transaction cannot be rolled back in such cases by issuing a `ROLLBACK` statement.

13.3.3 Statements That Cause an Implicit Commit

The statements listed in this section (and any synonyms for them) implicitly end any transaction active in the current session, as if you had done a `COMMIT` before executing the statement.

- **Data definition language (DDL) statements that define or modify database objects.** `ALTER DATABASE ... UPGRADE DATA DIRECTORY NAME`, `ALTER EVENT`, `ALTER PROCEDURE`, `ALTER SERVER`, `ALTER TABLE`, `CREATE DATABASE`, `CREATE EVENT`, `CREATE INDEX`, `CREATE PROCEDURE`, `CREATE SERVER`, `CREATE TABLE`, `DROP DATABASE`, `DROP EVENT`, `DROP INDEX`, `DROP PROCEDURE`, `DROP SERVER`, `DROP TABLE`, `RENAME TABLE`, `TRUNCATE TABLE`.

  `ALTER FUNCTION`, `CREATE FUNCTION` and `DROP FUNCTION` also cause an implicit commit when used with stored functions, but not with user-defined functions. (`ALTER FUNCTION` can only be used with stored functions.)

  `CREATE TABLE` and `DROP TABLE` statements do not commit a transaction if the `TEMPORARY` keyword is used. (This does not apply to other operations on temporary tables such as `ALTER TABLE` and `CREATE INDEX`, which do cause a commit.) However, although no implicit commit occurs, neither can the statement be rolled back, which means that the use of such statements causes transactional atomicity to be violated. For example, if you use `CREATE TEMPORARY TABLE` and then roll back the transaction, the table remains in existence.

  The `CREATE TABLE` statement in `InnoDB` is processed as a single transaction. This means that a `ROLLBACK` from the user does not undo `CREATE TABLE` statements the user made during that transaction.

Beginning with MySQL 5.1.3, `ALTER VIEW`, `CREATE TRIGGER`, `CREATE VIEW`, `DROP TRIGGER`, and `DROP VIEW` cause an implicit commit.

Beginning with MySQL 5.1.15, `CREATE TABLE ... SELECT` causes an implicit commit before and after the statement is executed when you are creating nontemporary tables. (No commit occurs for `CREATE TEMPORARY TABLE ... SELECT`.) This is to prevent an issue during replication where the table could be created on the master after a rollback, but fail to be recorded in the binary log, and therefore not replicated to the slave. For more information, see Bug #22865.

- **Statements that implicitly use or modify tables in the `mysql` database.** Beginning with MySQL 5.1.3, `CREATE USER`, `DROP USER`, and `RENAME USER` cause an implicit commit. Beginning with MySQL 5.1.23, `GRANT`, `REVOKE`, and `SET PASSWORD` statements cause an implicit commit.

- **Transaction-control and locking statements.** `BEGIN`, `LOCK TABLES`, `SET autocommit = 1` (if the value is not already 1), `START TRANSACTION`, `UNLOCK TABLES`.

  `UNLOCK TABLES` commits a transaction only if any tables currently have been locked with `LOCK TABLES`. This does not occur for `UNLOCK TABLES` following `FLUSH TABLES WITH READ LOCK` because the latter statement does not acquire table-level locks.

  Transactions cannot be nested. This is a consequence of the implicit commit performed for any current transaction when you issue a `START TRANSACTION` statement or one of its synonyms.

  Statements that cause an implicit commit cannot be used in an XA transaction while the transaction is in an `ACTIVE` state.

  The `BEGIN` statement differs from the use of the `BEGIN` keyword that starts a `BEGIN ... END` compound statement. The latter does not cause an implicit commit. See Section 13.6.1, "BEGIN ... END Compound-Statement Syntax".

- **Data loading statements.** `LOAD DATA INFILE`. Before MySQL 5.1.12, `LOAD DATA INFILE` caused an implicit commit for all storage engines. As of MySQL 5.1.12, it causes an implicit commit only for tables using the `NDB` storage engine. For more information, see Bug #11151.

- **Administrative statements.** `CACHE INDEX`, `LOAD INDEX INTO CACHE`. Beginning with MySQL 5.1.10, `ANALYZE TABLE`, `CHECK TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` cause an implicit commit.

13.3.4 SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax

```
SAVEPOINT identifier
ROLLBACK [WORK] TO [SAVEPOINT] identifier
RELEASE SAVEPOINT identifier
```

`InnoDB` supports the SQL statements `SAVEPOINT`, `ROLLBACK TO SAVEPOINT`, `RELEASE SAVEPOINT` and the optional `WORK` keyword for `ROLLBACK`.

The `SAVEPOINT` statement sets a named transaction savepoint with a name of *identifier*. If the current transaction has a savepoint with the same name, the old savepoint is deleted and a new one is set.

The `ROLLBACK TO SAVEPOINT` statement rolls back a transaction to the named savepoint without terminating the transaction. Modifications that the current transaction made to rows after the savepoint was set are undone in the rollback, but `InnoDB` does *not* release the row locks that were stored in memory

after the savepoint. (For a new inserted row, the lock information is carried by the transaction ID stored in the row; the lock is not separately stored in memory. In this case, the row lock is released in the undo.) Savepoints that were set at a later time than the named savepoint are deleted.

If the `ROLLBACK TO SAVEPOINT` statement returns the following error, it means that no savepoint with the specified name exists:

```
ERROR 1305 (42000): SAVEPOINT identifier does not exist
```

The `RELEASE SAVEPOINT` statement removes the named savepoint from the set of savepoints of the current transaction. No commit or rollback occurs. It is an error if the savepoint does not exist.

All savepoints of the current transaction are deleted if you execute a `COMMIT`, or a `ROLLBACK` that does not name a savepoint.

A new savepoint level is created when a stored function is invoked or a trigger is activated. The savepoints on previous levels become unavailable and thus do not conflict with savepoints on the new level. When the function or trigger terminates, any savepoints it created are released and the previous savepoint level is restored.

13.3.5 LOCK TABLES and UNLOCK TABLES Syntax

```
LOCK TABLES
    tbl_name [[AS] alias] lock_type
    [, tbl_name [[AS] alias] lock_type] ...

lock_type:
    READ [LOCAL]
  | [LOW_PRIORITY] WRITE

UNLOCK TABLES
```

MySQL enables client sessions to acquire table locks explicitly for the purpose of cooperating with other sessions for access to tables, or to prevent other sessions from modifying tables during periods when a session requires exclusive access to them. A session can acquire or release locks only for itself. One session cannot acquire locks for another session or release locks held by another session.

Locks may be used to emulate transactions or to get more speed when updating tables. This is explained in more detail later in this section.

`LOCK TABLES` explicitly acquires table locks for the current client session. Table locks can be acquired for base tables or views. You must have the `LOCK TABLES` privilege, and the `SELECT` privilege for each object to be locked.

For view locking, `LOCK TABLES` adds all base tables used in the view to the set of tables to be locked and locks them automatically. If you lock a table explicitly with `LOCK TABLES`, any tables used in triggers are also locked implicitly, as described in Section 13.3.5.2, "LOCK TABLES and Triggers".

`UNLOCK TABLES` explicitly releases any table locks held by the current session. `LOCK TABLES` implicitly releases any table locks held by the current session before acquiring new locks.

Another use for `UNLOCK TABLES` is to release the global read lock acquired with the `FLUSH TABLES WITH READ LOCK` statement, which enables you to lock all tables in all databases. See Section 13.7.6.3, "FLUSH Syntax". (This is a very convenient way to get backups if you have a file system such as Veritas that can take snapshots in time.)

A table lock protects only against inappropriate reads or writes by other sessions. The session holding the lock, even a read lock, can perform table-level operations such as `DROP TABLE`. Truncate operations are not transaction-safe, so an error occurs if the session attempts one during an active transaction or while holding a table lock.

The following discussion applies only to non-`TEMPORARY` tables. `LOCK TABLES` is permitted (but ignored) for a `TEMPORARY` table. The table can be accessed freely by the session within which it was created, regardless of what other locking may be in effect. No lock is necessary because no other session can see the table.

For information about other conditions on the use of `LOCK TABLES` and statements that cannot be used while `LOCK TABLES` is in effect, see Section 13.3.5.3, "Table-Locking Restrictions and Conditions"

Rules for Lock Acquisition

To acquire table locks within the current session, use the `LOCK TABLES` statement. The following lock types are available:

`READ [LOCAL]` lock:

- The session that holds the lock can read the table (but not write it).

- Multiple sessions can acquire a `READ` lock for the table at the same time.

- Other sessions can read the table without explicitly acquiring a `READ` lock.

- The `LOCAL` modifier enables nonconflicting `INSERT` statements (concurrent inserts) by other sessions to execute while the lock is held. (See Section 8.11.3, "Concurrent Inserts".) However, `READ LOCAL` cannot be used if you are going to manipulate the database using processes external to the server while you hold the lock. For `InnoDB` tables, `READ LOCAL` is the same as `READ`.

`[LOW_PRIORITY] WRITE` lock:

- The session that holds the lock can read and write the table.

- Only the session that holds the lock can access the table. No other session can access it until the lock is released.

- Lock requests for the table by other sessions block while the `WRITE` lock is held.

- The `LOW_PRIORITY` modifier affects lock scheduling if the `WRITE` lock request must wait, as described later.

If the `LOCK TABLES` statement must wait due to locks held by other sessions on any of the tables, it blocks until all locks can be acquired.

A session that requires locks must acquire all the locks that it needs in a single `LOCK TABLES` statement. While the locks thus obtained are held, the session can access only the locked tables. For example, in the following sequence of statements, an error occurs for the attempt to access `t2` because it was not locked in the `LOCK TABLES` statement:

```
mysql> LOCK TABLES t1 READ;
mysql> SELECT COUNT(*) FROM t1;
+----------+
| COUNT(*) |
+----------+
|        3 |
```

```
+----------+
mysql> SELECT COUNT(*) FROM t2;
ERROR 1100 (HY000): Table 't2' was not locked with LOCK TABLES
```

Tables in the `INFORMATION_SCHEMA` database are an exception. They can be accessed without being locked explicitly even while a session holds table locks obtained with `LOCK TABLES`.

You cannot refer to a locked table multiple times in a single query using the same name. Use aliases instead, and obtain a separate lock for the table and each alias:

```
mysql> LOCK TABLE t WRITE, t AS t1 READ;
mysql> INSERT INTO t SELECT * FROM t;
ERROR 1100: Table 't' was not locked with LOCK TABLES
mysql> INSERT INTO t SELECT * FROM t AS t1;
```

The error occurs for the first `INSERT` because there are two references to the same name for a locked table. The second `INSERT` succeeds because the references to the table use different names.

If your statements refer to a table by means of an alias, you must lock the table using that same alias. It does not work to lock the table without specifying the alias:

```
mysql> LOCK TABLE t READ;
mysql> SELECT * FROM t AS myalias;
ERROR 1100: Table 'myalias' was not locked with LOCK TABLES
```

Conversely, if you lock a table using an alias, you must refer to it in your statements using that alias:

```
mysql> LOCK TABLE t AS myalias READ;
mysql> SELECT * FROM t;
ERROR 1100: Table 't' was not locked with LOCK TABLES
mysql> SELECT * FROM t AS myalias;
```

`WRITE` locks normally have higher priority than `READ` locks to ensure that updates are processed as soon as possible. This means that if one session obtains a `READ` lock and then another session requests a `WRITE` lock, subsequent `READ` lock requests wait until the session that requested the `WRITE` lock has obtained the lock and released it. A request for a `LOW_PRIORITY WRITE` lock, by contrast, permits subsequent `READ` lock requests by other sessions to be satisfied first if they occur while the `LOW_PRIORITY WRITE` request is waiting. You should use `LOW_PRIORITY WRITE` locks only if you are sure that eventually there will be a time when no sessions have a `READ` lock. For `InnoDB` tables in transactional mode (autocommit = 0), a waiting `LOW_PRIORITY WRITE` lock acts like a regular `WRITE` lock and causes subsequent `READ` lock requests to wait.

`LOCK TABLES` acquires locks as follows:

1. Sort all tables to be locked in an internally defined order. From the user standpoint, this order is undefined.

2. If a table is to be locked with a read and a write lock, put the write lock request before the read lock request.

3. Lock one table at a time until the session gets all locks.

This policy ensures that table locking is deadlock free. There are, however, other things you need to be aware of about this policy: If you are using a `LOW_PRIORITY WRITE` lock for a table, it means only that MySQL waits for this particular lock until there are no other sessions that want a `READ` lock. When the session has gotten the `WRITE` lock and is waiting to get the lock for the next table in the lock table list,

all other sessions wait for the `WRITE` lock to be released. If this becomes a serious problem with your application, you should consider converting some of your tables to transaction-safe tables.

> **Note**
>
> `LOCK TABLES` or `UNLOCK TABLES`, when applied to a partitioned table, always locks or unlocks the entire table. See Section 18.5.4, "Partitioning and Table-Level Locking".

Rules for Lock Release

When the table locks held by a session are released, they are all released at the same time. A session can release its locks explicitly, or locks may be released implicitly under certain conditions.

- A session can release its locks explicitly with `UNLOCK TABLES`.

- If a session issues a `LOCK TABLES` statement to acquire a lock while already holding locks, its existing locks are released implicitly before the new locks are granted.

- If a session begins a transaction (for example, with `START TRANSACTION`), an implicit `UNLOCK TABLES` is performed, which causes existing locks to be released. (For additional information about the interaction between table locking and transactions, see Section 13.3.5.1, "Interaction of Table Locking and Transactions".)

If the connection for a client session terminates, whether normally or abnormally, the server implicitly releases all table locks held by the session (transactional and nontransactional). If the client reconnects, the locks will no longer be in effect. In addition, if the client had an active transaction, the server rolls back the transaction upon disconnect, and if reconnect occurs, the new session begins with autocommit enabled. For this reason, clients may wish to disable auto-reconnect. With auto-reconnect in effect, the client is not notified if reconnect occurs but any table locks or current transaction will have been lost. With auto-reconnect disabled, if the connection drops, an error occurs for the next statement issued. The client can detect the error and take appropriate action such as reacquiring the locks or redoing the transaction. See Section 21.8.15, "Controlling Automatic Reconnection Behavior".

> **Note**
>
> If you use `ALTER TABLE` on a locked table, it may become unlocked. For example, if you attempt a second `ALTER TABLE` operation, the result may be an error `Table 'tbl_name' was not locked with LOCK TABLES`. To handle this, lock the table again prior to the second alteration. See also Section B.5.6.1, "Problems with ALTER TABLE".

13.3.5.1 Interaction of Table Locking and Transactions

`LOCK TABLES` and `UNLOCK TABLES` interact with the use of transactions as follows:

- `LOCK TABLES` is not transaction-safe and implicitly commits any active transaction before attempting to lock the tables.

- `UNLOCK TABLES` implicitly commits any active transaction, but only if `LOCK TABLES` has been used to acquire table locks. For example, in the following set of statements, `UNLOCK TABLES` releases the global read lock but does not commit the transaction because no table locks are in effect:

```
FLUSH TABLES WITH READ LOCK;
START TRANSACTION;
SELECT ... ;
UNLOCK TABLES;
```

- Beginning a transaction (for example, with `START TRANSACTION`) implicitly commits any current transaction and releases existing table locks.

- `FLUSH TABLES WITH READ LOCK` acquires a global read lock and not table locks, so it is not subject to the same behavior as `LOCK TABLES` and `UNLOCK TABLES` with respect to table locking and implicit commits. For example, `START TRANSACTION` does not release the global read lock. See Section 13.7.6.3, "FLUSH Syntax".

- Other statements that implicitly cause transactions to be committed do not release existing table locks. For a list of such statements, see Section 13.3.3, "Statements That Cause an Implicit Commit".

- The correct way to use `LOCK TABLES` and `UNLOCK TABLES` with transactional tables, such as `InnoDB` tables, is to begin a transaction with `SET autocommit = 0` (not `START TRANSACTION`) followed by `LOCK TABLES`, and to not call `UNLOCK TABLES` until you commit the transaction explicitly. For example, if you need to write to table `t1` and read from table `t2`, you can do this:

```
SET autocommit=0;
LOCK TABLES t1 WRITE, t2 READ, ...;
... do something with tables t1 and t2 here ...
COMMIT;
UNLOCK TABLES;
```

  When you call `LOCK TABLES`, `InnoDB` internally takes its own table lock, and MySQL takes its own table lock. `InnoDB` releases its internal table lock at the next commit, but for MySQL to release its table lock, you have to call `UNLOCK TABLES`. You should not have `autocommit = 1`, because then `InnoDB` releases its internal table lock immediately after the call of `LOCK TABLES`, and deadlocks can very easily happen. `InnoDB` does not acquire the internal table lock at all if `autocommit = 1`, to help old applications avoid unnecessary deadlocks.

- `ROLLBACK` does not release table locks.

13.3.5.2 LOCK TABLES and Triggers

If you lock a table explicitly with `LOCK TABLES`, any tables used in triggers are also locked implicitly:

- The locks are taken as the same time as those acquired explicitly with the `LOCK TABLES` statement.

- The lock on a table used in a trigger depends on whether the table is used only for reading. If so, a read lock suffices. Otherwise, a write lock is used.

- If a table is locked explicitly for reading with `LOCK TABLES`, but needs to be locked for writing because it might be modified within a trigger, a write lock is taken rather than a read lock. (That is, an implicit write lock needed due to the table's appearance within a trigger causes an explicit read lock request for the table to be converted to a write lock request.)

Suppose that you lock two tables, `t1` and `t2`, using this statement:

```
LOCK TABLES t1 WRITE, t2 READ;
```

If `t1` or `t2` have any triggers, tables used within the triggers will also be locked. Suppose that `t1` has a trigger defined like this:

```
CREATE TRIGGER t1_a_ins AFTER INSERT ON t1 FOR EACH ROW
BEGIN
  UPDATE t4 SET count = count+1
      WHERE id = NEW.id AND EXISTS (SELECT a FROM t3);
```

```
  INSERT INTO t2 VALUES(1, 2);
END;
```

The result of the `LOCK TABLES` statement is that `t1` and `t2` are locked because they appear in the statement, and `t3` and `t4` are locked because they are used within the trigger:

- `t1` is locked for writing per the `WRITE` lock request.

- `t2` is locked for writing, even though the request is for a `READ` lock. This occurs because `t2` is inserted into within the trigger, so the `READ` request is converted to a `WRITE` request.

- `t3` is locked for reading because it is only read from within the trigger.

- `t4` is locked for writing because it might be updated within the trigger.

13.3.5.3 Table-Locking Restrictions and Conditions

You can safely use `KILL` to terminate a session that is waiting for a table lock. See Section 13.7.6.4, "KILL Syntax".

You should *not* lock any tables that you are using with `INSERT DELAYED`. An `INSERT DELAYED` in this case results in an error because the insert must be handled by a separate thread, not by the session which holds the lock.

`LOCK TABLES` and `UNLOCK TABLES` cannot be used within stored programs.

For some operations, system tables in the `mysql` database must be accessed. For example, the `HELP` statement requires the contents of the server-side help tables, and `CONVERT_TZ()` might need to read the time zone tables. Before MySQL 5.1.17, to perform such operations while a `LOCK TABLES` statement is in effect, you must also lock the requisite system tables explicitly or a lock error occurs. As of 5.1.17, the server implicitly locks the system tables for reading as necessary so that you need not lock them explicitly. These tables are treated as just described:

```
mysql.help_category
mysql.help_keyword
mysql.help_relation
mysql.help_topic
mysql.proc
mysql.time_zone
mysql.time_zone_leap_second
mysql.time_zone_name
mysql.time_zone_transition
mysql.time_zone_transition_type
```

If you want to explicitly place a `WRITE` lock on any of those tables with a `LOCK TABLES` statement, the table must be the only one locked; no other table can be locked with the same statement.

Normally, you do not need to lock tables, because all single `UPDATE` statements are atomic; no other session can interfere with any other currently executing SQL statement. However, there are a few cases when locking tables may provide an advantage:

- If you are going to run many operations on a set of `MyISAM` tables, it is much faster to lock the tables you are going to use. Locking `MyISAM` tables speeds up inserting, updating, or deleting on them because MySQL does not flush the key cache for the locked tables until `UNLOCK TABLES` is called. Normally, the key cache is flushed after each SQL statement.

  The downside to locking the tables is that no session can update a `READ`-locked table (including the one holding the lock) and no session can access a `WRITE`-locked table other than the one holding the lock.

- If you are using tables for a nontransactional storage engine, you must use `LOCK TABLES` if you want to ensure that no other session modifies the tables between a `SELECT` and an `UPDATE`. The example shown here requires `LOCK TABLES` to execute safely:

```
LOCK TABLES trans READ, customer WRITE;
SELECT SUM(value) FROM trans WHERE customer_id=some_id;
UPDATE customer
  SET total_value=sum_from_previous_statement
  WHERE customer_id=some_id;
UNLOCK TABLES;
```

Without `LOCK TABLES`, it is possible that another session might insert a new row in the `trans` table between execution of the `SELECT` and `UPDATE` statements.

You can avoid using `LOCK TABLES` in many cases by using relative updates (`UPDATE customer SET value=value+new_value`) or the `LAST_INSERT_ID()` function. See Section 1.8.2.3, "Transactions and Atomic Operations".

You can also avoid locking tables in some cases by using the user-level advisory lock functions `GET_LOCK()` and `RELEASE_LOCK()`. These locks are saved in a hash table in the server and implemented with `pthread_mutex_lock()` and `pthread_mutex_unlock()` for high speed. See Section 12.16, "Miscellaneous Functions".

See Section 8.11.1, "Internal Locking Methods", for more information on locking policy.

13.3.6 SET TRANSACTION Syntax

```
SET [GLOBAL | SESSION] TRANSACTION ISOLATION LEVEL
  {
       REPEATABLE READ
     | READ COMMITTED
     | READ UNCOMMITTED
     | SERIALIZABLE
  }
```

This statement sets the transaction isolation level, used for operations on `InnoDB` tables.

Scope of the Isolation Level

You can set the isolation level globally, for the current session, or for the next transaction:

- With the `GLOBAL` keyword, the statement sets the default transaction level globally for all subsequent sessions. Existing sessions are unaffected.

- With the `SESSION` keyword, the statement sets the default transaction level for all subsequent transactions performed within the current session.

- Without any `SESSION` or `GLOBAL` keyword, the statement sets the isolation level for the next (not started) transaction performed within the current session. Subsequent transactions revert to using the `SESSION` isolation level.

A change to the global default isolation level requires the `SUPER` privilege. Any session is free to change its session isolation level (even in the middle of a transaction), or the isolation level for its next transaction.

`SET TRANSACTION ISOLATION LEVEL` without `GLOBAL` or `SESSION` is not permitted while there is an active transaction:

```
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.02 sec)

mysql> SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
ERROR 1568 (25001): Transaction isolation level can't be changed
while a transaction is in progress
```

To set the global default isolation level at server startup, use the `--transaction-isolation=level` option to `mysqld` on the command line or in an option file. Values of `level` for this option use dashes than spaces, so the permissible values are `READ-UNCOMMITTED`, `READ-COMMITTED`, `REPEATABLE-READ`, or `SERIALIZABLE`. For example, to set the default isolation level to `REPEATABLE READ`, use these lines in the `[mysqld]` section of an option file:

```
[mysqld]
transaction-isolation = REPEATABLE-READ
```

It is possible to check or set the global and session transaction isolation levels at runtime by using the `tx_isolation` system variable:

```
SELECT @@GLOBAL.tx_isolation, @@tx_isolation;
SET GLOBAL tx_isolation='REPEATABLE-READ';
SET SESSION tx_isolation='SERIALIZABLE';
```

Details and Usage of Isolation Levels

`InnoDB` supports each of the transaction isolation levels described here using different locking strategies. You can enforce a high degree of consistency with the default `REPEATABLE READ` level, for operations on crucial data where ACID compliance is important. Or you can relax the consistency rules with `READ COMMITTED` or even `READ UNCOMMITTED`, in situations such as bulk reporting where precise consistency and repeatable results are less important than minimizing the amount of overhead for locking. `SERIALIZABLE` enforces even stricter rules than `REPEATABLE READ`, and is used mainly in specialized situations, such as with XA transactions and for troubleshooting issues with concurrency and deadlocks.

The following list describes how MySQL supports the different transaction levels. The list goes from the most commonly used level to the least used.

- `REPEATABLE READ`

  This is the default isolation level for `InnoDB`. For consistent reads, there is an important difference from the `READ COMMITTED` isolation level: All consistent reads within the same transaction read the snapshot established by the first read. This convention means that if you issue several plain (nonlocking) `SELECT` statements within the same transaction, these `SELECT` statements are consistent also with respect to each other. See Section 14.6.4.4, "Consistent Nonlocking Reads".

  For locking reads (`SELECT` with `FOR UPDATE` or `LOCK IN SHARE MODE`), `UPDATE`, and `DELETE` statements, locking depends on whether the statement uses a unique index with a unique search condition, or a range-type search condition. For a unique index with a unique search condition, `InnoDB` locks only the index record found, not the gap before it. For other search conditions, `InnoDB` locks the index range scanned, using gap locks or next-key (gap plus index-record) locks to block insertions by other sessions into the gaps covered by the range.

- `READ COMMITTED`

  A somewhat Oracle-like isolation level with respect to consistent (nonlocking) reads: Each consistent read, even within the same transaction, sets and reads its own fresh snapshot. See Section 14.6.4.4, "Consistent Nonlocking Reads".

For locking reads (`SELECT` with `FOR UPDATE` or `LOCK IN SHARE MODE`), `UPDATE` statements, and `DELETE` statements, `InnoDB` locks only index records, not the gaps before them, and thus permits the free insertion of new records next to locked records.

> **Note**
>
> In MySQL 5.1, when `READ COMMITTED` isolation level is used or the `innodb_locks_unsafe_for_binlog` system variable is enabled, there is no `InnoDB` gap locking except for foreign-key constraint checking and duplicate-key checking. Also, record locks for nonmatching rows are released after MySQL has evaluated the `WHERE` condition.
>
> As of MySQL 5.1, if you use `READ COMMITTED` or enable `innodb_locks_unsafe_for_binlog`, you *must* use row-based binary logging.

- `READ UNCOMMITTED`

  `SELECT` statements are performed in a nonlocking fashion, but a possible earlier version of a row might be used. Thus, using this isolation level, such reads are not consistent. This is also called a "dirty read." Otherwise, this isolation level works like `READ COMMITTED`.

- `SERIALIZABLE`

  This level is like `REPEATABLE READ`, but `InnoDB` implicitly converts all plain `SELECT` statements to `SELECT ... LOCK IN SHARE MODE` if `autocommit` is disabled. If `autocommit` is enabled, the `SELECT` is its own transaction. It therefore is known to be read only and can be serialized if performed as a consistent (nonlocking) read and need not block for other transactions. (To force a plain `SELECT` to block if other transactions have modified the selected rows, disable `autocommit`.)

For additional information about isolation levels and `InnoDB` transactions, see Section 14.6.4, "InnoDB Transaction Model and Locking".

13.3.7 XA Transactions

Support for XA transactions is available for the `InnoDB` storage engine. The MySQL XA implementation is based on the X/Open CAE document *Distributed Transaction Processing: The XA Specification*. This document is published by The Open Group and available at http://www.opengroup.org/public/pubs/catalog/c193.htm. Limitations of the current XA implementation are described in Section C.5, "Restrictions on XA Transactions".

On the client side, there are no special requirements. The XA interface to a MySQL server consists of SQL statements that begin with the `XA` keyword. MySQL client programs must be able to send SQL statements and to understand the semantics of the XA statement interface. They do not need be linked against a recent client library. Older client libraries also will work.

Among the MySQL Connectors, MySQL Connector/J 5.0.0 supports XA directly (by means of a class interface that handles the XA SQL statement interface for you).

XA supports distributed transactions, that is, the ability to permit multiple separate transactional resources to participate in a global transaction. Transactional resources often are RDBMSs but may be other kinds of resources.

A global transaction involves several actions that are transactional in themselves, but that all must either complete successfully as a group, or all be rolled back as a group. In essence, this extends ACID

properties "up a level" so that multiple ACID transactions can be executed in concert as components of a global operation that also has ACID properties. (As with nondistributed transactions, `SERIALIZABLE` may be preferred if your applications are sensitive to read phenomena. `REPEATABLE READ` may not be sufficient for distributed transactions.)

Some examples of distributed transactions:

- An application may act as an integration tool that combines a messaging service with an RDBMS. The application makes sure that transactions dealing with message sending, retrieval, and processing that also involve a transactional database all happen in a global transaction. You can think of this as "transactional email."

- An application performs actions that involve different database servers, such as a MySQL server and an Oracle server (or multiple MySQL servers), where actions that involve multiple servers must happen as part of a global transaction, rather than as separate transactions local to each server.

- A bank keeps account information in an RDBMS and distributes and receives money through automated teller machines (ATMs). It is necessary to ensure that ATM actions are correctly reflected in the accounts, but this cannot be done with the RDBMS alone. A global transaction manager integrates the ATM and database resources to ensure overall consistency of financial transactions.

Applications that use global transactions involve one or more Resource Managers and a Transaction Manager:

- A Resource Manager (RM) provides access to transactional resources. A database server is one kind of resource manager. It must be possible to either commit or roll back transactions managed by the RM.

- A Transaction Manager (TM) coordinates the transactions that are part of a global transaction. It communicates with the RMs that handle each of these transactions. The individual transactions within a global transaction are "branches" of the global transaction. Global transactions and their branches are identified by a naming scheme described later.

The MySQL implementation of XA MySQL enables a MySQL server to act as a Resource Manager that handles XA transactions within a global transaction. A client program that connects to the MySQL server acts as the Transaction Manager.

To carry out a global transaction, it is necessary to know which components are involved, and bring each component to a point when it can be committed or rolled back. Depending on what each component reports about its ability to succeed, they must all commit or roll back as an atomic group. That is, either all components must commit, or all components must roll back. To manage a global transaction, it is necessary to take into account that any component or the connecting network might fail.

The process for executing a global transaction uses two-phase commit (2PC). This takes place after the actions performed by the branches of the global transaction have been executed.

1. In the first phase, all branches are prepared. That is, they are told by the TM to get ready to commit. Typically, this means each RM that manages a branch records the actions for the branch in stable storage. The branches indicate whether they are able to do this, and these results are used for the second phase.

2. In the second phase, the TM tells the RMs whether to commit or roll back. If all branches indicated when they were prepared that they will be able to commit, all branches are told to commit. If any branch indicated when it was prepared that it will not be able to commit, all branches are told to roll back.

In some cases, a global transaction might use one-phase commit (1PC). For example, when a Transaction Manager finds that a global transaction consists of only one transactional resource (that is, a single branch), that resource can be told to prepare and commit at the same time.

13.3.7.1 XA Transaction SQL Syntax

To perform XA transactions in MySQL, use the following statements:

```
XA {START|BEGIN} xid [JOIN|RESUME]

XA END xid [SUSPEND [FOR MIGRATE]]

XA PREPARE xid

XA COMMIT xid [ONE PHASE]

XA ROLLBACK xid

XA RECOVER
```

For `XA START`, the `JOIN` and `RESUME` clauses are not supported.

For `XA END` the `SUSPEND [FOR MIGRATE]` clause is not supported.

Each XA statement begins with the `XA` keyword, and most of them require an `xid` value. An `xid` is an XA transaction identifier. It indicates which transaction the statement applies to. `xid` values are supplied by the client, or generated by the MySQL server. An `xid` value has from one to three parts:

```
xid: gtrid [, bqual [, formatID ]]
```

`gtrid` is a global transaction identifier, `bqual` is a branch qualifier, and `formatID` is a number that identifies the format used by the `gtrid` and `bqual` values. As indicated by the syntax, `bqual` and `formatID` are optional. The default `bqual` value is `''` if not given. The default `formatID` value is 1 if not given.

`gtrid` and `bqual` must be string literals, each up to 64 bytes (not characters) long. `gtrid` and `bqual` can be specified in several ways. You can use a quoted string (`'ab'`), hex string (`X'6162'`, `0x6162`), or bit value (`b'nnnn'`).

`formatID` is an unsigned integer.

The `gtrid` and `bqual` values are interpreted in bytes by the MySQL server's underlying XA support routines. However, while an SQL statement containing an XA statement is being parsed, the server works with some specific character set. To be safe, write `gtrid` and `bqual` as hex strings.

`xid` values typically are generated by the Transaction Manager. Values generated by one TM must be different from values generated by other TMs. A given TM must be able to recognize its own `xid` values in a list of values returned by the `XA RECOVER` statement.

For `XA START xid` starts an XA transaction with the given `xid` value. Each XA transaction must have a unique `xid` value, so the value must not currently be used by another XA transaction. Uniqueness is assessed using the `gtrid` and `bqual` values. All following XA statements for the XA transaction must be specified using the same `xid` value as that given in the `XA START` statement. If you use any of those statements but specify an `xid` value that does not correspond to some existing XA transaction, an error occurs.

One or more XA transactions can be part of the same global transaction. All XA transactions within a given global transaction must use the same `gtrid` value in the `xid` value. For this reason, `gtrid` values must be globally unique so that there is no ambiguity about which global transaction a given XA transaction is part of. The `bqual` part of the `xid` value must be different for each XA transaction within a global transaction. (The requirement that `bqual` values be different is a limitation of the current MySQL XA implementation. It is not part of the XA specification.)

The `XA RECOVER` statement returns information for those XA transactions on the MySQL server that are in the `PREPARED` state. (See Section 13.3.7.2, "XA Transaction States".) The output includes a row for each such XA transaction on the server, regardless of which client started it.

`XA RECOVER` output rows look like this (for an example `xid` value consisting of the parts `'abc'`, `'def'`, and `7`):

```
mysql> XA RECOVER;
+----------+--------------+--------------+--------+
| formatID | gtrid_length | bqual_length | data   |
+----------+--------------+--------------+--------+
|        7 |            3 |            3 | abcdef |
+----------+--------------+--------------+--------+
```

The output columns have the following meanings:

- `formatID` is the `formatID` part of the transaction `xid`

- `gtrid_length` is the length in bytes of the `gtrid` part of the `xid`

- `bqual_length` is the length in bytes of the `bqual` part of the `xid`

- `data` is the concatenation of the `gtrid` and `bqual` parts of the `xid`

13.3.7.2 XA Transaction States

An XA transaction progresses through the following states:

1. Use `XA START` to start an XA transaction and put it in the `ACTIVE` state.

2. For an `ACTIVE` XA transaction, issue the SQL statements that make up the transaction, and then issue an `XA END` statement. `XA END` puts the transaction in the `IDLE` state.

3. For an `IDLE` XA transaction, you can issue either an `XA PREPARE` statement or an `XA COMMIT ... ONE PHASE` statement:

   - `XA PREPARE` puts the transaction in the `PREPARED` state. An `XA RECOVER` statement at this point will include the transaction's `xid` value in its output, because `XA RECOVER` lists all XA transactions that are in the `PREPARED` state.

   - `XA COMMIT ... ONE PHASE` prepares and commits the transaction. The `xid` value will not be listed by `XA RECOVER` because the transaction terminates.

4. For a `PREPARED` XA transaction, you can issue an `XA COMMIT` statement to commit and terminate the transaction, or `XA ROLLBACK` to roll back and terminate the transaction.

Here is a simple XA transaction that inserts a row into a table as part of a global transaction:

```
mysql> XA START 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO mytable (i) VALUES(10);
Query OK, 1 row affected (0.04 sec)

mysql> XA END 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> XA PREPARE 'xatest';
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> XA COMMIT 'xatest';
Query OK, 0 rows affected (0.00 sec)
```

Within the context of a given client connection, XA transactions and local (non-XA) transactions are mutually exclusive. For example, if `XA START` has been issued to begin an XA transaction, a local transaction cannot be started until the XA transaction has been committed or rolled back. Conversely, if a local transaction has been started with `START TRANSACTION`, no XA statements can be used until the transaction has been committed or rolled back.

If an XA transaction is in the `ACTIVE` state, you cannot issue any statements that cause an implicit commit. That would violate the XA contract because you could not roll back the XA transaction. You will receive the following error if you try to execute such a statement:

```
ERROR 1399 (XAE07): XAER_RMFAIL: The command cannot be executed
when global transaction is in the ACTIVE state
```

Statements to which the preceding remark applies are listed at Section 13.3.3, "Statements That Cause an Implicit Commit".

13.4 Replication Statements

Replication can be controlled through the SQL interface using the statements described in this section. One group of statements controls master servers, the other controls slave servers.

13.4.1 SQL Statements for Controlling Master Servers

This section discusses statements for managing master replication servers. Section 13.4.2, "SQL Statements for Controlling Slave Servers", discusses statements for managing slave servers.

In addition to the statements described here, the following `SHOW` statements are used with master servers in replication. For information about these statements, see Section 13.7.5, "SHOW Syntax".

- `SHOW BINARY LOGS`

- `SHOW BINLOG EVENTS`

- `SHOW MASTER STATUS`

- `SHOW SLAVE HOSTS`

13.4.1.1 PURGE BINARY LOGS Syntax

```
PURGE { BINARY | MASTER } LOGS
    { TO 'log_name' | BEFORE datetime_expr }
```

The binary log is a set of files that contain information about data modifications made by the MySQL server. The log consists of a set of binary log files, plus an index file (see Section 5.4.4, "The Binary Log").

The `PURGE BINARY LOGS` statement deletes all the binary log files listed in the log index file prior to the specified log file name or date. `BINARY` and `MASTER` are synonyms. Deleted log files also are removed from the list recorded in the index file, so that the given log file becomes the first in the list.

This statement has no effect if the server was not started with the `--log-bin` option to enable binary logging.

Examples:

```
PURGE BINARY LOGS TO 'mysql-bin.010';
PURGE BINARY LOGS BEFORE '2008-04-02 22:46:26';
```

The `BEFORE` variant's *datetime_expr* argument should evaluate to a `DATETIME` value (a value in `'YYYY-MM-DD hh:mm:ss'` format).

This statement is safe to run while slaves are replicating. You need not stop them. If you have an active slave that currently is reading one of the log files you are trying to delete, this statement does nothing and fails with an error. However, if a slave is not connected and you happen to purge one of the log files it has yet to read, the slave will be unable to replicate after it reconnects.

To safely purge binary log files, follow this procedure:

1. On each slave server, use `SHOW SLAVE STATUS` to check which log file it is reading.

2. Obtain a listing of the binary log files on the master server with `SHOW BINARY LOGS`.

3. Determine the earliest log file among all the slaves. This is the target file. If all the slaves are up to date, this is the last log file on the list.

4. Make a backup of all the log files you are about to delete. (This step is optional, but always advisable.)

5. Purge all log files up to but not including the target file.

You can also set the `expire_logs_days` system variable to expire binary log files automatically after a given number of days (see Section 5.1.4, "Server System Variables"). If you are using replication, you should set the variable no lower than the maximum number of days your slaves might lag behind the master.

Prior to MySQL 5.1.24, `PURGE BINARY LOGS TO` and `PURGE BINARY LOGS BEFORE` did not behave in the same way (and neither one behaved correctly) when binary log files listed in the `.index` file had been removed from the system by some other means (such as using `rm` on Linux). Beginning with MySQL 5.1.24, both variants of the statement fail with an error in such cases. (Bug #18199, Bug #18453) To handle such errors, edit the `.index` file (which is a simple text file) manually to ensure that it lists only the binary log files that are actually present, then run again the `PURGE BINARY LOGS` statement that failed.

13.4.1.2 RESET MASTER Syntax

```
RESET MASTER
```

Deletes all binary log files listed in the index file, resets the binary log index file to be empty, and creates a new binary log file. This statement is intended to be used only when the master is started for the first time.

> **Important**
>
> The effects of `RESET MASTER` differ from those of `PURGE BINARY LOGS` in 2 key ways:
>
> 1. `RESET MASTER` removes *all* binary log files that are listed in the index file, leaving only a single, empty binary log file with a numeric suffix of `.000001`, whereas the numbering is not reset by `PURGE BINARY LOGS`.
>
> 2. `RESET MASTER` is *not* intended to be used while any replication slaves are running. The behavior of `RESET MASTER` when used while slaves are running is undefined (and thus unsupported), whereas `PURGE BINARY LOGS` may be safely used while replication slaves are running.

> See also Section 13.4.1.1, "PURGE BINARY LOGS Syntax".

`RESET MASTER` can prove useful when you first set up the master and the slave, so that you can verify the setup as follows:

1. Start the master and slave, and start replication (see Section 16.1.1, "How to Set Up Replication").

2. Execute a few test queries on the master.

3. Check that the queries were replicated to the slave.

4. When replication is running correctly, issue `STOP SLAVE` followed by `RESET SLAVE` on the slave, then verify that any unwanted data no longer exists on the slave.

5. Issue `RESET MASTER` on the master to clean up the test queries.

After verifying the setup and getting rid of any unwanted and log files generated by testing, you can start the slave and begin replicating.

13.4.1.3 SET sql_log_bin Syntax

```
SET sql_log_bin = {0|1}
```

Disables or enables binary logging for the current session (`sql_log_bin` is a session variable) if the client has the `SUPER` privilege. The statement fails with an error if the client does not have that privilege.

13.4.2 SQL Statements for Controlling Slave Servers

This section discusses statements for managing slave replication servers. Section 13.4.1, "SQL Statements for Controlling Master Servers", discusses statements for managing master servers.

In addition to the statements described here, `SHOW SLAVE STATUS` is also used with replication slaves. For information about this statement, see Section 13.7.5.36, "SHOW SLAVE STATUS Syntax".

13.4.2.1 CHANGE MASTER TO Syntax

```
CHANGE MASTER TO option [, option] ...

option:
    MASTER_BIND = 'interface_name'
  | MASTER_HOST = 'host_name'
  | MASTER_USER = 'user_name'
  | MASTER_PASSWORD = 'password'
  | MASTER_PORT = port_num
  | MASTER_CONNECT_RETRY = interval
  | MASTER_HEARTBEAT_PERIOD = interval
  | MASTER_LOG_FILE = 'master_log_name'
  | MASTER_LOG_POS = master_log_pos
  | RELAY_LOG_FILE = 'relay_log_name'
  | RELAY_LOG_POS = relay_log_pos
  | MASTER_SSL = {0|1}
  | MASTER_SSL_CA = 'ca_file_name'
  | MASTER_SSL_CAPATH = 'ca_directory_name'
  | MASTER_SSL_CERT = 'cert_file_name'
  | MASTER_SSL_KEY = 'key_file_name'
  | MASTER_SSL_CIPHER = 'cipher_list'
  | MASTER_SSL_VERIFY_SERVER_CERT = {0|1}
```

```
    | IGNORE_SERVER_IDS = (server_id_list)

server_id_list:
    [server_id [, server_id] ... ]
```

`CHANGE MASTER TO` changes the parameters that the slave server uses for connecting to the master server, for reading the master binary log, and reading the slave relay log. It also updates the contents of the `master.info` and `relay-log.info` files. To use `CHANGE MASTER TO`, the slave replication threads must be stopped (use `STOP SLAVE` if necessary).

Options not specified retain their value, except as indicated in the following discussion. Thus, in most cases, there is no need to specify options that do not change. For example, if the password to connect to your MySQL master has changed, you just need to issue these statements to tell the slave about the new password:

```
STOP SLAVE; -- if replication was running
CHANGE MASTER TO MASTER_PASSWORD='new3cret';
START SLAVE; -- if you want to restart replication
```

`MASTER_HOST`, `MASTER_USER`, `MASTER_PASSWORD`, and `MASTER_PORT` provide information to the slave about how to connect to its master:

- `MASTER_HOST` and `MASTER_PORT` are the host name (or IP address) of the master host and its TCP/IP port.

  > **Note**
  >
  > Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

  If you specify the `MASTER_HOST` or `MASTER_PORT` option, the slave assumes that the master server is different from before (even if the option value is the same as its current value.) In this case, the old values for the master binary log file name and position are considered no longer applicable, so if you do not specify `MASTER_LOG_FILE` and `MASTER_LOG_POS` in the statement, `MASTER_LOG_FILE=''` and `MASTER_LOG_POS=4` are silently appended to it.

  Setting `MASTER_HOST=''` (that is, setting its value explicitly to an empty string) is *not* the same as not setting `MASTER_HOST` at all. Setting this option to an empty string causes `START SLAVE` subsequently to fail. This issue is addressed in MySQL 5.5. (Bug #28796)

- `MASTER_USER` and `MASTER_PASSWORD` are the user name and password of the account to use for connecting to the master.

  The password used for a MySQL Replication slave account in a `CHANGE MASTER TO` statement is limited to 32 characters in length; if the password is longer, the statement succeeds, but any excess characters are silently truncated. This is an issue specific to MySQL Replication, which is fixed in MySQL 5.7. (Bug #11752299, Bug #43439)

  The text of a running `CHANGE MASTER TO` statement, including values for `MASTER_USER` and `MASTER_PASSWORD`, can be seen in the output of a concurrent `SHOW PROCESSLIST` statement.

The `MASTER_SSL_xxx` options provide information about using SSL for the connection. They correspond to the `--ssl-xxx` options described in Section 6.4.5, "Command Options for Secure Connections", and Section 16.3.7, "Setting Up Replication to Use Secure Connections". `MASTER_SSL_VERIFY_SERVER_CERT` was added in MySQL 5.1.18. These options can be changed even on slaves that are compiled without SSL support. They are saved to the `master.info` file, but are ignored if the slave does not have SSL support enabled.

MASTER_CONNECT_RETRY specifies how many seconds to wait between connect retries. The default is 60. The *number* of reconnection attempts is limited by the --master-retry-count server option; for more information, see Section 16.1.3, "Replication and Binary Logging Options and Variables".

The next two options (MASTER_BIND and MASTER_HEARTBEAT_PERIOD) are available in MySQL Cluster NDB 6.3 and later, but are not supported in mainline MySQL 5.1:

MASTER_BIND is for use on replication slaves having multiple network interfaces, and determines which of the slave's network interfaces is chosen for connecting to the master.

The ability to bind a replication slave to specific network interface was added in MySQL Cluster NDB 6.3.4.

MASTER_HEARTBEAT_PERIOD sets the interval in seconds between replication heartbeats. Whenever the master's binary log is updated with an event, the waiting period for the next heartbeat is reset. *interval* is a decimal value having the range 0 to 4294967 seconds and a resolution in milliseconds; the smallest nonzero value is 0.001. Heartbeats are sent by the master only if there are no unsent events in the binary log file for a period longer than *interval*.

Setting *interval* to 0 disables heartbeats altogether. The default value for *interval* is equal to the value of slave_net_timeout divided by 2.

Setting @@global.slave_net_timeout to a value less than that of the current heartbeat interval results in a warning being issued. The effect of issuing RESET SLAVE on the heartbeat interval is to reset it to the default value.

MASTER_HEARTBEAT_PERIOD was added in MySQL Cluster NDB 6.3.4.

MASTER_LOG_FILE and MASTER_LOG_POS are the coordinates at which the slave I/O thread should begin reading from the master the next time the thread starts. RELAY_LOG_FILE and RELAY_LOG_POS are the coordinates at which the slave SQL thread should begin reading from the relay log the next time the thread starts. If you specify either of MASTER_LOG_FILE or MASTER_LOG_POS, you cannot specify RELAY_LOG_FILE or RELAY_LOG_POS. If neither of MASTER_LOG_FILE or MASTER_LOG_POS is specified, the slave uses the last coordinates of the *slave SQL thread* before CHANGE MASTER TO was issued. This ensures that there is no discontinuity in replication, even if the slave SQL thread was late compared to the slave I/O thread, when you merely want to change, say, the password to use.

CHANGE MASTER TO *deletes all relay log files* and starts a new one, unless you specify RELAY_LOG_FILE or RELAY_LOG_POS. In that case, relay log files are kept; the relay_log_purge global variable is set silently to 0.

IGNORE_SERVER_IDS was added in MySQL Cluster NDB 6.1.29, MySQL Cluster NDB 6.3.31, MySQL Cluster NDB 7.0.11, and MySQL Cluster NDB 7.1.0 (see Bug #47037). This option takes a comma-separated list of 0 or more server IDs. Events originating from the corresponding servers are ignored, with the exception of log rotation and deletion events, which are still recorded in the relay log.

In circular replication, the originating server normally acts as the terminator of its own events, so that they are not applied more than once. Thus, this option is useful in circular replication when one of the servers in the circle is removed. Suppose that you have a circular replication setup with 4 servers, having server IDs 1, 2, 3, and 4, and server 3 fails. When bridging the gap by starting replication from server 2 to server 4, you can include IGNORE_SERVER_IDS = (3) in the CHANGE MASTER TO statement that you issue on server 4 to tell it to use server 2 as its master instead of server 3. Doing so causes it to ignore and not to propagate any statements that originated with the server that is no longer in use.

If a CHANGE MASTER TO statement is issued without any IGNORE_SERVER_IDS option, any existing list is preserved; RESET SLAVE also has no effect on the server ID list. To clear the list of ignored servers, it is necessary to use the option with an empty list:

```
CHANGE MASTER TO IGNORE_SERVER_IDS = ();
```

If `IGNORE_SERVER_IDS` contains the server's own ID and the server was started with the `--replicate-same-server-id` option enabled, an error results.

Beginning with MySQL 5.1.47, invoking `CHANGE MASTER TO` causes the previous values for `MASTER_HOST`, `MASTER_PORT`, `MASTER_LOG_FILE`, and `MASTER_LOG_POS` to be written to the error log, along with other information about the slave's state prior to execution.

`CHANGE MASTER TO` is useful for setting up a slave when you have the snapshot of the master and have recorded the master binary log coordinates corresponding to the time of the snapshot. After loading the snapshot into the slave to synchronize it with the master, you can run `CHANGE MASTER TO MASTER_LOG_FILE='log_name', MASTER_LOG_POS=log_pos` on the slave to specify the coordinates at which the slave should begin reading the master binary log.

The following example changes the master server the slave uses and establishes the master binary log coordinates from which the slave begins reading. This is used when you want to set up the slave to replicate the master:

```
CHANGE MASTER TO
  MASTER_HOST='master2.mycompany.com',
  MASTER_USER='replication',
  MASTER_PASSWORD='bigs3cret',
  MASTER_PORT=3306,
  MASTER_LOG_FILE='master2-bin.001',
  MASTER_LOG_POS=4,
  MASTER_CONNECT_RETRY=10;
```

The next example shows an operation that is less frequently employed. It is used when the slave has relay log files that you want it to execute again for some reason. To do this, the master need not be reachable. You need only use `CHANGE MASTER TO` and start the SQL thread (`START SLAVE SQL_THREAD`):

```
CHANGE MASTER TO
  RELAY_LOG_FILE='slave-relay-bin.006',
  RELAY_LOG_POS=4025;
```

You can even use the second operation in a nonreplication setup with a standalone, nonslave server for recovery following a crash. Suppose that your server has crashed and you have restored it from a backup. You want to replay the server's own binary log files (not relay log files, but regular binary log files), named (for example) `myhost-bin.*`. First, make a backup copy of these binary log files in some safe place, in case you don't exactly follow the procedure below and accidentally have the server purge the binary log. Use `SET GLOBAL relay_log_purge=0` for additional safety. Then start the server without the `--log-bin` option, Instead, use the `--replicate-same-server-id`, `--relay-log=myhost-bin` (to make the server believe that these regular binary log files are relay log files) and `--skip-slave-start` options. After the server starts, issue these statements:

```
CHANGE MASTER TO
  RELAY_LOG_FILE='myhost-bin.153',
  RELAY_LOG_POS=410,
  MASTER_HOST='some_dummy_string';
START SLAVE SQL_THREAD;
```

The server reads and executes its own binary log files, thus achieving crash recovery. Once the recovery is finished, run `STOP SLAVE`, shut down the server, delete the `master.info` and `relay-log.info` files, and restart the server with its original options.

Specifying the `MASTER_HOST` option (even with a dummy value) is required to make the server think it is a slave.

The following table shows the maximum permissible length for the string-valued options.

Option	Maximum Length
`MASTER_HOST`	60
`MASTER_USER`	16
`MASTER_PASSWORD`	32
`MASTER_LOG_FILE`	255
`RELAY_LOG_FILE`	255
`MASTER_SSL_CA`	255
`MASTER_SSL_CAPATH`	255
`MASTER_SSL_CERT`	255
`MASTER_SSL_KEY`	255
`MASTER_SSL_CIPHER`	511

13.4.2.2 LOAD DATA FROM MASTER Syntax

```
LOAD DATA FROM MASTER
```

Note

This feature is deprecated and should be avoided. It is subject to removal in a future version of MySQL.

Since the current implementation of `LOAD DATA FROM MASTER` and `LOAD TABLE FROM MASTER` is very limited, these statements are deprecated as of MySQL 4.1 and removed in MySQL 5.5.

The recommended alternative solution to using `LOAD DATA FROM MASTER` or `LOAD TABLE FROM MASTER` is using `mysqldump` or `mysqlhotcopy`. The latter requires Perl and two Perl modules (`DBI` and `DBD:mysql`) and works for `MyISAM` and `ARCHIVE` tables only. With `mysqldump`, you can create SQL dumps on the master and pipe (or copy) these to a `mysql` client on the slave. This has the advantage of working for all storage engines, but can be quite slow, since it works using `SELECT`.

This statement takes a snapshot of the master and copies it to the slave. It updates the values of `MASTER_LOG_FILE` and `MASTER_LOG_POS` so that the slave starts replicating from the correct position. Any table and database exclusion rules specified with the `--replicate-*-do-*` and `--replicate-*-ignore-*` options are honored. `--replicate-rewrite-db` is *not* taken into account because a user could use this option to set up a nonunique mapping such as `--replicate-rewrite-db="db1->db3"` and `--replicate-rewrite-db="db2->db3"`, which would confuse the slave when loading tables from the master.

Use of this statement is subject to the following conditions:

- It works only for `MyISAM` tables. Attempting to load a non-`MyISAM` table results in the following error:

  ```
  ERROR 1189 (08S01): Net error reading from master
  ```

- It acquires a global read lock on the master while taking the snapshot, which prevents updates on the master during the load operation.

If you are loading large tables, you might have to increase the values of `net_read_timeout` and `net_write_timeout` on both the master and slave servers. See Section 5.1.4, "Server System Variables".

`LOAD DATA FROM MASTER` does *not* copy any tables from the `mysql` database. This makes it easy to have different users and privileges on the master and the slave.

To use `LOAD DATA FROM MASTER`, the replication account that is used to connect to the master must have the `RELOAD` and `SUPER` privileges on the master and the `SELECT` privilege for all master tables you want to load. All master tables for which the user does not have the `SELECT` privilege are ignored by `LOAD DATA FROM MASTER`. This is because the master hides them from the user: `LOAD DATA FROM MASTER` calls `SHOW DATABASES` to know the master databases to load, but `SHOW DATABASES` returns only databases for which the user has some privilege. See Section 13.7.5.15, "SHOW DATABASES Syntax". On the slave side, the user that issues `LOAD DATA FROM MASTER` must have privileges for dropping and creating the databases and tables that are copied.

13.4.2.3 LOAD TABLE tbl_name FROM MASTER Syntax

```
LOAD TABLE tbl_name FROM MASTER
```

> **Note**
>
> This feature is deprecated and should be avoided. It is subject to removal in a future version of MySQL.

Since the current implementation of `LOAD DATA FROM MASTER` and `LOAD TABLE FROM MASTER` is very limited, these statements are deprecated as of MySQL 4.1 and removed in MySQL 5.5.

The recommended alternative solution to using `LOAD DATA FROM MASTER` or `LOAD TABLE FROM MASTER` is using `mysqldump` or `mysqlhotcopy`. The latter requires Perl and two Perl modules (`DBI` and `DBD:mysql`) and works for `MyISAM` and `ARCHIVE` tables only. With `mysqldump`, you can create SQL dumps on the master and pipe (or copy) these to a `mysql` client on the slave. This has the advantage of working for all storage engines, but can be quite slow, since it works using `SELECT`.

Transfers a copy of the table from the master to the slave. This statement is implemented mainly debugging `LOAD DATA FROM MASTER` operations. To use `LOAD TABLE`, the account used for connecting to the master server must have the `RELOAD` and `SUPER` privileges on the master and the `SELECT` privilege for the master table to load. On the slave side, the user that issues `LOAD TABLE FROM MASTER` must have privileges for dropping and creating the table.

The conditions for `LOAD DATA FROM MASTER` apply here as well. For example, `LOAD TABLE FROM MASTER` works only for `MyISAM` tables. The timeout notes for `LOAD DATA FROM MASTER` apply as well.

13.4.2.4 MASTER_POS_WAIT() Syntax

```
SELECT MASTER_POS_WAIT('master_log_file', master_log_pos [, timeout])
```

This is actually a function, not a statement. It is used to ensure that the slave has read and executed events up to a given position in the master's binary log. See Section 12.16, "Miscellaneous Functions", for a full description.

13.4.2.5 RESET SLAVE Syntax

```
RESET SLAVE
```

RESET SLAVE makes the slave forget its replication position in the master's binary log. This statement is meant to be used for a clean start: It deletes the `master.info` and `relay-log.info` files, all the relay log files, and starts a new relay log file. To use RESET SLAVE, the slave replication threads must be stopped (use STOP SLAVE if necessary).

> **Note**
>
> All relay log files are deleted, even if they have not been completely executed by the slave SQL thread. (This is a condition likely to exist on a replication slave if you have issued a STOP SLAVE statement or if the slave is highly loaded.)

If any startup options for setting connection parameters (such as master host, master port, master user, and master password) are in use, then any corresponding connection information stored in the `master.info` file is immediately reset using the values specified for these options. Options for which values are not specified are cleared. However, since these options are deprecated in MySQL 5.1 and removed altogether from MySQL 5.5, you are encouraged to use a CHANGE MASTER TO statement instead to reset the connection parameters. (If you do not use the startup options, you must issue CHANGE MASTER TO in such cases if you do not want the connection settings to be cleared.)

If the slave SQL thread was in the middle of replicating temporary tables when it was stopped, and RESET SLAVE is issued, these replicated temporary tables are deleted on the slave.

> **Note**
>
> When used on a MySQL Cluster replication slave SQL node, RESET SLAVE clears the `mysql.ndb_apply_status` table. You should keep in mind when using this statement that `ndb_apply_status` uses the NDB storage engine and so is shared by all SQL nodes attached to the slave cluster.

13.4.2.6 SET GLOBAL sql_slave_skip_counter Syntax

```
SET GLOBAL sql_slave_skip_counter = N
```

This statement skips the next N events from the master. This is useful for recovering from replication stops caused by a statement.

This statement is valid only when the slave threads are not running. Otherwise, it produces an error.

When using this statement, it is important to understand that the binary log is actually organized as a sequence of groups known as *event groups*. Each event group consists of a sequence of events.

- For transactional tables, an event group corresponds to a transaction.

- For nontransactional tables, an event group corresponds to a single SQL statement.

> **Note**
>
> A single transaction can contain changes to both transactional and nontransactional tables.

When you use SET GLOBAL sql_slave_skip_counter to skip events and the result is in the middle of a group, the slave continues to skip events until it reaches the end of the group. Execution then starts with the next event group.

Beginning with MySQL 5.1.47, issuing this statement causes the previous values of `RELAY_LOG_FILE`, `RELAY_LOG_POS`, and `sql_slave_skip_counter` to be written to the error log.

13.4.2.7 START SLAVE Syntax

```
START SLAVE [thread_types]

START SLAVE [SQL_THREAD] UNTIL
    MASTER_LOG_FILE = 'log_name', MASTER_LOG_POS = log_pos

START SLAVE [SQL_THREAD] UNTIL
    RELAY_LOG_FILE = 'log_name', RELAY_LOG_POS = log_pos

thread_types:
    [thread_type [, thread_type] ... ]

thread_type: IO_THREAD | SQL_THREAD
```

`START SLAVE` with no `thread_type` options starts both of the slave threads. The I/O thread reads events from the master server and stores them in the relay log. The SQL thread reads events from the relay log and executes them. `START SLAVE` requires the `SUPER` privilege.

If `START SLAVE` succeeds in starting the slave threads, it returns without any error. However, even in that case, it might be that the slave threads start and then later stop (for example, because they do not manage to connect to the master or read its binary log, or some other problem). `START SLAVE` does not warn you about this. You must check the slave's error log for error messages generated by the slave threads, or check that they are running satisfactorily with `SHOW SLAVE STATUS`.

`START SLAVE` sends an acknowledgment to the user after both the I/O thread and the SQL thread have started. However, the I/O thread may not yet have connected. For this reason, a successful `START SLAVE` causes `SHOW SLAVE STATUS` to show `Slave_SQL_Running=Yes`, but this does not guarantee that `Slave_IO_Running=Yes` (because `Slave_IO_Running=Yes` only if the I/O thread is running *and connected*). For more information, see Section 13.7.5.36, "SHOW SLAVE STATUS Syntax", and Section 16.1.4.1, "Checking Replication Status".

You can add `IO_THREAD` and `SQL_THREAD` options to the statement to name which of the threads to start.

An `UNTIL` clause may be added to specify that the slave should start and run until the SQL thread reaches a given point in the master binary log or in the slave relay log. When the SQL thread reaches that point, it stops. If the `SQL_THREAD` option is specified in the statement, it starts only the SQL thread. Otherwise, it starts both slave threads. If the SQL thread is running, the `UNTIL` clause is ignored and a warning is issued.

For an `UNTIL` clause, you must specify both a log file name and position. Do not mix master and relay log options.

Any `UNTIL` condition is reset by a subsequent `STOP SLAVE` statement, a `START SLAVE` statement that includes no `UNTIL` clause, or a server restart.

The `UNTIL` clause can be useful for debugging replication, or to cause replication to proceed until just before the point where you want to avoid having the slave replicate an event. For example, if an unwise `DROP TABLE` statement was executed on the master, you can use `UNTIL` to tell the slave to execute up to that point but no farther. To find what the event is, use `mysqlbinlog` with the master binary log or slave relay log, or by using a `SHOW BINLOG EVENTS` statement.

If you are using `UNTIL` to have the slave process replicated queries in sections, it is recommended that you start the slave with the `--skip-slave-start` option to prevent the SQL thread from running when

the slave server starts. It is probably best to use this option in an option file rather than on the command line, so that an unexpected server restart does not cause it to be forgotten.

The `SHOW SLAVE STATUS` statement includes output fields that display the current values of the `UNTIL` condition.

In old versions of MySQL (before 4.0.5), this statement was called `SLAVE START`. This usage is still accepted in MySQL 5.1 for backward compatibility, but is deprecated and is removed in MySQL 5.6.

13.4.2.8 STOP SLAVE Syntax

```
STOP SLAVE [thread_types]

thread_types:
    [thread_type [, thread_type] ... ]

thread_type: IO_THREAD | SQL_THREAD
```

Stops the slave threads. `STOP SLAVE` requires the `SUPER` privilege. Recommended best practice is to execute `STOP SLAVE` on the slave before stopping the slave server (see Section 5.1.11, "The Server Shutdown Process", for more information).

When using the row-based logging format: Prior to MySQL 5.1.35, you should *always* execute `STOP SLAVE` on the slave before stopping the slave server to help avoid the possibility of an inconsistent slave; in MySQL 5.1.35 and later, you should execute this statement on the slave prior to shutting down the slave server if you are replicating any tables that use a nontransactional storage engine (see the *Note* later in this section). In MySQL 5.1.55 and later, you can also use `STOP SLAVE SQL_THREAD` for this purpose.

Like `START SLAVE`, this statement may be used with the `IO_THREAD` and `SQL_THREAD` options to name the thread or threads to be stopped.

> **Note**
>
> The transactional behavior of `STOP SLAVE` changed in MySQL 5.1.35. Previously, it took effect immediately. Beginning with MySQL 5.1.35, it waits until any current replication event group affecting one or more nontransactional tables has finished executing (if there is any such replication group), or until the user issues a `KILL QUERY` or `KILL CONNECTION` statement. (Bug #319, Bug #38205)

In old versions of MySQL (before 4.0.5), this statement was called `SLAVE STOP`. This usage is still accepted in MySQL 5.1 for backward compatibility, but is deprecated and is removed in MySQL 5.6.

13.5 SQL Syntax for Prepared Statements

MySQL 5.1 provides support for server-side prepared statements. This support takes advantage of the efficient client/server binary protocol, provided that you use an appropriate client programming interface. Candidate interfaces include the MySQL C API client library (for C programs), MySQL Connector/J (for Java programs), and MySQL Connector/Net. For example, the C API provides a set of function calls that make up its prepared statement API. See Section 21.8.8, "C API Prepared Statements". Other language interfaces can provide support for prepared statements that use the binary protocol by linking in the C client library, one example being the `mysqli` extension, available in PHP 5.0 and later.

An alternative SQL interface to prepared statements is available. This interface is not as efficient as using the binary protocol through a prepared statement API, but requires no programming because it is available directly at the SQL level:

- You can use it when no programming interface is available to you.

- You can use it from any program that enables you to send SQL statements to the server to be executed, such as the `mysql` client program.

- You can use it even if the client is using an old version of the client library. The only requirement is that you be able to connect to a server that is recent enough to support SQL syntax for prepared statements.

SQL syntax for prepared statements is intended to be used for situations such as these:

- You want to test how prepared statements work in your application before coding it.

- An application has problems executing prepared statements and you want to determine interactively what the problem is.

- You want to create a test case that describes a problem you are having with prepared statements, so that you can file a bug report.

- You need to use prepared statements but do not have access to a programming API that supports them.

SQL syntax for prepared statements is based on three SQL statements:

- `PREPARE` prepares a statement for execution (see Section 13.5.1, "PREPARE Syntax").

- `EXECUTE` executes a prepared statement (see Section 13.5.2, "EXECUTE Syntax").

- `DEALLOCATE PREPARE` releases a prepared statement (see Section 13.5.3, "DEALLOCATE PREPARE Syntax").

The following examples show two equivalent ways of preparing a statement that computes the hypotenuse of a triangle given the lengths of the two sides.

The first example shows how to create a prepared statement by using a string literal to supply the text of the statement:

```
mysql> PREPARE stmt1 FROM 'SELECT SQRT(POW(?,2) + POW(?,2)) AS hypotenuse';
mysql> SET @a = 3;
mysql> SET @b = 4;
mysql> EXECUTE stmt1 USING @a, @b;
+------------+
| hypotenuse |
+------------+
|          5 |
+------------+
mysql> DEALLOCATE PREPARE stmt1;
```

The second example is similar, but supplies the text of the statement as a user variable:

```
mysql> SET @s = 'SELECT SQRT(POW(?,2) + POW(?,2)) AS hypotenuse';
mysql> PREPARE stmt2 FROM @s;
mysql> SET @a = 6;
mysql> SET @b = 8;
mysql> EXECUTE stmt2 USING @a, @b;
+------------+
| hypotenuse |
+------------+
|         10 |
+------------+
mysql> DEALLOCATE PREPARE stmt2;
```

Here is an additional example that demonstrates how to choose the table on which to perform a query at runtime, by storing the name of the table as a user variable:

```
mysql> USE test;
mysql> CREATE TABLE t1 (a INT NOT NULL);
mysql> INSERT INTO t1 VALUES (4), (8), (11), (32), (80);

mysql> SET @table = 't1';
mysql> SET @s = CONCAT('SELECT * FROM ', @table);

mysql> PREPARE stmt3 FROM @s;
mysql> EXECUTE stmt3;
+----+
| a  |
+----+
|  4 |
|  8 |
| 11 |
| 32 |
| 80 |
+----+

mysql> DEALLOCATE PREPARE stmt3;
```

A prepared statement is specific to the session in which it was created. If you terminate a session without deallocating a previously prepared statement, the server deallocates it automatically.

A prepared statement is also global to the session. If you create a prepared statement within a stored routine, it is not deallocated when the stored routine ends.

To guard against too many prepared statements being created simultaneously, set the max_prepared_stmt_count system variable. To prevent the use of prepared statements, set the value to 0.

The following SQL statements can be used in prepared statements:

```
ALTER TABLE
CALL
COMMIT
{CREATE | DROP} INDEX
{CREATE | DROP} TABLE
{CREATE | DROP} VIEW
DELETE
DO
INSERT
RENAME TABLE
REPLACE
SELECT
SET
SHOW (most variants)
TRUNCATE TABLE
UPDATE
```

As of MySQL 5.1.10, the following additional statements are supported:

```
ANALYZE TABLE
OPTIMIZE TABLE
REPAIR TABLE
```

As of MySQL 5.1.12, the following additional statements are supported:

```
CACHE INDEX
CHANGE MASTER
CHECKSUM {TABLE | TABLES}
{CREATE | RENAME | DROP} DATABASE
{CREATE | RENAME | DROP} USER
FLUSH {TABLE | TABLES | TABLES WITH READ LOCK | HOSTS | PRIVILEGES
   | LOGS | STATUS | MASTER | SLAVE | DES_KEY_FILE | USER_RESOURCES}
GRANT
INSTALL PLUGIN
KILL
LOAD INDEX INTO CACHE
RESET {MASTER | SLAVE | QUERY CACHE}
REVOKE
SHOW {AUTHORS | CONTRIBUTORS | WARNINGS | ERRORS}
SHOW BINLOG EVENTS
SHOW CREATE {PROCEDURE | FUNCTION | EVENT | TABLE | VIEW}
SHOW {MASTER | BINARY} LOGS
SHOW {MASTER | SLAVE} STATUS
SLAVE {START | STOP}
UNINSTALL PLUGIN
```

Other statements are not supported in MySQL 5.1.

Generally, statements not permitted in SQL prepared statements are also not permitted in stored programs. Exceptions are noted in Section C.1, "Restrictions on Stored Programs".

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, "Automatic Prepared Statement Repreparation".

Placeholders can be used for the arguments of the LIMIT clause when using prepared statements. See Section 13.2.8, "SELECT Syntax".

In prepared CALL statements used with PREPARE and EXECUTE, placeholder support for OUT and INOUT parameters is not available in MySQL 5.1. See Section 13.2.1, "CALL Syntax", for an example and a workaround. Placeholders can be used for IN parameters regardless of version.

SQL syntax for prepared statements cannot be used in nested fashion. That is, a statement passed to PREPARE cannot itself be a PREPARE, EXECUTE, or DEALLOCATE PREPARE statement.

SQL syntax for prepared statements is distinct from using prepared statement API calls. For example, you cannot use the mysql_stmt_prepare() C API function to prepare a PREPARE, EXECUTE, or DEALLOCATE PREPARE statement.

SQL syntax for prepared statements can be used within stored procedures, but not in stored functions or triggers. However, a cursor cannot be used for a dynamic statement that is prepared and executed with PREPARE and EXECUTE. The statement for a cursor is checked at cursor creation time, so the statement cannot be dynamic.

SQL syntax for prepared statements does not support multi-statements (that is, multiple statements within a single string separated by ";" characters).

Before MySQL 5.1.17, prepared statements do not use the query cache. As of 5.1.17, prepared statements use the query cache under the conditions described in Section 8.10.3.1, "How the Query Cache Operates".

To write C programs that use the CALL SQL statement to execute stored procedures that contain prepared statements, the CLIENT_MULTI_RESULTS flag must be enabled. This is because each CALL returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure.

CLIENT_MULTI_RESULTS can be enabled when you call mysql_real_connect(), either explicitly by passing the CLIENT_MULTI_RESULTS flag itself, or implicitly by passing CLIENT_MULTI_STATEMENTS (which also enables CLIENT_MULTI_RESULTS). For additional information, see Section 13.2.1, "CALL Syntax".

13.5.1 PREPARE Syntax

```
PREPARE stmt_name FROM preparable_stmt
```

The PREPARE statement prepares a SQL statement and assigns it a name, stmt_name, by which to refer to the statement later. The prepared statement is executed with EXECUTE and released with DEALLOCATE PREPARE. For examples, see Section 13.5, "SQL Syntax for Prepared Statements".

Statement names are not case sensitive. preparable_stmt is either a string literal or a user variable that contains the text of the SQL statement. The text must represent a single statement, not multiple statements. Within the statement, ? characters can be used as parameter markers to indicate where data values are to be bound to the query later when you execute it. The ? characters should not be enclosed within quotation marks, even if you intend to bind them to string values. Parameter markers can be used only where data values should appear, not for SQL keywords, identifiers, and so forth.

If a prepared statement with the given name already exists, it is deallocated implicitly before the new statement is prepared. This means that if the new statement contains an error and cannot be prepared, an error is returned and no statement with the given name exists.

The scope of a prepared statement is the session within which it is created, which as several implications:

- A prepared statement created in one session is not available to other sessions.

- When a session ends, whether normally or abnormally, its prepared statements no longer exist. If auto-reconnect is enabled, the client is not notified that the connection was lost. For this reason, clients may wish to disable auto-reconnect. See Section 21.8.15, "Controlling Automatic Reconnection Behavior".

- A prepared statement created within a stored program continues to exist after the program finishes executing and can be executed outside the program later.

- A statement prepared in stored program context cannot refer to stored procedure or function parameters or local variables because they go out of scope when the program ends and would be unavailable were the statement to be executed later outside the program. As a workaround, refer instead to user-defined variables, which also have session scope; see Section 9.4, "User-Defined Variables".

13.5.2 EXECUTE Syntax

```
EXECUTE stmt_name
    [USING @var_name [, @var_name] ...]
```

After preparing a statement with PREPARE, you execute it with an EXECUTE statement that refers to the prepared statement name. If the prepared statement contains any parameter markers, you must supply a USING clause that lists user variables containing the values to be bound to the parameters. Parameter values can be supplied only by user variables, and the USING clause must name exactly as many variables as the number of parameter markers in the statement.

You can execute a given prepared statement multiple times, passing different variables to it or setting the variables to different values before each execution.

For examples, see Section 13.5, "SQL Syntax for Prepared Statements".

13.5.3 DEALLOCATE PREPARE Syntax

```
{DEALLOCATE | DROP} PREPARE stmt_name
```

To deallocate a prepared statement produced with `PREPARE`, use a `DEALLOCATE PREPARE` statement that refers to the prepared statement name. Attempting to execute a prepared statement after deallocating it results in an error.

For examples, see Section 13.5, "SQL Syntax for Prepared Statements".

13.5.4 Automatic Prepared Statement Repreparation

As of MySQL 5.1.25, metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. This applies to prepared statements processed at the SQL level (using the `PREPARE` statement) and those processed using the binary client/server protocol (using the `mysql_stmt_prepare()` C API function).

The server attempts repreparation up to three times. An error occurs if all attempts fail.

Metadata changes occur for DDL statements such as those that create, drop, alter, rename, or truncate tables, or that analyze, optimize, or repair tables. Repreparation also occurs after referenced tables or views are flushed from the table definition cache, either implicitly to make room for new entries in the cache, or explicitly due to `FLUSH TABLES`.

Table content changes (for example, with `INSERT` or `UPDATE`) do not cause repreparation, nor do `SELECT` statements.

Repreparation is automatic, but to the extent that it occurs, diminishes prepared statement performance.

Repreparation uses the default database and SQL mode that were in effect for the original preparation.

The `Com_stmt_reprepare` status variable tracks the number of repreparations.

An incompatibility with older versions of MySQL (before 5.1.25) is that a prepared statement may return a different set of columns or different column types from one execution to the next. For example, if the prepared statement is `SELECT * FROM t1`, altering `t1` to contain a different number of columns causes the next execution to return a number of columns different from the previous execution.

Older versions of the client library cannot handle this change in behavior. For applications that use prepared statements with a server that performs automatic repreparation, an upgrade to the new client library is strongly recommended.

13.6 MySQL Compound-Statement Syntax

This section describes the syntax for the `BEGIN ... END` compound statement and other statements that can be used in the body of stored programs: Stored procedures and functions, triggers, and events. These objects are defined in terms of SQL code that is stored on the server for later invocation (see Chapter 19, *Stored Programs and Views*).

A compound statement is a block that can contain other blocks; declarations for variables, condition handlers, and cursors; and flow control constructs such as loops and conditional tests.

13.6.1 BEGIN ... END Compound-Statement Syntax

```
[begin_label:] BEGIN
    [statement_list]
END [end_label]
```

`BEGIN ... END` syntax is used for writing compound statements, which can appear within stored programs (stored procedures and functions, triggers, and events). A compound statement can contain multiple statements, enclosed by the `BEGIN` and `END` keywords. `statement_list` represents a list of one or more statements, each terminated by a semicolon (`;`) statement delimiter. The `statement_list` itself is optional, so the empty compound statement (`BEGIN END`) is legal.

`BEGIN ... END` blocks can be nested.

Use of multiple statements requires that a client is able to send statement strings containing the `;` statement delimiter. In the `mysql` command-line client, this is handled with the `delimiter` command. Changing the `;` end-of-statement delimiter (for example, to `//`) permit `;` to be used in a program body. For an example, see Section 19.1, "Defining Stored Programs".

A `BEGIN ... END` block can be labeled. See Section 13.6.2, "Statement Label Syntax".

The optional `[NOT] ATOMIC` clause is not supported. This means that no transactional savepoint is set at the start of the instruction block and the `BEGIN` clause used in this context has no effect on the current transaction.

> **Note**
>
> Within all stored programs, the parser treats `BEGIN [WORK]` as the beginning of a `BEGIN ... END` block. To begin a transaction in this context, use `START TRANSACTION` instead.

13.6.2 Statement Label Syntax

```
[begin_label:] BEGIN
    [statement_list]
END [end_label]

[begin_label:] LOOP
    statement_list
END LOOP [end_label]

[begin_label:] REPEAT
    statement_list
UNTIL search_condition
END REPEAT [end_label]

[begin_label:] WHILE search_condition DO
    statement_list
END WHILE [end_label]
```

Labels are permitted for `BEGIN ... END` blocks and for the `LOOP`, `REPEAT`, and `WHILE` statements. Label use for those statements follows these rules:

- `begin_label` must be followed by a colon.

- `begin_label` can be given without `end_label`. If `end_label` is present, it must be the same as `begin_label`.

- `end_label` cannot be given without `begin_label`.

- Labels at the same nesting level must be distinct.

- Labels can be up to 16 characters long.

To refer to a label within the labeled construct, use an `ITERATE` or `LEAVE` statement. The following example uses those statements to continue iterating or terminate the loop:

```
CREATE PROCEDURE doiterate(p1 INT)
BEGIN
  label1: LOOP
    SET p1 = p1 + 1;
    IF p1 < 10 THEN ITERATE label1; END IF;
    LEAVE label1;
  END LOOP label1;
END;
```

The scope of a block label does not include the code for handlers declared within the block. For details, see Section 13.6.7.2, "DECLARE ... HANDLER Syntax".

13.6.3 DECLARE Syntax

The `DECLARE` statement is used to define various items local to a program:

- Local variables. See Section 13.6.4, "Variables in Stored Programs".

- Conditions and handlers. See Section 13.6.7, "Condition Handling".

- Cursors. See Section 13.6.6, "Cursors".

`DECLARE` is permitted only inside a `BEGIN ... END` compound statement and must be at its start, before any other statements.

Declarations must follow a certain order. Cursor declarations must appear before handler declarations. Variable and condition declarations must appear before cursor or handler declarations.

13.6.4 Variables in Stored Programs

System variables and user-defined variables can be used in stored programs, just as they can be used outside stored-program context. In addition, stored programs can use `DECLARE` to define local variables, and stored routines (procedures and functions) can be declared to take parameters that communicate values between the routine and its caller.

- To declare local variables, use the `DECLARE` statement, as described in Section 13.6.4.1, "Local Variable DECLARE Syntax".

- Variables can be set directly with the `SET` statement. See Section 13.7.4.1, "SET Syntax for Variable Assignment".

- Results from queries can be retrieved into local variables using `SELECT ... INTO var_list` or by opening a cursor and using `FETCH ... INTO var_list`. See Section 13.2.8.1, "SELECT ... INTO Syntax", and Section 13.6.6, "Cursors".

For information about the scope of local variables and how MySQL resolves ambiguous names, see Section 13.6.4.2, "Local Variable Scope and Resolution".

13.6.4.1 Local Variable DECLARE Syntax

```
DECLARE var_name [, var_name] ... type [DEFAULT value]
```

This statement declares local variables within stored programs. To provide a default value for a variable, include a DEFAULT clause. The value can be specified as an expression; it need not be a constant. If the DEFAULT clause is missing, the initial value is NULL.

Local variables are treated like stored routine parameters with respect to data type and overflow checking. See Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax".

Variable declarations must appear before cursor or handler declarations.

Local variable names are not case sensitive. Permissible characters and quoting rules are the same as for other identifiers, as described in Section 9.2, "Schema Object Names".

The scope of a local variable is the BEGIN ... END block within which it is declared. The variable can be referred to in blocks nested within the declaring block, except those blocks that declare a variable with the same name.

For examples of variable declarations, see Section 13.6.4.2, "Local Variable Scope and Resolution".

13.6.4.2 Local Variable Scope and Resolution

The scope of a local variable is the BEGIN ... END block within which it is declared. The variable can be referred to in blocks nested within the declaring block, except those blocks that declare a variable with the same name.

Because local variables are in scope only during stored program execution, references to them are not permitted in prepared statements created within a stored program. Prepared statement scope is the current session, not the stored program, so the statement could be executed after the program ends, at which point the variables would no longer be in scope. For example, SELECT ... INTO local_var cannot be used as a prepared statement. This restriction also applies to stored procedure and function parameters. See Section 13.5.1, "PREPARE Syntax".

A local variable should not have the same name as a table column. If an SQL statement, such as a SELECT ... INTO statement, contains a reference to a column and a declared local variable with the same name, MySQL currently interprets the reference as the name of a variable. Consider the following procedure definition:

```
CREATE PROCEDURE sp1 (x VARCHAR(5))
BEGIN
  DECLARE xname VARCHAR(5) DEFAULT 'bob';
  DECLARE newname VARCHAR(5);
  DECLARE xid INT;

  SELECT xname, id INTO newname, xid
    FROM table1 WHERE xname = xname;
  SELECT newname;
END;
```

MySQL interprets xname in the SELECT statement as a reference to the xname *variable* rather than the xname *column*. Consequently, when the procedure sp1() is called, the newname variable returns the value 'bob' regardless of the value of the table1.xname column.

Similarly, the cursor definition in the following procedure contains a SELECT statement that refers to xname. MySQL interprets this as a reference to the variable of that name rather than a column reference.

```
CREATE PROCEDURE sp2 (x VARCHAR(5))
BEGIN
  DECLARE xname VARCHAR(5) DEFAULT 'bob';
  DECLARE newname VARCHAR(5);
  DECLARE xid INT;
  DECLARE done TINYINT DEFAULT 0;
  DECLARE cur1 CURSOR FOR SELECT xname, id FROM table1;
  DECLARE CONTINUE HANDLER FOR NOT FOUND SET done = 1;

  OPEN cur1;
  read_loop: LOOP
    FETCH FROM cur1 INTO newname, xid;
    IF done THEN LEAVE read_loop; END IF;
    SELECT newname;
  END LOOP;
  CLOSE cur1;
END;
```

See also Section C.1, "Restrictions on Stored Programs".

13.6.5 Flow Control Statements

MySQL supports the IF, CASE, ITERATE, LEAVE LOOP, WHILE, and REPEAT constructs for flow control within stored programs. It also supports RETURN within stored functions.

Many of these constructs contain other statements, as indicated by the grammar specifications in the following sections. Such constructs may be nested. For example, an IF statement might contain a WHILE loop, which itself contains a CASE statement.

MySQL does not support FOR loops.

13.6.5.1 CASE Syntax

```
CASE case_value
    WHEN when_value THEN statement_list
    [WHEN when_value THEN statement_list] ...
    [ELSE statement_list]
END CASE
```

Or:

```
CASE
    WHEN search_condition THEN statement_list
    [WHEN search_condition THEN statement_list] ...
    [ELSE statement_list]
END CASE
```

The CASE statement for stored programs implements a complex conditional construct.

Note

There is also a CASE *expression*, which differs from the CASE *statement* described here. See Section 12.4, "Control Flow Functions". The CASE statement cannot have an ELSE NULL clause, and it is terminated with END CASE instead of END.

For the first syntax, *case_value* is an expression. This value is compared to the *when_value* expression in each WHEN clause until one of them is equal. When an equal *when_value* is found, the corresponding THEN clause *statement_list* executes. If no *when_value* is equal, the ELSE clause *statement_list* executes, if there is one.

This syntax cannot be used to test for equality with `NULL` because `NULL = NULL` is false. See Section 3.3.4.6, "Working with NULL Values".

For the second syntax, each `WHEN` clause *search_condition* expression is evaluated until one is true, at which point its corresponding `THEN` clause *statement_list* executes. If no *search_condition* is equal, the `ELSE` clause *statement_list* executes, if there is one.

If no *when_value* or *search_condition* matches the value tested and the `CASE` statement contains no `ELSE` clause, a `Case not found for CASE statement` error results.

Each *statement_list* consists of one or more SQL statements; an empty *statement_list* is not permitted.

To handle situations where no value is matched by any `WHEN` clause, use an `ELSE` containing an empty `BEGIN ... END` block, as shown in this example. (The indentation used here in the `ELSE` clause is for purposes of clarity only, and is not otherwise significant.)

```
DELIMITER |

CREATE PROCEDURE p()
  BEGIN
    DECLARE v INT DEFAULT 1;

    CASE v
      WHEN 2 THEN SELECT v;
      WHEN 3 THEN SELECT 0;
      ELSE
         BEGIN
         END;
    END CASE;
  END;
  |
```

13.6.5.2 IF Syntax

```
IF search_condition THEN statement_list
    [ELSEIF search_condition THEN statement_list] ...
    [ELSE statement_list]
END IF
```

The `IF` statement for stored programs implements a basic conditional construct.

> **Note**
>
> There is also an `IF()` *function*, which differs from the `IF` *statement* described here. See Section 12.4, "Control Flow Functions". The `IF` statement can have `THEN`, `ELSE`, and `ELSEIF` clauses, and it is terminated with `END IF`.

If the *search_condition* evaluates to true, the corresponding `THEN` or `ELSEIF` clause *statement_list* executes. If no *search_condition* matches, the `ELSE` clause *statement_list* executes.

Each *statement_list* consists of one or more SQL statements; an empty *statement_list* is not permitted.

An `IF ... END IF` block, like all other flow-control blocks used within stored programs, must be terminated with a semicolon, as shown in this example:

```
DELIMITER //

CREATE FUNCTION SimpleCompare(n INT, m INT)
  RETURNS VARCHAR(20)

  BEGIN
    DECLARE s VARCHAR(20);

    IF n > m THEN SET s = '>';
    ELSEIF n = m THEN SET s = '=';
    ELSE SET s = '<';
    END IF;

    SET s = CONCAT(n, ' ', s, ' ', m);

    RETURN s;
  END //

DELIMITER ;
```

As with other flow-control constructs, `IF ... END IF` blocks may be nested within other flow-control constructs, including other `IF` statements. Each `IF` must be terminated by its own `END IF` followed by a semicolon. You can use indentation to make nested flow-control blocks more easily readable by humans (although this is not required by MySQL), as shown here:

```
DELIMITER //

CREATE FUNCTION VerboseCompare (n INT, m INT)
  RETURNS VARCHAR(50)

  BEGIN
    DECLARE s VARCHAR(50);

    IF n = m THEN SET s = 'equals';
    ELSE
      IF n > m THEN SET s = 'greater';
      ELSE SET s = 'less';
      END IF;

      SET s = CONCAT('is ', s, ' than');
    END IF;

    SET s = CONCAT(n, ' ', s, ' ', m, '.');

    RETURN s;
  END //

DELIMITER ;
```

In this example, the inner `IF` is evaluated only if `n` is not equal to `m`.

13.6.5.3 ITERATE Syntax

```
ITERATE label
```

`ITERATE` can appear only within `LOOP`, `REPEAT`, and `WHILE` statements. `ITERATE` means "start the loop again."

For an example, see Section 13.6.5.5, "LOOP Syntax".

13.6.5.4 LEAVE Syntax

```
LEAVE label
```

This statement is used to exit the flow control construct that has the given label. If the label is for the outermost stored program block, `LEAVE` exits the program.

`LEAVE` can be used within `BEGIN ... END` or loop constructs (`LOOP`, `REPEAT`, `WHILE`).

For an example, see Section 13.6.5.5, "LOOP Syntax".

13.6.5.5 LOOP Syntax

```
[begin_label:] LOOP
    statement_list
END LOOP [end_label]
```

`LOOP` implements a simple loop construct, enabling repeated execution of the statement list, which consists of one or more statements, each terminated by a semicolon (`;`) statement delimiter. The statements within the loop are repeated until the loop is terminated. Usually, this is accomplished with a `LEAVE` statement. Within a stored function, `RETURN` can also be used, which exits the function entirely.

Neglecting to include a loop-termination statement results in an infinite loop.

A `LOOP` statement can be labeled. For the rules regarding label use, see Section 13.6.2, "Statement Label Syntax".

Example:

```
CREATE PROCEDURE doiterate(p1 INT)
BEGIN
  label1: LOOP
    SET p1 = p1 + 1;
    IF p1 < 10 THEN
      ITERATE label1;
    END IF;
    LEAVE label1;
  END LOOP label1;
  SET @x = p1;
END;
```

13.6.5.6 REPEAT Syntax

```
[begin_label:] REPEAT
    statement_list
UNTIL search_condition
END REPEAT [end_label]
```

The statement list within a `REPEAT` statement is repeated until the `search_condition` expression is true. Thus, a `REPEAT` always enters the loop at least once. `statement_list` consists of one or more statements, each terminated by a semicolon (`;`) statement delimiter.

A `REPEAT` statement can be labeled. For the rules regarding label use, see Section 13.6.2, "Statement Label Syntax".

Example:

```
mysql> delimiter //
```

```
mysql> CREATE PROCEDURE dorepeat(p1 INT)
    -> BEGIN
    ->   SET @x = 0;
    ->   REPEAT
    ->     SET @x = @x + 1;
    ->   UNTIL @x > p1 END REPEAT;
    -> END
    -> //
Query OK, 0 rows affected (0.00 sec)

mysql> CALL dorepeat(1000)//
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @x//
+------+
| @x   |
+------+
| 1001 |
+------+
1 row in set (0.00 sec)
```

13.6.5.7 RETURN Syntax

```
RETURN expr
```

The RETURN statement terminates execution of a stored function and returns the value *expr* to the function caller. There must be at least one RETURN statement in a stored function. There may be more than one if the function has multiple exit points.

This statement is not used in stored procedures, triggers, or events. The LEAVE statement can be used to exit a stored program of those types.

13.6.5.8 WHILE Syntax

```
[begin_label:] WHILE search_condition DO
    statement_list
END WHILE [end_label]
```

The statement list within a WHILE statement is repeated as long as the *search_condition* expression is true. *statement_list* consists of one or more SQL statements, each terminated by a semicolon (*;*) statement delimiter.

A WHILE statement can be labeled. For the rules regarding label use, see Section 13.6.2, "Statement Label Syntax".

Example:

```
CREATE PROCEDURE dowhile()
BEGIN
  DECLARE v1 INT DEFAULT 5;

  WHILE v1 > 0 DO
    ...
    SET v1 = v1 - 1;
  END WHILE;
END;
```

13.6.6 Cursors

MySQL supports cursors inside stored programs. The syntax is as in embedded SQL. Cursors have these properties:

- Asensitive: The server may or may not make a copy of its result table

- Read only: Not updatable

- Nonscrollable: Can be traversed only in one direction and cannot skip rows

Cursor declarations must appear before handler declarations and after variable and condition declarations.

Example:

```
CREATE PROCEDURE curdemo()
BEGIN
  DECLARE done INT DEFAULT FALSE;
  DECLARE a CHAR(16);
  DECLARE b, c INT;
  DECLARE cur1 CURSOR FOR SELECT id,data FROM test.t1;
  DECLARE cur2 CURSOR FOR SELECT i FROM test.t2;
  DECLARE CONTINUE HANDLER FOR NOT FOUND SET done = TRUE;

  OPEN cur1;
  OPEN cur2;

  read_loop: LOOP
    FETCH cur1 INTO a, b;
    FETCH cur2 INTO c;
    IF done THEN
      LEAVE read_loop;
    END IF;
    IF b < c THEN
      INSERT INTO test.t3 VALUES (a,b);
    ELSE
      INSERT INTO test.t3 VALUES (a,c);
    END IF;
  END LOOP;

  CLOSE cur1;
  CLOSE cur2;
END;
```

13.6.6.1 Cursor CLOSE Syntax

```
CLOSE cursor_name
```

This statement closes a previously opened cursor. For an example, see Section 13.6.6, "Cursors".

An error occurs if the cursor is not open.

If not closed explicitly, a cursor is closed at the end of the `BEGIN ... END` block in which it was declared.

13.6.6.2 Cursor DECLARE Syntax

```
DECLARE cursor_name CURSOR FOR select_statement
```

This statement declares a cursor and associates it with a `SELECT` statement that retrieves the rows to be traversed by the cursor. To fetch the rows later, use a `FETCH` statement. The number of columns retrieved by the `SELECT` statement must match the number of output variables specified in the `FETCH` statement.

The `SELECT` statement cannot have an `INTO` clause.

Cursor declarations must appear before handler declarations and after variable and condition declarations.

A stored program may contain multiple cursor declarations, but each cursor declared in a given block must have a unique name. For an example, see Section 13.6.6, "Cursors".

For information available through `SHOW` statements, it is possible in many cases to obtain equivalent information by using a cursor with an `INFORMATION_SCHEMA` table.

13.6.6.3 Cursor FETCH Syntax

```
FETCH [[NEXT] FROM] cursor_name INTO var_name [, var_name] ...
```

This statement fetches the next row for the `SELECT` statement associated with the specified cursor (which must be open), and advances the cursor pointer. If a row exists, the fetched columns are stored in the named variables. The number of columns retrieved by the `SELECT` statement must match the number of output variables specified in the `FETCH` statement.

If no more rows are available, a No Data condition occurs with SQLSTATE value `'02000'`. To detect this condition, you can set up a handler for it (or for a `NOT FOUND` condition). For an example, see Section 13.6.6, "Cursors".

13.6.6.4 Cursor OPEN Syntax

```
OPEN cursor_name
```

This statement opens a previously declared cursor. For an example, see Section 13.6.6, "Cursors".

13.6.7 Condition Handling

Conditions may arise during stored program execution that require special handling, such as exiting the current program block or continuing execution. Handlers can be defined for general conditions such as warnings or exceptions, or for specific conditions such as a particular error code. Specific conditions can be assigned names and referred to that way in handlers.

To name a condition, use the `DECLARE ... CONDITION` statement. To declare a handler, use the `DECLARE ... HANDLER` statement. See Section 13.6.7.1, "DECLARE ... CONDITION Syntax", and Section 13.6.7.2, "DECLARE ... HANDLER Syntax".

Other statements related to conditions are `SIGNAL`, `RESIGNAL`, and `GET DIAGNOSTICS`. The `SIGNAL` and `RESIGNAL` statements are not supported until MySQL 5.5. The `GET DIAGNOSTICS` statement is not supported until MySQL 5.6.

Before MySQL 5.6.3, if a statement that generates a warning or error causes a condition handler to be invoked, the handler may not clear the diagnostic area. This might lead to the appearance that the handler was not invoked. The following discussion demonstrates the issue and provides a workaround.

Suppose that a table `t1` is empty. The following procedure selects from it, raising a No Data condition:

```
CREATE PROCEDURE p1()
BEGIN
  DECLARE a INT;
  DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
      SET @handler_invoked = 1;
```

```
    END;
  SELECT c1 INTO a FROM t1;
END;
```

As can be seen from the following sequence of statements, the condition is not cleared by handler invocation (otherwise, the SHOW WARNINGS output would be empty). But as can be seen by the value of @handler_invoked, the handler was indeed invoked (otherwise its value would be 0).

```
mysql> SET @handler_invoked = 0;
Query OK, 0 rows affected (0.00 sec)

mysql> CALL p1();
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+----------------------------------------------------+
| Level   | Code | Message                                            |
+---------+------+----------------------------------------------------+
| Warning | 1329 | No data - zero rows fetched, selected, or processed |
+---------+------+----------------------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @handler_invoked;
+------------------+
| @handler_invoked |
+------------------+
|                1 |
+------------------+
1 row in set (0.00 sec)
```

There are two ways to work around this issue:

- Add an extra dummy statement that clears warnings at the end of the condition handler:

```
CREATE PROCEDURE p1()
BEGIN
  DECLARE a INT;
  DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
      SET @handler_invoked = 1;
      SELECT 1 FROM (SELECT 1) AS t;
    END;
  SELECT c1 INTO a FROM t1;
END;
```

This works for CONTINUE and EXIT handlers.

- Put an extra dummy statement that clears warnings following the statement that causes handler activation:

```
CREATE PROCEDURE p1()
BEGIN
  DECLARE a INT;
  DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
      SET @handler_invoked = 1;
      SELECT 1 FROM (SELECT 1) AS t;
    END;
  SELECT c1 INTO a FROM t1;
END;
```

This works only for CONTINUE handlers.

This issue is resolved as of MySQL 5.6.3 and no workaround is needed.

13.6.7.1 DECLARE ... CONDITION Syntax

```
DECLARE condition_name CONDITION FOR condition_value

condition_value:
    mysql_error_code
  | SQLSTATE [VALUE] sqlstate_value
```

The `DECLARE ... CONDITION` statement declares a named error condition, associating a name with a condition that needs specific handling. The name can be referred to in a subsequent `DECLARE ... HANDLER` statement (see Section 13.6.7.2, "DECLARE ... HANDLER Syntax").

Condition declarations must appear before cursor or handler declarations.

The `condition_value` for `DECLARE ... CONDITION` indicates the specific condition or class of conditions to associate with the condition name. It can take the following forms:

- `mysql_error_code`: An integer literal indicating a MySQL error code, such as 1051 to specify "unknown table":

```
DECLARE CONTINUE HANDLER FOR 1051
  BEGIN
    -- body of handler
  END;
```

  Do not use MySQL error code 0 because that indicates success rather than an error condition. For a list of MySQL error codes, see Section B.3, "Server Error Codes and Messages".

- SQLSTATE [VALUE] `sqlstate_value`: A 5-character string literal indicating an SQLSTATE value, such as `'42S01'` to specify "unknown table":

```
DECLARE CONTINUE HANDLER FOR SQLSTATE '42S02'
  BEGIN
    -- body of handler
  END;
```

  Do not use SQLSTATE values that begin with `'00'` because those indicate success rather than an error condition. For a list of SQLSTATE values, see Section B.3, "Server Error Codes and Messages".

Using names for conditions can help make stored program code clearer. For example, this handler applies to attempts to drop a nonexistent table, but that is apparent only if you know that 1051 is the MySQL error code for "unknown table":

```
DECLARE CONTINUE HANDLER FOR 1051
  BEGIN
    -- body of handler
  END;
```

By declaring a name for the condition, the purpose of the handler is more readily seen:

```
DECLARE no_such_table CONDITION FOR 1051;
DECLARE CONTINUE HANDLER FOR no_such_table
  BEGIN
    -- body of handler
```

```
END;
```

Here is a named condition for the same condition, but based on the corresponding SQLSTATE value rather than the MySQL error code:

```
DECLARE no_such_table CONDITION FOR SQLSTATE '42S02';
DECLARE CONTINUE HANDLER FOR no_such_table
  BEGIN
    -- body of handler
  END;
```

13.6.7.2 DECLARE ... HANDLER Syntax

```
DECLARE handler_action HANDLER
    FOR condition_value [, condition_value] ...
    statement

handler_action:
    CONTINUE
  | EXIT
  | UNDO

condition_value:
    mysql_error_code
  | SQLSTATE [VALUE] sqlstate_value
  | condition_name
  | SQLWARNING
  | NOT FOUND
  | SQLEXCEPTION
```

The `DECLARE ... HANDLER` statement specifies a handler that deals with one or more conditions. If one of these conditions occurs, the specified `statement` executes. `statement` can be a simple statement such as `SET var_name = value`, or a compound statement written using `BEGIN` and `END` (see Section 13.6.1, "BEGIN ... END Compound-Statement Syntax").

Handler declarations must appear after variable or condition declarations.

The `handler_action` value indicates what action the handler takes after execution of the handler statement:

- `CONTINUE`: Execution of the current program continues.

- `EXIT`: Execution terminates for the `BEGIN ... END` compound statement in which the handler is declared. This is true even if the condition occurs in an inner block.

- `UNDO`: Not supported.

The `condition_value` for `DECLARE ... HANDLER` indicates the specific condition or class of conditions that activates the handler. It can take the following forms:

- `mysql_error_code`: An integer literal indicating a MySQL error code.

  Do not use MySQL error code 0 because that indicates success rather than an error condition. For a list of MySQL error codes, see Section B.3, "Server Error Codes and Messages".

- SQLSTATE [VALUE] `sqlstate_value`: A 5-character string literal indicating an SQLSTATE value.

  Do not use SQLSTATE values that begin with `'00'` because those indicate success rather than an error condition. For a list of SQLSTATE values, see Section B.3, "Server Error Codes and Messages".

- *condition_name*: A condition name previously specified with `DECLARE ... CONDITION`. A condition name can be associated with a MySQL error code or SQLSTATE value. See Section 13.6.7.1, "DECLARE ... CONDITION Syntax".

- `SQLWARNING`: Shorthand for the class of SQLSTATE values that begin with `'01'`.

```
DECLARE CONTINUE HANDLER FOR SQLWARNING
   BEGIN
     -- body of handler
   END;
```

- `NOT FOUND`: Shorthand for the class of SQLSTATE values that begin with `'02'`. This is relevant within the context of cursors and is used to control what happens when a cursor reaches the end of a data set. If no more rows are available, a No Data condition occurs with SQLSTATE value `'02000'`. To detect this condition, you can set up a handler for it or for a `NOT FOUND` condition.

```
DECLARE CONTINUE HANDLER FOR NOT FOUND
   BEGIN
     -- body of handler
   END;
```

For another example, see Section 13.6.6, "Cursors". The `NOT FOUND` condition also occurs for `SELECT ... INTO var_list` statements that retrieve no rows.

- `SQLEXCEPTION`: Shorthand for the class of SQLSTATE values that do not begin with `'00'`, `'01'`, or `'02'`.

```
DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
   BEGIN
     -- body of handler
   END;
```

If a condition occurs for which no handler has been declared, the action taken depends on the condition class:

- For `SQLEXCEPTION` conditions, the stored program terminates at the statement that raised the condition, as if there were an `EXIT` handler. If the program was called by another stored program, the calling program handles the condition using the handler selection rules applied to its own handlers.

- For `SQLWARNING` or `NOT FOUND` conditions, the program continues executing, as if there were a `CONTINUE` handler.

The following example uses a handler for `SQLSTATE '23000'`, which occurs for a duplicate-key error:

```
mysql> CREATE TABLE test.t (s1 INT, PRIMARY KEY (s1));
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter //

mysql> CREATE PROCEDURE handlerdemo ()
    -> BEGIN
    ->   DECLARE CONTINUE HANDLER FOR SQLSTATE '23000' SET @x2 = 1;
    ->   SET @x = 1;
    ->   INSERT INTO test.t VALUES (1);
    ->   SET @x = 2;
    ->   INSERT INTO test.t VALUES (1);
    ->   SET @x = 3;
    -> END;
    -> //
```

```
Query OK, 0 rows affected (0.00 sec)

mysql> CALL handlerdemo()//
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @x//
    +------+
    | @x   |
    +------+
    | 3    |
    +------+
    1 row in set (0.00 sec)
```

Notice that @x is 3 after the procedure executes, which shows that execution continued to the end of the procedure after the error occurred. If the DECLARE ... HANDLER statement had not been present, MySQL would have taken the default action (EXIT) after the second INSERT failed due to the PRIMARY KEY constraint, and SELECT @x would have returned 2.

To ignore a condition, declare a CONTINUE handler for it and associate it with an empty block. For example:

```
DECLARE CONTINUE HANDLER FOR SQLWARNING BEGIN END;
```

The scope of a block label does not include the code for handlers declared within the block. Therefore, the statement associated with a handler cannot use ITERATE or LEAVE to refer to labels for blocks that enclose the handler declaration. Consider the following example, where the REPEAT block has a label of retry:

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 3;
  retry:
    REPEAT
      BEGIN
        DECLARE CONTINUE HANDLER FOR SQLWARNING
          BEGIN
            ITERATE retry;     # illegal
          END;
        IF i < 0 THEN
          LEAVE retry;         # legal
        END IF;
        SET i = i - 1;
      END;
    UNTIL FALSE END REPEAT;
END;
```

The retry label is in scope for the IF statement within the block. It is not in scope for the CONTINUE handler, so the reference there is invalid and results in an error:

```
ERROR 1308 (42000): LEAVE with no matching label: retry
```

To avoid references to outer labels in handlers, use one of these strategies:

• To leave the block, use an EXIT handler. If no block cleanup is required, the BEGIN ... END handler body can be empty:

```
DECLARE EXIT HANDLER FOR SQLWARNING BEGIN END;
```

Otherwise, put the cleanup statements in the handler body:

```
DECLARE EXIT HANDLER FOR SQLWARNING
  BEGIN
    block cleanup statements
  END;
```

- To continue execution, set a status variable in a `CONTINUE` handler that can be checked in the enclosing block to determine whether the handler was invoked. The following example uses the variable `done` for this purpose:

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 3;
  DECLARE done INT DEFAULT FALSE;
  retry:
    REPEAT
      BEGIN
        DECLARE CONTINUE HANDLER FOR SQLWARNING
          BEGIN
            SET done = TRUE;
          END;
        IF done OR i < 0 THEN
          LEAVE retry;
        END IF;
        SET i = i - 1;
      END;
    UNTIL FALSE END REPEAT;
END;
```

13.7 Database Administration Statements

13.7.1 Account Management Statements

MySQL account information is stored in the tables of the `mysql` database. This database and the access control system are discussed extensively in Chapter 5, *MySQL Server Administration*, which you should consult for additional details.

> **Important**
>
> Some releases of MySQL introduce changes to the structure of the grant tables to add new privileges or features. To ensure that you can take advantage of any new capabilities, update your grant tables to have the current structure whenever you update to a new version of MySQL. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

In MySQL 5.1 and later, when the `read_only` system variable is enabled, account-management statements require the `SUPER` privilege, in addition to any other required privileges. This is because they modify tables in the `mysql` database.

13.7.1.1 CREATE USER Syntax

```
CREATE USER user_specification [, user_specification] ...

user_specification:
    user [ identified_option ]

identified_option: {
    IDENTIFIED BY 'auth_string'
```

```
    |  IDENTIFIED BY PASSWORD 'hash_string'
}
```

The `CREATE USER` statement creates new MySQL accounts. An error occurs if you try to create an account that already exists.

To use `CREATE USER`, you must have the global `CREATE USER` privilege or the `INSERT` privilege for the `mysql` database. In MySQL 5.1 and later, when the `read_only` system variable is enabled, `CREATE USER` additionally requires the `SUPER` privilege.

For each account, `CREATE USER` creates a new row in the `mysql.user` table with no privileges. Depending on the syntax used, `CREATE USER` may also assign the account a password.

Each `user_specification` clause consists of an account name and information about how authentication occurs for clients that use the account. This part of `CREATE USER` syntax is shared with `GRANT`, so the description here applies to `GRANT` as well.

Each account name uses the format described in Section 6.2.3, "Specifying Account Names". For example:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'mypass';
```

If you specify only the user name part of the account name, a host name part of `'%'` is used.

`CREATE USER` examples:

- To enable the user to connect with no password, include no `IDENTIFIED BY` clause:

  ```
  CREATE USER 'jeffrey'@'localhost';
  ```

- To assign a password, use `IDENTIFIED BY` with the literal cleartext password value:

  ```
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'mypass';
  ```

- To avoid specifying the cleartext password if you know its hash value (the value that `PASSWORD()` would return for the password), specify the hash value preceded by the keyword `PASSWORD`:

  ```
  CREATE USER 'jeffrey'@'localhost'
  IDENTIFIED BY PASSWORD '*90E462C37378CED12064BB3388827D2BA3A9B689';
  ```

For additional information about setting passwords, see Section 6.3.5, "Assigning Account Passwords".

> **Important**
>
> `CREATE USER` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, "Passwords and Logging". For similar information about client-side logging, see Section 4.5.1.3, "mysql Logging".

13.7.1.2 DROP USER Syntax

```
DROP USER user [, user] ...
```

The `DROP USER` statement removes one or more MySQL accounts and their privileges. It removes privilege rows for the account from all grant tables. An error occurs for accounts that do not exist.

To use `DROP USER`, you must have the global `CREATE USER` privilege or the `DELETE` privilege for the `mysql` database. In MySQL 5.1 and later, when the `read_only` system variable is enabled, `DROP USER` additionally requires the `SUPER` privilege.

Each account name uses the format described in Section 6.2.3, "Specifying Account Names". For example:

```
DROP USER 'jeffrey'@'localhost';
```

If you specify only the user name part of the account name, a host name part of `'%'` is used.

> **Important**
>
> `DROP USER` does not automatically close any open user sessions. Rather, in the event that a user with an open session is dropped, the statement does not take effect until that user's session is closed. Once the session is closed, the user is dropped, and that user's next attempt to log in will fail. *This is by design*.

`DROP USER` does not automatically drop or invalidate databases or objects within them that the old user created. This includes stored programs or views for which the `DEFINER` attribute names the dropped user. Attempts to access such objects may produce an error if they execute in definer security context. (For information about security context, see Section 19.6, "Access Control for Stored Programs and Views".)

13.7.1.3 GRANT Syntax

```
GRANT
    priv_type [(column_list)]
      [, priv_type [(column_list)]] ...
    ON [object_type] priv_level
    TO user_specification [, user_specification] ...
    [REQUIRE {NONE | tls_option [[AND] tls_option] ...}]
    [WITH {GRANT OPTION | resource_option} ...]

object_type: {
    TABLE
  | FUNCTION
  | PROCEDURE
}

priv_level: {
    *
  | *.*
  | db_name.*
  | db_name.tbl_name
  | tbl_name
  | db_name.routine_name
}

user_specification:
    user [ auth_option ]

auth_option: {
    IDENTIFIED BY 'auth_string'
  | IDENTIFIED BY PASSWORD 'hash_string'
}

tls_option: {
    SSL
  | X509
  | CIPHER 'cipher'
  | ISSUER 'issuer'
  | SUBJECT 'subject'
```

```
}

resource_option: {
  | MAX_QUERIES_PER_HOUR count
  | MAX_UPDATES_PER_HOUR count
  | MAX_CONNECTIONS_PER_HOUR count
  | MAX_USER_CONNECTIONS count
}
```

The `GRANT` statement grants privileges to MySQL user accounts. `GRANT` also serves to specify other account characteristics such as use of secure connections and limits on access to server resources.

To use `GRANT`, you must have the `GRANT OPTION` privilege, and you must have the privileges that you are granting. In MySQL 5.1 and later, when the `read_only` system variable is enabled, `GRANT` additionally requires the `SUPER` privilege.

The `REVOKE` statement is related to `GRANT` and enables administrators to remove account privileges. See Section 13.7.1.5, "REVOKE Syntax".

Normally, a database administrator first uses `CREATE USER` to create an account, then `GRANT` to define its privileges and characteristics. For example:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'mypass';
GRANT ALL ON db1.* TO 'jeffrey'@'localhost';
GRANT SELECT ON db2.invoice TO 'jeffrey'@'localhost';
GRANT USAGE ON *.* TO 'jeffrey'@'localhost' WITH MAX_QUERIES_PER_HOUR 90;
```

> **Note**
>
> Examples shown here include no `IDENTIFIED` clause. It is assumed that you establish passwords with `CREATE USER` at account-creation time to avoid creating insecure accounts.

If an account named in a `GRANT` statement does not already exist, `GRANT` may create it under the conditions described later in the discussion of the `NO_AUTO_CREATE_USER` SQL mode.

From the `mysql` program, `GRANT` responds with `Query OK, 0 rows affected` when executed successfully. To determine what privileges result from the operation, use `SHOW GRANTS`. See Section 13.7.5.22, "SHOW GRANTS Syntax".

There are several aspects to the `GRANT` statement, described under the following topics in this section:

- Privileges Supported by MySQL

- Global Privileges

- Database Privileges

- Table Privileges

- Column Privileges

- Stored Routine Privileges

- Account Names and Passwords

- Implicit Account Creation

- Other Account Characteristics

- MySQL and Standard SQL Versions of GRANT

`GRANT` supports host names up to 60 characters long. Database, table, column, and routine names can be up to 64 characters. User names can be up to 16 characters.

> **Warning**
>
> *The permissible length for user names cannot be changed by altering the `mysql.user` table. Attempting to do so results in unpredictable behavior which may even make it impossible for users to log in to the MySQL server.* You should never alter the structure of tables in the `mysql` database in any manner whatsoever except by means of the procedure described in Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

> **Important**
>
> `GRANT` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, "Passwords and Logging". For similar information about client-side logging, see Section 4.5.1.3, "mysql Logging".

Privileges Supported by MySQL

The following table summarizes the permissible `priv_type` privilege types that can be specified for the `GRANT` and `REVOKE` statements, and the levels at which each privilege can be granted. For additional information about these privileges, see Section 6.2.1, "Privileges Provided by MySQL".

Table 13.2 Permissible Privileges for GRANT and REVOKE

Privilege	Meaning and Grantable Levels
`ALL [PRIVILEGES]`	Grant all privileges at specified access level except `GRANT OPTION`
`ALTER`	Enable use of `ALTER TABLE`. Levels: Global, database, table.
`ALTER ROUTINE`	Enable stored routines to be altered or dropped. Levels: Global, database, procedure.
`CREATE`	Enable database and table creation. Levels: Global, database, table.
`CREATE ROUTINE`	Enable stored routine creation. Levels: Global, database.
`CREATE TEMPORARY TABLES`	Enable use of `CREATE TEMPORARY TABLE`. Levels: Global, database.
`CREATE USER`	Enable use of `CREATE USER`, `DROP USER`, `RENAME USER`, and `REVOKE ALL PRIVILEGES`. Level: Global.
`CREATE VIEW`	Enable views to be created or altered. Levels: Global, database, table.
`DELETE`	Enable use of `DELETE`. Level: Global, database, table.
`DROP`	Enable databases, tables, and views to be dropped. Levels: Global, database, table.
`EVENT`	Enable use of events for the Event Scheduler. Levels: Global, database.
`EXECUTE`	Enable the user to execute stored routines. Levels: Global, database, table.
`FILE`	Enable the user to cause the server to read or write files. Level: Global.
`GRANT OPTION`	Enable privileges to be granted to or removed from other accounts. Levels: Global, database, table, procedure.

Privilege	Meaning and Grantable Levels
`INDEX`	Enable indexes to be created or dropped. Levels: Global, database, table.
`INSERT`	Enable use of `INSERT`. Levels: Global, database, table, column.
`LOCK TABLES`	Enable use of `LOCK TABLES` on tables for which you have the `SELECT` privilege. Levels: Global, database.
`PROCESS`	Enable the user to see all processes with `SHOW PROCESSLIST`. Level: Global.
`REFERENCES`	Not implemented
`RELOAD`	Enable use of `FLUSH` operations. Level: Global.
`REPLICATION CLIENT`	Enable the user to ask where master or slave servers are. Level: Global.
`REPLICATION SLAVE`	Enable replication slaves to read binary log events from the master. Level: Global.
`SELECT`	Enable use of `SELECT`. Levels: Global, database, table, column.
`SHOW DATABASES`	Enable `SHOW DATABASES` to show all databases. Level: Global.
`SHOW VIEW`	Enable use of `SHOW CREATE VIEW`. Levels: Global, database, table.
`SHUTDOWN`	Enable use of `mysqladmin shutdown`. Level: Global.
`SUPER`	Enable use of other administrative operations such as `CHANGE MASTER TO`, `KILL`, `PURGE BINARY LOGS`, `SET GLOBAL`, and `mysqladmin debug` command. Level: Global.
`TRIGGER`	Enable trigger operations. Levels: Global, database, table.
`UPDATE`	Enable use of `UPDATE`. Levels: Global, database, table, column.
`USAGE`	Synonym for "no privileges"

The `EVENT` and `TRIGGER` privileges were added in MySQL 5.1.6. A trigger is associated with a table, so to create or drop a trigger, you must have the `TRIGGER` privilege for the table, not the trigger. (Before MySQL 5.1.6, the `SUPER` privilege was required to create or drop triggers.)

In `GRANT` statements, the `ALL [PRIVILEGES]` privilege is named by itself and cannot be specified along with other privileges. It stands for all privileges available for the level at which privileges are to be granted except for the `GRANT OPTION` privilege.

`USAGE` can be specified to create a user that has no privileges, or to specify the `REQUIRE` or `WITH` clauses for an account without changing its existing privileges.

MySQL account information is stored in the tables of the `mysql` database. For additional details, consult Section 6.2, "The MySQL Access Privilege System", which discusses the `mysql` database and the access control system extensively.

If the grant tables hold privilege rows that contain mixed-case database or table names and the `lower_case_table_names` system variable is set to a nonzero value, `REVOKE` cannot be used to revoke these privileges. It will be necessary to manipulate the grant tables directly. (`GRANT` will not create such rows when `lower_case_table_names` is set, but such rows might have been created prior to setting that variable.)

Privileges can be granted at several levels, depending on the syntax used for the `ON` clause. For `REVOKE`, the same `ON` syntax specifies which privileges to remove.

For the global, database, table, and routine levels, `GRANT ALL` assigns only the privileges that exist at the level you are granting. For example, `GRANT ALL ON db_name.*` is a database-level statement, so it

does not grant any global-only privileges such as `FILE`. Granting `ALL` does not assign the `GRANT OPTION` privilege.

The `object_type` clause, if present, should be specified as `TABLE`, `FUNCTION`, or `PROCEDURE` when the following object is a table, a stored function, or a stored procedure.

The privileges for a database, table, column, or routine are formed additively as the logical `OR` of the privileges at each of the privilege levels. For example, if a user has a global `SELECT` privilege, the privilege cannot be denied by an absence of the privilege at the database, table, or column level. Details of the privilege-checking procedure are presented in Section 6.2.5, "Access Control, Stage 2: Request Verification".

If you are using table, column, or routine privileges for even one user, the server examines table, column, and routine privileges for all users and this slows down MySQL a bit. Similarly, if you limit the number of queries, updates, or connections for any users, the server must monitor these values.

MySQL enables you to grant privileges on databases or tables that do not exist. For tables, the privileges to be granted must include the `CREATE` privilege. *This behavior is by design*, and is intended to enable the database administrator to prepare user accounts and privileges for databases or tables that are to be created at a later time.

> ⚠️ **Important**
>
> *MySQL does not automatically revoke any privileges when you drop a database or table*. However, if you drop a routine, any routine-level privileges granted for that routine are revoked.

Global Privileges

Global privileges are administrative or apply to all databases on a given server. To assign global privileges, use `ON *.*` syntax:

```
GRANT ALL ON *.* TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON *.* TO 'someuser'@'somehost';
```

Before MySQL 5.1.12, privileges also are assigned at the global level if you use `ON *` syntax and you have *not* selected a default database. As of 5.1.12, `ON *` requires a default database and produces an error if there is none.

The `CREATE USER`, `FILE`, `PROCESS`, `RELOAD`, `REPLICATION CLIENT`, `REPLICATION SLAVE`, `SHOW DATABASES`, `SHUTDOWN`, and `SUPER` privileges are administrative and can only be granted globally.

Other privileges can be granted globally or at more specific levels.

MySQL stores global privileges in the `mysql.user` table.

Database Privileges

Database privileges apply to all objects in a given database. To assign database-level privileges, use `ON db_name.*` syntax:

```
GRANT ALL ON mydb.* TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON mydb.* TO 'someuser'@'somehost';
```

If you use `ON *` syntax (rather than `ON *.*`) and you have selected a default database, privileges are assigned at the database level for the default database. An error occurs if there is no default database.

The `CREATE`, `DROP`, `EVENT`, `GRANT OPTION`, and `LOCK TABLES` privileges can be specified at the database level. Table or routine privileges also can be specified at the database level, in which case they apply to all tables or routines in the database.

MySQL stores database privileges in the `mysql.db` table.

Table Privileges

Table privileges apply to all columns in a given table. To assign table-level privileges, use `ON db_name.tbl_name` syntax:

```
GRANT ALL ON mydb.mytbl TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON mydb.mytbl TO 'someuser'@'somehost';
```

If you specify `tbl_name` rather than `db_name.tbl_name`, the statement applies to `tbl_name` in the default database. An error occurs if there is no default database.

The permissible `priv_type` values at the table level are `ALTER`, `CREATE VIEW`, `CREATE`, `DELETE`, `DROP`, `GRANT OPTION`, `INDEX`, `INSERT`, `SELECT`, `SHOW VIEW`, `TRIGGER`, and `UPDATE`.

MySQL stores table privileges in the `mysql.tables_priv` table.

Column Privileges

Column privileges apply to single columns in a given table. Each privilege to be granted at the column level must be followed by the column or columns, enclosed within parentheses.

```
GRANT SELECT (col1), INSERT (col1,col2) ON mydb.mytbl TO 'someuser'@'somehost';
```

The permissible `priv_type` values for a column (that is, when you use a `column_list` clause) are `INSERT`, `SELECT`, and `UPDATE`.

MySQL stores column privileges in the `mysql.columns_priv` table.

Stored Routine Privileges

The `ALTER ROUTINE`, `CREATE ROUTINE`, `EXECUTE`, and `GRANT OPTION` privileges apply to stored routines (procedures and functions). They can be granted at the global and database levels. Except for `CREATE ROUTINE`, these privileges can be granted at the routine level for individual routines.

```
GRANT CREATE ROUTINE ON mydb.* TO 'someuser'@'somehost';
GRANT EXECUTE ON PROCEDURE mydb.myproc TO 'someuser'@'somehost';
```

The permissible `priv_type` values at the routine level are `ALTER ROUTINE`, `EXECUTE`, and `GRANT OPTION`. `CREATE ROUTINE` is not a routine-level privilege because you must have this privilege to create a routine in the first place.

MySQL stores routine-level privileges in the `mysql.procs_priv` table.

Account Names and Passwords

The `user_specification` clause names a user and optionally provides authentication information such as a password.

The `user` value indicates the MySQL account to which the `GRANT` statement applies. To accommodate granting rights to users from arbitrary hosts, MySQL supports specifying the `user` value in the form

user_name@host_name. If a *user_name* or *host_name* value is legal as an unquoted identifier, you need not quote it. However, quotation marks are necessary to specify a *user_name* string containing special characters (such as "`-`"), or a *host_name* string containing special characters or wildcard characters (such as "`%`"); for example, `'test-user'@'%.com'`. Quote the user name and host name separately.

You can specify wildcards in the host name. For example, *user_name*`@'%.example.com'` applies to *user_name* for any host in the `example.com` domain, and *user_name*`@'192.168.1.%'` applies to *user_name* for any host in the `192.168.1` class C subnet.

The simple form *user_name* is a synonym for *user_name*`@'%'`.

MySQL does not support wildcards in user names. To refer to an anonymous user, specify an account with an empty user name with the `GRANT` statement:

```
GRANT ALL ON test.* TO ''@'localhost' ...;
```

In this case, any user who connects from the local host with the correct password for the anonymous user will be permitted access, with the privileges associated with the anonymous-user account.

For additional information about user name and host name values in account names, see Section 6.2.3, "Specifying Account Names".

To specify quoted values, quote database, table, column, and routine names as identifiers. Quote user names and host names as identifiers or as strings. Quote passwords as strings. For string-quoting and identifier-quoting guidelines, see Section 9.1.1, "String Literals", and Section 9.2, "Schema Object Names".

The "`_`" and "`%`" wildcards are permitted when specifying database names in `GRANT` statements that grant privileges at the global or database levels. This means, for example, that if you want to use a "`_`" character as part of a database name, you should specify it as "`\_`" in the `GRANT` statement, to prevent the user from being able to access additional databases matching the wildcard pattern; for example, `GRANT ... ON` `` `foo\_bar`.* TO .... ``

> ⊗ **Warning**
>
> If you permit anonymous users to connect to the MySQL server, you should also grant privileges to all local users as *user_name*`@localhost`. Otherwise, the anonymous user account for `localhost` in the `mysql.user` table (created during MySQL installation) is used when named users try to log in to the MySQL server from the local machine. For details, see Section 6.2.4, "Access Control, Stage 1: Connection Verification".

To determine whether the preceding warning applies to you, execute the following query, which lists any anonymous users:

```
SELECT Host, User FROM mysql.user WHERE User='';
```

To avoid the problem just described, delete the local anonymous user account using this statement:

```
DROP USER ''@'localhost';
```

To indicate how a user should authenticate when connecting to the server, the *user_specification* value may include an `IDENTIFIED` clause to specify a password. Syntax of the user specification is the same as for the `CREATE USER` statement. For details, see Section 13.7.1.1, "CREATE USER Syntax".

When `IDENTIFIED BY` is present and you have the global grant privilege (`GRANT OPTION`), the password becomes the new password for the account, even if the account exists and already has a password. Without `IDENTIFIED BY`, the account password remains unchanged.

If the `NO_AUTO_CREATE_USER` SQL mode is not enabled and the account named in a `GRANT` statement does not exist in the `mysql.user` table, `GRANT` creates it. If you specify no `IDENTIFIED BY` clause or provide an empty password, the user has no password. *This is very insecure.*

If `NO_AUTO_CREATE_USER` is enabled and the account does not exist, `GRANT` fails and does not create the account unless the `IDENTIFIED BY` clause is given to provide a nonempty password.

Other Account Characteristics

MySQL can check X509 certificate attributes in addition to the usual authentication that is based on the user name and credentials. For background information on the use of SSL with MySQL, see Section 6.4, "Using Secure Connections".

The optional `REQUIRE` clause specifies SSL-related options for a MySQL account, using one or more `tls_option` values.

Implicit Account Creation

`GRANT` permits these `tls_option` values:

- `NONE`

  Indicates that the account has no SSL or X509 requirements. Unencrypted connections are permitted if the user name and password are valid. However, encrypted connections can also be used, at the client's option, if the client has the proper certificate and key files. That is, the client need not specify any SSL command options, in which case the connection will be unencrypted. To use an encrypted connection, the client must specify either the `--ssl-ca` option, or all three of the `--ssl-ca`, `--ssl-key`, and `--ssl-cert` options.

  `NONE` is the default if no SSL-related `REQUIRE` options are specified.

- `SSL`

  Tells the server to permit only encrypted connections for the account.

  ```
  GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
    REQUIRE SSL;
  ```

  To connect, the client must specify the `--ssl-ca` option to authenticate the server certificate, and may additionally specify the `--ssl-key` and `--ssl-cert` options. If neither the `--ssl-ca` option nor `--ssl-capath` option is specified, the client does not authenticate the server certificate.

- `X509`

  Requires that the client must have a valid certificate but the exact certificate, issuer, and subject do not matter. The only requirement is that it should be possible to verify its signature with one of the CA certificates. Use of X509 certificates always implies encryption, so the `SSL` option is unnecessary in this case.

  ```
  GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
    REQUIRE X509;
  ```

The client must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.) This is true for `ISSUER` and `SUBJECT` as well because those `REQUIRE` options imply the requirements of `X509`.

- `ISSUER 'issuer'`

Places the restriction on connection attempts that the client must present a valid X509 certificate issued by CA `'issuer'`. If the client presents a certificate that is valid but has a different issuer, the server rejects the connection. Use of X509 certificates always implies encryption, so the `SSL` option is unnecessary in this case.

Because `ISSUER` implies the requirements of `X509`, the client must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.)

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  REQUIRE ISSUER '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL/CN=CA/emailAddress=ca@example.com';
```

> **Note**
>
> If MySQL is linked against a version of OpenSSL older than 0.9.6h, use `Email` rather than `emailAddress` in the `'issuer'` value.

- `SUBJECT 'subject'`

Places the restriction on connection attempts that the client must present a valid X509 certificate containing the subject `subject`. If the client presents a certificate that is valid but has a different subject, the server rejects the connection. Use of X509 certificates always implies encryption, so the `SSL` option is unnecessary in this case.

Because `SUBJECT` implies the requirements of `X509`, the client must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.)

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL demo client certificate/
    CN=client/emailAddress=client@example.com';
```

MySQL does a simple string comparison of the `'subject'` value to the value in the certificate, so lettercase and component ordering must be given exactly as present in the certificate.

> **Note**
>
> Regarding `emailAddress`, see the note in the description of `REQUIRE ISSUER`.

- `CIPHER 'cipher'`

Requests a specific cipher method for encrypting connections. This option is needed to ensure that ciphers and key lengths of sufficient strength are used. SSL itself can be weak if old algorithms using short encryption keys are used.

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
```

```
    REQUIRE CIPHER 'EDH-RSA-DES-CBC3-SHA';
```

The `SUBJECT`, `ISSUER`, and `CIPHER` options can be combined in the `REQUIRE` clause like this:

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL demo client certificate/
    CN=client/emailAddress=client@example.com'
  AND ISSUER '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL/CN=CA/emailAddress=ca@example.com'
  AND CIPHER 'EDH-RSA-DES-CBC3-SHA';
```

The order of the options does not matter, but no option can be specified twice. The `AND` keyword is optional between `REQUIRE` options.

The optional `WITH` clause is used for these purposes:

- To enable a user to grant privileges to other users

- To specify resource limits for a user

The `WITH GRANT OPTION` clause gives the user the ability to give to other users any privileges the user has at the specified privilege level.

To grant the `GRANT OPTION` privilege to an account without otherwise changing its privileges, do this:

```
GRANT USAGE ON *.* TO 'someuser'@'somehost' WITH GRANT OPTION;
```

Be careful to whom you give the `GRANT OPTION` privilege because two users with different privileges may be able to combine privileges!

You cannot grant another user a privilege which you yourself do not have; the `GRANT OPTION` privilege enables you to assign only those privileges which you yourself possess.

Be aware that when you grant a user the `GRANT OPTION` privilege at a particular privilege level, any privileges the user possesses (or may be given in the future) at that level can also be granted by that user to other users. Suppose that you grant a user the `INSERT` privilege on a database. If you then grant the `SELECT` privilege on the database and specify `WITH GRANT OPTION`, that user can give to other users not only the `SELECT` privilege, but also `INSERT`. If you then grant the `UPDATE` privilege to the user on the database, the user can grant `INSERT`, `SELECT`, and `UPDATE`.

For a nonadministrative user, you should not grant the `ALTER` privilege globally or for the `mysql` database. If you do that, the user can try to subvert the privilege system by renaming tables!

For additional information about security risks associated with particular privileges, see Section 6.2.1, "Privileges Provided by MySQL".

It is possible to place limits on use of server resources by an account, as discussed in Section 6.3.4, "Setting Account Resource Limits". To do so, use a `WITH` clause that specifies one or more `resource_option` values. Limits not specified retain their current values.

`GRANT` permits these `resource_option` values:

- `MAX_QUERIES_PER_HOUR count`, `MAX_UPDATES_PER_HOUR count`,
  `MAX_CONNECTIONS_PER_HOUR count`

These options restrict the number of queries, updates, and connections to the server permitted to this account during any given one-hour period. (Queries for which results are served from the query cache do not count against the `MAX_QUERIES_PER_HOUR` limit.) If *count* is `0` (the default), this means that there is no limitation for the account.

- `MAX_USER_CONNECTIONS` *count*

  Restricts the maximum number of simultaneous connections to the server by the account. A nonzero *count* specifies the limit for the account explicitly. If *count* is `0` (the default), the server determines the number of simultaneous connections for the account from the global value of the `max_user_connections` system variable. If `max_user_connections` is also zero, there is no limit for the account.

If a given resource limit is specified multiple times, the last instance takes precedence.

To specify resource limits for an existing user without affecting existing privileges, use `GRANT USAGE` at the global level (`ON *.*`) and name the limits to be changed. For example:

```
GRANT USAGE ON *.* TO ...
  WITH MAX_QUERIES_PER_HOUR 500 MAX_UPDATES_PER_HOUR 100;
```

MySQL and Standard SQL Versions of GRANT

The biggest differences between the MySQL and standard SQL versions of `GRANT` are:

- MySQL associates privileges with the combination of a host name and user name and not with only a user name.

- Standard SQL does not have global or database-level privileges, nor does it support all the privilege types that MySQL supports.

- MySQL does not support the standard SQL `UNDER` privilege.

- Standard SQL privileges are structured in a hierarchical manner. If you remove a user, all privileges the user has been granted are revoked. This is also true in MySQL if you use `DROP USER`. See Section 13.7.1.2, "DROP USER Syntax".

- In standard SQL, when you drop a table, all privileges for the table are revoked. In standard SQL, when you revoke a privilege, all privileges that were granted based on that privilege are also revoked. In MySQL, privileges can be dropped only with explicit `DROP USER` or `REVOKE` statements or by manipulating the MySQL grant tables directly.

- In MySQL, it is possible to have the `INSERT` privilege for only some of the columns in a table. In this case, you can still execute `INSERT` statements on the table, provided that you insert values only for those columns for which you have the `INSERT` privilege. The omitted columns are set to their implicit default values if strict SQL mode is not enabled. In strict mode, the statement is rejected if any of the omitted columns have no default value. (Standard SQL requires you to have the `INSERT` privilege on all columns.) For information about strict SQL mode and implicit default values, see Section 5.1.7, "Server SQL Modes", and Section 11.6, "Data Type Default Values".

13.7.1.4 RENAME USER Syntax

```
RENAME USER old_user TO new_user
    [, old_user TO new_user] ...
```

The `RENAME USER` statement renames existing MySQL accounts. An error occurs for old accounts that do not exist or new accounts that already exist.

To use `RENAME USER`, you must have the global `CREATE USER` privilege or the `UPDATE` privilege for the `mysql` database. In MySQL 5.1 and later, when the `read_only` system variable is enabled, `RENAME USER` additionally requires the `SUPER` privilege.

Each account name uses the format described in Section 6.2.3, "Specifying Account Names". For example:

```
RENAME USER 'jeffrey'@'localhost' TO 'jeff'@'127.0.0.1';
```

If you specify only the user name part of the account name, a host name part of `'%'` is used.

`RENAME USER` causes the privileges held by the old user to be those held by the new user. However, `RENAME USER` does not automatically drop or invalidate databases or objects within them that the old user created. This includes stored programs or views for which the `DEFINER` attribute names the old user. Attempts to access such objects may produce an error if they execute in definer security context. (For information about security context, see Section 19.6, "Access Control for Stored Programs and Views".)

The privilege changes take effect as indicated in Section 6.2.6, "When Privilege Changes Take Effect".

13.7.1.5 REVOKE Syntax

```
REVOKE
    priv_type [(column_list)]
      [, priv_type [(column_list)]] ...
    ON [object_type] priv_level
    FROM user [, user] ...

REVOKE ALL PRIVILEGES, GRANT OPTION
    FROM user [, user] ...
```

The `REVOKE` statement enables system administrators to revoke privileges from MySQL accounts.

In MySQL 5.1 and later, when the `read_only` system variable is enabled, `REVOKE` requires the `SUPER` privilege in addition to any other required privileges described in the following discussion.

Each account name uses the format described in Section 6.2.3, "Specifying Account Names". For example:

```
REVOKE INSERT ON *.* FROM 'jeffrey'@'localhost';
```

If you specify only the user name part of the account name, a host name part of `'%'` is used.

For details on the levels at which privileges exist, the permissible `priv_type` and `priv_level` values, and the syntax for specifying users and passwords, see Section 13.7.1.3, "GRANT Syntax"

To use the first `REVOKE` syntax, you must have the `GRANT OPTION` privilege, and you must have the privileges that you are revoking.

To revoke all privileges, use the second syntax, which drops all global, database, table, column, and routine privileges for the named user or users:

```
REVOKE ALL PRIVILEGES, GRANT OPTION FROM user [, user] ...
```

To use this REVOKE syntax, you must have the global CREATE USER privilege or the UPDATE privilege for the mysql database.

REVOKE removes privileges, but does not drop mysql.user table entries. To remove a user account entirely, use DROP USER (see Section 13.7.1.2, "DROP USER Syntax") or DELETE.

If the grant tables hold privilege rows that contain mixed-case database or table names and the lower_case_table_names system variable is set to a nonzero value, REVOKE cannot be used to revoke these privileges. It will be necessary to manipulate the grant tables directly. (GRANT will not create such rows when lower_case_table_names is set, but such rows might have been created prior to setting the variable.)

When successfully executed from the mysql program, REVOKE responds with Query OK, 0 rows affected. To determine what privileges result from the operation, use SHOW GRANTS. See Section 13.7.5.22, "SHOW GRANTS Syntax".

13.7.1.6 SET PASSWORD Syntax

```
SET PASSWORD [FOR user] = password_option

password_option: {
    PASSWORD('auth_string')
  | OLD_PASSWORD('auth_string')
  | 'hash_string'
}
```

The SET PASSWORD statement assigns a password to a MySQL user account, specified as either a cleartext (unencrypted) or encrypted value:

- `'auth_string'` represents a cleartext password.

- `'hash_string'` represents an encrypted password.

SET PASSWORD can be used with or without an explicitly named user account:

- With a FOR user clause, the statement sets the password for the named account, which must exist:

  ```
  SET PASSWORD FOR 'jeffrey'@'localhost' = password_option;
  ```

  In this case, you must have the UPDATE privilege for the mysql database.

- With no FOR user clause, the statement sets the password for the current user:

  ```
  SET PASSWORD = password_option;
  ```

  Any client who connects to the server using a nonanonymous account can change the password for that account. To see which account the server authenticated you as, invoke the CURRENT_USER() function:

  ```
  SELECT CURRENT_USER();
  ```

In MySQL 5.1 and later, when the read_only system variable is enabled, SET PASSWORD requires the SUPER privilege in addition to any other required privileges.

If a FOR user clause is given, the account name uses the format described in Section 6.2.3, "Specifying Account Names". The user value should be given as 'user_name'@'host_name', where

`'user_name'` and `'host_name'` are exactly as listed in the `User` and `Host` columns of the account's `mysql.user` table row. If you specify only a user name, a host name of `'%'` is used. For example, to set the password for an account with `User` and `Host` column values of `'bob'` and `'%.example.org'`, write the statement like this:

```
SET PASSWORD FOR 'bob'@'%.example.org' = PASSWORD('auth_string');
```

The password can be specified in these ways:

- Using the `PASSWORD()` function

  The `'auth_string'` function argument is the cleartext (unencrypted) password. `PASSWORD()` hashes the password and returns the encrypted password string for storage in the `mysql.user` account row.

  The `PASSWORD()` function hashes the password using the hashing method determined by the value of the `old_passwords` system variable value. For descriptions of the permitted values, see Section 5.1.4, "Server System Variables".

- Using the `OLD_PASSWORD()` function:

  The `'auth_string'` function argument is the cleartext (unencrypted) password. `OLD_PASSWORD()` hashes the password using pre-4.1 hashing and returns the encrypted password string for storage in the `mysql.user` account row.

- Using an already encrypted password string

  The password is specified as a string literal. It must represent the already encrypted password value, in the hash format required by the authentication method used for the account.

For more information about setting passwords, see Section 6.3.5, "Assigning Account Passwords".

> **Important**
>
> `SET PASSWORD` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, "Passwords and Logging". For similar information about client-side logging, see Section 4.5.1.3, "mysql Logging".

> **Caution**
>
> If you are connecting to a MySQL 4.1 or later server using a pre-4.1 client program, do not change your password without first reading Section 6.1.2.4, "Password Hashing in MySQL". The default password hashing format changed in MySQL 4.1, and if you change your password, it might be stored using a hashing format that pre-4.1 clients cannot generate, thus preventing you from connecting to the server afterward.

If you are using MySQL Replication, be aware that, currently, a password used by a replication slave as part of a `CHANGE MASTER TO` statement is effectively limited to 32 characters in length; if the password is longer, any excess characters are truncated. This is not due to any limit imposed by the MySQL Server generally, but rather is an issue specific to MySQL Replication. (For more information, see Bug #43439.)

13.7.2 Table Maintenance Statements

13.7.2.1 ANALYZE TABLE Syntax

```
ANALYZE [NO_WRITE_TO_BINLOG | LOCAL] TABLE
    tbl_name [, tbl_name] ...
```

`ANALYZE TABLE` analyzes and stores the key distribution for a table. During the analysis, the table is locked with a read lock for `InnoDB` and `MyISAM`. This statement works with `InnoDB`, `NDB`, and `MyISAM` tables. For `MyISAM` tables, this statement is equivalent to using `myisamchk --analyze`. This statement does not work with views.

For more information on how the analysis works within `InnoDB`, see Section 14.6.6.7, "Limits on InnoDB Tables".

MySQL uses the stored key distribution to decide the order in which tables should be joined when you perform a join on something other than a constant. In addition, key distributions can be used when deciding which indexes to use for a specific table within a query.

This statement requires `SELECT` and `INSERT` privileges for the table.

Beginning with MySQL 5.1.27, `ANALYZE TABLE` is also supported for partitioned tables. Also beginning with MySQL 5.1.27, you can use `ALTER TABLE ... ANALYZE PARTITION` to analyze one or more partitions; for more information, see Section 13.1.7, "ALTER TABLE Syntax", and Section 18.3.3, "Maintenance of Partitions".

`ANALYZE TABLE` returns a result set with the following columns.

Column	Value
`Table`	The table name
`Op`	Always `analyze`
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

You can check the stored key distribution with the `SHOW INDEX` statement. See Section 13.7.5.23, "SHOW INDEX Syntax".

If the table has not changed since the last `ANALYZE TABLE` statement, the table is not analyzed again.

By default, the server writes `ANALYZE TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

13.7.2.2 BACKUP TABLE Syntax

```
BACKUP TABLE tbl_name [, tbl_name] ... TO '/path/to/backup/directory'
```

Note

This statement is deprecated and is removed in MySQL 5.5. As an alternative, `mysqldump` or `mysqlhotcopy` can be used instead.

`BACKUP TABLE` copies to the backup directory the minimum number of table files needed to restore the table, after flushing any buffered changes to disk. The statement works only for `MyISAM` tables; it does not work for views. `BACKUP TABLE` works by copying the table's `.frm` definition and `.MYD` data files. The `.MYI` index file can be rebuilt from those two files. The directory should be specified as a full path name. To restore the table, use `RESTORE TABLE`.

During the backup, a read lock is held for each table, one at time, as they are being backed up. If you want to back up several tables as a snapshot (preventing any of them from being changed during the backup operation), issue a `LOCK TABLES` statement first, to obtain a read lock for all tables in the group.

`BACKUP TABLE` returns a result set with the following columns.

Column	Value
Table	The table name
Op	Always `backup`
Msg_type	`status`, `error`, `info`, `note`, or `warning`
Msg_text	An informational message

13.7.2.3 CHECK TABLE Syntax

```
CHECK TABLE tbl_name [, tbl_name] ... [option] ...

option = {
    FOR UPGRADE
  | QUICK
  | FAST
  | MEDIUM
  | EXTENDED
  | CHANGED
}
```

`CHECK TABLE` checks a table or tables for errors. `CHECK TABLE` works for `InnoDB`, `MyISAM`, and `ARCHIVE` tables. Starting with MySQL 5.1.9, `CHECK TABLE` is also valid for `CSV` tables, see Section 14.13, "The CSV Storage Engine". For `MyISAM` tables, the key statistics are updated as well.

`CHECK TABLE` can also check views for problems, such as tables that are referenced in the view definition that no longer exist.

Beginning with MySQL 5.1.27, `CHECK TABLE` is also supported for partitioned tables. Also beginning with MySQL 5.1.27, you can use `ALTER TABLE ... CHECK PARTITION` to check one or more partitions; for more information, see Section 13.1.7, "ALTER TABLE Syntax", and Section 18.3.3, "Maintenance of Partitions".

Output

`CHECK TABLE` returns a result set with the following columns.

Column	Value
Table	The table name
Op	Always `check`
Msg_type	`status`, `error`, `info`, `note`, or `warning`
Msg_text	An informational message

The statement might produce many rows of information for each checked table. The last row has a `Msg_type` value of `status` and the `Msg_text` normally should be `OK`. If you don't get `OK`, or `Table is already up to date` for a `MyISAM` table, you should normally run a repair of the table. See Section 7.6, "MyISAM Table Maintenance and Crash Recovery". `Table is already up to date` means that the storage engine for the table indicated that there was no need to check the table.

Checking Version Compatibility

The `FOR UPGRADE` option checks whether the named tables are compatible with the current version of MySQL. This option was added in MySQL 5.1.7. With `FOR UPGRADE`, the server checks each table to determine whether there have been any incompatible changes in any of the table's data types or indexes since the table was created. If not, the check succeeds. Otherwise, if there is a possible incompatibility, the server runs a full check on the table (which might take some time). If the full check succeeds, the server marks the table's `.frm` file with the current MySQL version number. Marking the `.frm` file ensures that further checks for the table with the same version of the server will be fast.

Incompatibilities might occur because the storage format for a data type has changed or because its sort order has changed. Our aim is to avoid these changes, but occasionally they are necessary to correct problems that would be worse than an incompatibility between releases.

`FOR UPGRADE` discovers these incompatibilities:

- The indexing order for end-space in `TEXT` columns for `InnoDB` and `MyISAM` tables changed between MySQL 4.1 and 5.0.

- The storage method of the new `DECIMAL` data type changed between MySQL 5.0.3 and 5.0.5.

- As of MySQL 5.1.25, if your table was created by a different version of the MySQL server than the one you are currently running, `FOR UPGRADE` indicates that the table has an `.frm` file with an incompatible version. In this case, the result set returned by `CHECK TABLE` contains a line with a `Msg_type` value of `error` and a `Msg_text` value of `Table upgrade required. Please do "REPAIR TABLE `tbl_name`" to fix it!`

- Changes are sometimes made to character sets or collations that require table indexes to be rebuilt. For details about these changes and when `FOR UPGRADE` detects them, see Section 2.13.3, "Checking Whether Tables or Indexes Must Be Rebuilt".

Checking Data Consistency

The following table shows the other check options that can be given. These options are passed to the storage engine, which may use them or not.

Type	Meaning
QUICK	Do not scan the rows to check for incorrect links. Applies to `InnoDB` and `MyISAM` tables and views.
FAST	Check only tables that have not been closed properly. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.
CHANGED	Check only tables that have been changed since the last check or that have not been closed properly. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.
MEDIUM	Scan rows to verify that deleted links are valid. This also calculates a key checksum for the rows and verifies this with a calculated checksum for the keys. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.
EXTENDED	Do a full key lookup for all keys for each row. This ensures that the table is 100% consistent, but takes a long time. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.

If none of the options `QUICK`, `MEDIUM`, or `EXTENDED` are specified, the default check type for dynamic-format `MyISAM` tables is `MEDIUM`. This has the same result as running `myisamchk --medium-check tbl_name` on the table. The default check type also is `MEDIUM` for static-format `MyISAM` tables, unless

`CHANGED` or `FAST` is specified. In that case, the default is `QUICK`. The row scan is skipped for `CHANGED` and `FAST` because the rows are very seldom corrupted.

You can combine check options, as in the following example that does a quick check on the table to determine whether it was closed properly:

```
CHECK TABLE test_table FAST QUICK;
```

> **Note**
>
> `CHECK TABLE` may change the table if the table is marked as "corrupted" or "not closed properly" but `CHECK TABLE` does not find any problems in the table. In this case, `CHECK TABLE` marks the table as okay.

If a table is corrupted, the problem is most likely in the indexes and not in the data part. All of the preceding check types check the indexes thoroughly and should thus find most errors.

If you just want to check a table that you assume is okay, you should use no check options or the `QUICK` option. The latter should be used when you are in a hurry and can take the very small risk that `QUICK` does not find an error in the data file. (In most cases, under normal usage, MySQL should find any error in the data file. If this happens, the table is marked as "corrupted" and cannot be used until it is repaired.)

`FAST` and `CHANGED` are mostly intended to be used from a script (for example, to be executed from `cron`) if you want to check tables from time to time. In most cases, `FAST` is to be preferred over `CHANGED`. (The only case when it is not preferred is when you suspect that you have found a bug in the `MyISAM` code.)

`EXTENDED` is to be used only after you have run a normal check but still get strange errors from a table when MySQL tries to update a row or find a row by key. This is very unlikely if a normal check has succeeded.

Use of `CHECK TABLE ... EXTENDED` might influence the execution plan generated by the query optimizer.

Some problems reported by `CHECK TABLE` cannot be corrected automatically:

- `Found row where the auto_increment column has the value 0`.

  This means that you have a row in the table where the `AUTO_INCREMENT` index column contains the value 0. (It is possible to create a row where the `AUTO_INCREMENT` column is 0 by explicitly setting the column to 0 with an `UPDATE` statement.)

  This is not an error in itself, but could cause trouble if you decide to dump the table and restore it or do an `ALTER TABLE` on the table. In this case, the `AUTO_INCREMENT` column changes value according to the rules of `AUTO_INCREMENT` columns, which could cause problems such as a duplicate-key error.

  To get rid of the warning, execute an `UPDATE` statement to set the column to some value other than 0.

InnoDB Details

The following notes apply to `InnoDB` tables:

- If `CHECK TABLE` encounters errors in `InnoDB` tables or indexes, it reports an error, and usually marks the index and sometimes marks the table as corrupted, preventing further use of the index or table.

- If `CHECK TABLE` encounters a corrupt page, the server exits to prevent error propagation (Bug #10132).

- If `CHECK TABLE` finds the wrong number of entries in a secondary index, it reports an error but does not cause a server exit or prevent access to the file.

- `CHECK TABLE` surveys the index page structure, then surveys each key entry. It does not validate the key pointer to a clustered record or follow the path for `BLOB` pointers.

- When an `InnoDB` table is stored in its own .ibd file in file-per-table mode, the first 3 pages of the `.ibd` contain header information rather than table or index data. The `CHECK TABLE` statement does not detect inconsistencies that affect only the header data. To verify the entire contents of an `InnoDB .ibd` file, use the `innochecksum` command.

- When running `CHECK TABLE` on large `InnoDB` tables, other threads may be blocked during `CHECK TABLE` execution. To avoid timeouts, the semaphore wait threshold (600 seconds) is extended by 2 hours (7200 seconds) for `CHECK TABLE` operations. If `InnoDB` detects semaphore waits of 240 seconds or more it starts printing `InnoDB` monitor output to the error log. If a lock request extends beyond the semaphore wait threshold, `InnoDB` will abort the process. To avoid the possibility of a semaphore wait timeout entirely, you can run `CHECK TABLE QUICK` instead of `CHECK TABLE`.

13.7.2.4 CHECKSUM TABLE Syntax

```
CHECKSUM TABLE tbl_name [, tbl_name] ... [ QUICK | EXTENDED ]
```

`CHECKSUM TABLE` reports a table checksum.

This statement is not supported for views. If you run `CHECKSUM TABLE` against a view, the `Checksum` column value is always `NULL`, and a warning is returned.

With `QUICK`, the live table checksum is reported if it is available, or `NULL` otherwise. This is very fast. A live checksum is enabled by specifying the `CHECKSUM=1` table option when you create the table; currently, this is supported only for `MyISAM` tables. See Section 13.1.17, "CREATE TABLE Syntax".

With `EXTENDED`, the entire table is read row by row and the checksum is calculated. This can be very slow for large tables.

If neither `QUICK` nor `EXTENDED` is specified, MySQL returns a live checksum if the table storage engine supports it and scans the table otherwise.

For a nonexistent table, `CHECKSUM TABLE` returns `NULL` and generates a warning.

In MySQL 5.1, `CHECKSUM TABLE` returns 0 for partitioned tables unless you include the `EXTENDED` option. This issue is resolved in MySQL 5.6. (Bug #11933226, Bug #60681)

The checksum value depends on the table row format. If the row format changes, the checksum also changes. For example, the storage format for `VARCHAR` changed between MySQL 4.1 and 5.0, so if a 4.1 table is upgraded to MySQL 5.0, the checksum value may change.

Important

If the checksums for two tables are different, then it is almost certain that the tables are different in some way. However, because the hashing function used by `CHECKSUM TABLE` is not guaranteed to be collision-free, there is a slight chance that two tables which are not identical can produce the same checksum.

13.7.2.5 OPTIMIZE TABLE Syntax

```
OPTIMIZE [NO_WRITE_TO_BINLOG | LOCAL] TABLE
    tbl_name [, tbl_name] ...
```

Reorganizes the physical storage of table data and associated index data, to reduce storage space and improve I/O efficiency when accessing the table. The exact changes made to each table depend on the storage engine used by that table. This statement does not work with views.

Use `OPTIMIZE TABLE` in these cases, depending on the type of table:

- After doing substantial insert, update, or delete operations on an `InnoDB` table that has its own `.ibd file` because it was created with the `innodb_file_per_table` option enabled. The table and indexes are reorganized, and disk space can be reclaimed for use by the operating system.

- After deleting a large part of a `MyISAM` or `ARCHIVE` table, or making many changes to a `MyISAM` or `ARCHIVE` table with variable-length rows (tables that have `VARCHAR`, `VARBINARY`, `BLOB`, or `TEXT` columns). Deleted rows are maintained in a linked list and subsequent `INSERT` operations reuse old row positions. You can use `OPTIMIZE TABLE` to reclaim the unused space and to defragment the data file. After extensive changes to a table, this statement may also improve performance of statements that use the table, sometimes significantly.

This statement requires `SELECT` and `INSERT` privileges for the table.

Beginning with MySQL 5.1.27, `OPTIMIZE TABLE` is also supported for partitioned tables. For information about using this statement with partitioned tables and table partitions, see Section 18.3.3, "Maintenance of Partitions".

`OPTIMIZE TABLE` works for `MyISAM`, `InnoDB`, and `ARCHIVE` tables. Beginning with MySQL Cluster NDB 6.3.7, `OPTIMIZE TABLE` is also supported for dynamic columns of in-memory `NDB` tables. It does not work for Disk Data tables. The performance of `OPTIMIZE` on Cluster tables can be tuned by adjusting the value of the `ndb_optimization_delay` system variable, which controls the number of milliseconds to wait between processing batches of rows by `OPTIMIZE TABLE`. For more information, see Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x".

Beginning with MySQL Cluster NDB 6.3.8, `OPTIMIZE TABLE` can be interrupted by (for example) killing the SQL thread performing the `OPTIMIZE` operation.

By default, `OPTIMIZE TABLE` does *not* work for tables created using any other storage engine and returns a result indicating this lack of support. You can make `OPTIMIZE TABLE` work for other storage engines by starting `mysqld` with the `--skip-new` option. In this case, `OPTIMIZE TABLE` is just mapped to `ALTER TABLE`.

For `MyISAM` tables, `OPTIMIZE TABLE` works as follows:

1. If the table has deleted or split rows, repair the table.

2. If the index pages are not sorted, sort them.

3. If the table's statistics are not up to date (and the repair could not be accomplished by sorting the index), update them.

For `InnoDB` tables, `OPTIMIZE TABLE` is mapped to `ALTER TABLE`, which rebuilds the table to update index statistics and free unused space in the clustered index. Beginning with MySQL 5.1.27, this is displayed in the output of `OPTIMIZE TABLE` when you run it on an `InnoDB` table, as shown here:

```
mysql> OPTIMIZE TABLE foo;
+----------+----------+----------+-------------------------------------------------------------------+
| Table    | Op       | Msg_type | Msg_text                                                          |
+----------+----------+----------+-------------------------------------------------------------------+
```

```
| test.foo | optimize | note     | Table does not support optimize, doing recreate + analyze instead |
| test.foo | optimize | status   | OK                                                                |
+----------+----------+----------+-------------------------------------------------------------------+
```

You can make `OPTIMIZE TABLE` work on other storage engines by starting `mysqld --skip-new` option. In this case, `OPTIMIZE TABLE` is just mapped to `ALTER TABLE`.

`OPTIMIZE TABLE` returns a result set with the following columns.

Column	Value
`Table`	The table name
`Op`	Always `optimize`
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

Note that MySQL locks the table during the time `OPTIMIZE TABLE` is running.

By default, the server writes `OPTIMIZE TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

`OPTIMIZE TABLE` does not sort R-tree indexes, such as spatial indexes on `POINT` columns. (Bug #23578)

As of MySQL 5.1.50, `OPTIMIZE TABLE` table catches and throws any errors that occur while copying table statistics from the old file to the newly created file. For example. if the user ID of the owner of the `.frm`, `.MYD`, or `.MYI` file is different from the user ID of the `mysqld` process, `OPTIMIZE TABLE` generates a "cannot change ownership of the file" error unless `mysqld` is started by the `root` user.

13.7.2.6 REPAIR TABLE Syntax

```
REPAIR [NO_WRITE_TO_BINLOG | LOCAL] TABLE
    tbl_name [, tbl_name] ...
    [QUICK] [EXTENDED] [USE_FRM]
```

`REPAIR TABLE` repairs a possibly corrupted table. By default, it has the same effect as `myisamchk --recover tbl_name`. `REPAIR TABLE` works for `MyISAM` and for `ARCHIVE` tables. Starting with MySQL 5.1.9, `REPAIR` is also valid for `CSV` tables. See Section 14.5, "The MyISAM Storage Engine", Section 14.12, "The ARCHIVE Storage Engine", and Section 14.13, "The CSV Storage Engine". This statement does not work with views.

This statement requires `SELECT` and `INSERT` privileges for the table.

Beginning with MySQL 5.1.27, `REPAIR TABLE` is also supported for partitioned tables. However, the `USE_FRM` option cannot be used with this statement on a partitioned table.

Also beginning with MySQL 5.1.27, you can use `ALTER TABLE ... REPAIR PARTITION` to repair one or more partitions; for more information, see Section 13.1.7, "ALTER TABLE Syntax", and Section 18.3.3, "Maintenance of Partitions".

Normally, you should never have to run `REPAIR TABLE`. However, if disaster strikes, this statement is very likely to get back all your data from a `MyISAM` table. If your tables become corrupted often, you should try to find the reason for it, to eliminate the need to use `REPAIR TABLE`. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing", and Section 14.5.4, "MyISAM Table Problems".

Caution

It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors. See Chapter 7, *Backup and Recovery*.

Warning

If the server crashes during a `REPAIR TABLE` operation, it is essential after restarting it that you immediately execute another `REPAIR TABLE` statement for the table before performing any other operations on it. In the worst case, you might have a new clean index file without information about the data file, and then the next operation you perform could overwrite the data file. This is an unlikely but possible scenario that underscores the value of making a backup first.

`REPAIR TABLE` returns a result set with the following columns.

Column	Value
`Table`	The table name
`Op`	Always `repair`
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

The `REPAIR TABLE` statement might produce many rows of information for each repaired table. The last row has a `Msg_type` value of `status` and `Msg_test` normally should be `OK`. If you do not get `OK` for a `MyISAM` table, you should try repairing it with `myisamchk --safe-recover`. (`REPAIR TABLE` does not implement all the options of `myisamchk`.) With `myisamchk --safe-recover`, you can also use options that `REPAIR TABLE` does not support, such as `--max-record-length`.

If you use the `QUICK` option, `REPAIR TABLE` tries to repair only the index file, and not the data file. This type of repair is like that done by `myisamchk --recover --quick`.

If you use the `EXTENDED` option, MySQL creates the index row by row instead of creating one index at a time with sorting. This type of repair is like that done by `myisamchk --safe-recover`.

The `USE_FRM` option is available for use if the `.MYI` index file is missing or if its header is corrupted. This option tells MySQL not to trust the information in the `.MYI` file header and to re-create it using information from the `.frm` file. This kind of repair cannot be done with `myisamchk`.

Note

Use the `USE_FRM` option *only* if you cannot use regular `REPAIR` modes! Telling the server to ignore the `.MYI` file makes important table metadata stored in the `.MYI` unavailable to the repair process, which can have deleterious consequences:

- The current `AUTO_INCREMENT` value is lost.

- The link to deleted records in the table is lost, which means that free space for deleted records will remain unoccupied thereafter.

- The `.MYI` header indicates whether the table is compressed. If the server ignores this information, it cannot tell that a table is compressed and repair can cause change or loss of table contents. This means that `USE_FRM` should not be used

> with compressed tables. That should not be necessary, anyway: Compressed tables are read only, so they should not become corrupt.

> **Caution**
>
> As of MySQL 5.1.25, if you use `USE_FRM` for a table that was created by a different version of the MySQL server than the one you are currently running, `REPAIR TABLE` will not attempt to repair the table. In this case, the result set returned by `REPAIR TABLE` contains a line with a `Msg_type` value of `error` and a `Msg_text` value of `Failed repairing incompatible .FRM file`.
>
> Prior to MySQL 5.1.25, *do not use* `USE_FRM` if your table was created by a different version of the MySQL server. Doing so risks the loss of all rows in the table. It is particularly dangerous to use `USE_FRM` after the server returns this message:
>
> ```
> Table upgrade required. Please do
> "REPAIR TABLE `tbl_name`"
> or dump/reload to fix it!
> ```

If `USE_FRM` is *not* used, `REPAIR TABLE` checks the table to see whether an upgrade is required. If so, it performs the upgrade, following the same rules as `CHECK TABLE ... FOR UPGRADE`. See Section 13.7.2.3, "CHECK TABLE Syntax", for more information. As of MySQL 5.1.25, `REPAIR TABLE` without `USE_FRM` upgrades the `.frm` file to the current version.

By default, the server writes `REPAIR TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

> **Important**
>
> In the event that a table on the master becomes corrupted and you run `REPAIR TABLE` on it, any resulting changes to the original table are *not* propagated to slaves.

You may be able to increase `REPAIR TABLE` performance by setting certain system variables. See Section 8.5.3, "Speed of REPAIR TABLE Statements".

As of MySQL 5.1.50, `REPAIR TABLE` table catches and throws any errors that occur while copying table statistics from the old corrupted file to the newly created file. For example. if the user ID of the owner of the `.frm`, `.MYD`, or `.MYI` file is different from the user ID of the `mysqld` process, `REPAIR TABLE` generates a "cannot change ownership of the file" error unless `mysqld` is started by the `root` user.

13.7.2.7 RESTORE TABLE Syntax

```
RESTORE TABLE tbl_name [, tbl_name] ... FROM '/path/to/backup/directory'
```

> **Note**
>
> This statement is deprecated and is removed in MySQL 5.5.

`RESTORE TABLE` restores the table or tables from a backup that was made with `BACKUP TABLE`. The directory should be specified as a full path name.

Existing tables are not overwritten; if you try to restore over an existing table, an error occurs. Just as for `BACKUP TABLE`, `RESTORE TABLE` currently works only for `MyISAM` tables. Restored tables are not

replicated from master to slave. If there is an existing view of the same name, the view is overwritten (views cannot be backed up using `BACKUP TABLE`).

The backup for each table consists of its `.frm` format file and `.MYD` data file. The restore operation restores those files, and then uses them to rebuild the `.MYI` index file. Restoring takes longer than backing up due to the need to rebuild the indexes. The more indexes the table has, the longer it takes.

`RESTORE TABLE` returns a result set with the following columns.

Column	Value
`Table`	The table name
`Op`	Always `restore`
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

13.7.3 Plugin and User-Defined Function Statements

13.7.3.1 CREATE FUNCTION Syntax for User-Defined Functions

```
CREATE [AGGREGATE] FUNCTION function_name RETURNS {STRING|INTEGER|REAL|DECIMAL}
    SONAME shared_library_name
```

A user-defined function (UDF) is a way to extend MySQL with a new function that works like a native (built-in) MySQL function such as `ABS()` or `CONCAT()`.

`function_name` is the name that should be used in SQL statements to invoke the function. The `RETURNS` clause indicates the type of the function's return value. `DECIMAL` is a legal value after `RETURNS`, but currently `DECIMAL` functions return string values and should be written like `STRING` functions.

`shared_library_name` is the base name of the shared object file that contains the code that implements the function. The file must be located in the plugin directory. This directory is given by the value of the `plugin_dir` system variable.

> **Note**
>
> This is a change in MySQL 5.1. For earlier versions of MySQL, the shared object can be located in any directory that is searched by your system's dynamic linker. For more information, see Section 22.3.2.5, "UDF Compiling and Installing".

To create a function, you must have the `INSERT` privilege for the `mysql` database. This is necessary because `CREATE FUNCTION` adds a row to the `mysql.func` system table that records the function's name, type, and shared library name. If you do not have this table, you should run the `mysql_upgrade` command to create it. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

An active function is one that has been loaded with `CREATE FUNCTION` and not removed with `DROP FUNCTION`. All active functions are reloaded each time the server starts, unless you start `mysqld` with the `--skip-grant-tables` option. In this case, UDF initialization is skipped and UDFs are unavailable.

For instructions on writing user-defined functions, see Section 22.3.2, "Adding a New User-Defined Function". For the UDF mechanism to work, functions must be written in C or C++ (or another language that can use C calling conventions), your operating system must support dynamic loading and you must have compiled `mysqld` dynamically (not statically).

An `AGGREGATE` function works exactly like a native MySQL aggregate (summary) function such as `SUM` or `COUNT()`. For `AGGREGATE` to work, your `mysql.func` table must contain a `type` column. If your `mysql.func` table does not have this column, you should run the `mysql_upgrade` program to create it (see Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables").

> **Note**
>
> To upgrade the shared library associated with a UDF, issue a `DROP FUNCTION` statement, upgrade the shared library, and then issue a `CREATE FUNCTION` statement. If you upgrade the shared library first and then use `DROP FUNCTION`, the server may crash.

13.7.3.2 DROP FUNCTION Syntax

```
DROP FUNCTION function_name
```

This statement drops the user-defined function (UDF) named *function_name*.

To drop a function, you must have the `DELETE` privilege for the `mysql` database. This is because `DROP FUNCTION` removes a row from the `mysql.func` system table that records the function's name, type, and shared library name.

> **Note**
>
> To upgrade the shared library associated with a UDF, issue a `DROP FUNCTION` statement, upgrade the shared library, and then issue a `CREATE FUNCTION` statement. If you upgrade the shared library first and then use `DROP FUNCTION`, the server may crash.

`DROP FUNCTION` is also used to drop stored functions (see Section 13.1.26, "DROP PROCEDURE and DROP FUNCTION Syntax").

13.7.3.3 INSTALL PLUGIN Syntax

```
INSTALL PLUGIN plugin_name SONAME 'shared_library_name'
```

This statement installs a server plugin. It requires the `INSERT` privilege for the `mysql.plugin` table.

plugin_name is the name of the plugin as defined in the plugin descriptor structure contained in the library file (see Section 22.2.4.2, "Plugin Data Structures"). Plugin names are not case sensitive. For maximal compatibility, plugin names should be limited to ASCII letters, digits, and underscore because they are used in C source files, shell command lines, M4 and Bourne shell scripts, and SQL environments.

shared_library_name is the name of the shared library that contains the plugin code. The name includes the file name extension (for example, `libmyplugin.so`, `libmyplugin.dll`, or `libmyplugin.dylib`).

The shared library must be located in the plugin directory (the directory named by the `plugin_dir` system variable). The library must be in the plugin directory itself, not in a subdirectory. By default, `plugin_dir` is the `plugin` directory under the directory named by the `pkglibdir` configuration variable, but it can be changed by setting the value of `plugin_dir` at server startup. For example, set its value in a `my.cnf` file:

```
[mysqld]
plugin_dir=/path/to/plugin/directory
```

If the value of `plugin_dir` is a relative path name, it is taken to be relative to the MySQL base directory (the value of the `basedir` system variable).

`INSTALL PLUGIN` loads and initializes the plugin code to make the plugin available for use. A plugin is initialized by executing its initialization function, which handles any setup that the plugin must perform before it can be used. When the server shuts down, it executes the deinitialization function for each plugin that is loaded so that the plugin has a chance to perform any final cleanup.

`INSTALL PLUGIN` also registers the plugin by adding a line that indicates the plugin name and library file name to the `mysql.plugin` table. At server startup, the server loads and initializes any plugin that is listed in the `mysql.plugin` table. This means that a plugin is installed with `INSTALL PLUGIN` only once, not every time the server starts. Plugin loading at startup does not occur if the server is started with the `--skip-grant-tables` option.

A plugin library can contain multiple plugins. For each of them to be installed, use a separate `INSTALL PLUGIN` statement. Each statement names a different plugin, but all of them specify the same library name.

As of MySQL 5.1.33, `INSTALL PLUGIN` causes the server to read option (`my.cnf`) files just as during server startup. This enables the plugin to pick up any relevant options from those files. It is possible to add plugin options to an option file even before loading a plugin (if the `loose` prefix is used). It is also possible to uninstall a plugin, edit `my.cnf`, and install the plugin again. Restarting the plugin this way enables it to the new option values without a server restart.

Before MySQL 5.1.33, a plugin is started with each option set to its default value.

For options that control individual plugin loading at server startup, see Section 5.1.8.1, "Installing and Uninstalling Plugins". If you need to load plugins for a single server startup when the `--skip-grant-tables` option is given (which tells the server not to read system tables), use the `--plugin-load` option. See Section 5.1.3, "Server Command Options".

To remove a plugin, use the `UNINSTALL PLUGIN` statement.

For additional information about plugin loading, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

To see what plugins are installed, use the `SHOW PLUGINS` statement or query the `INFORMATION_SCHEMA.PLUGINS` table.

If you recompile a plugin library and need to reinstall it, you can use either of the following methods:

- Use `UNINSTALL PLUGIN` to uninstall all plugins in the library, install the new plugin library file in the plugin directory, and then use `INSTALL PLUGIN` to install all plugins in the library. This procedure has the advantage that it can be used without stopping the server. However, if the plugin library contains many plugins, you must issue many `INSTALL PLUGIN` and `UNINSTALL PLUGIN` statements.

- Stop the server, install the new plugin library file in the plugin directory, and restart the server.

13.7.3.4 UNINSTALL PLUGIN Syntax

```
UNINSTALL PLUGIN plugin_name
```

This statement removes an installed server plugin. It requires the `DELETE` privilege for the `mysql.plugin` table. `UNINSTALL PLUGIN` is the complement of `INSTALL PLUGIN`.

`plugin_name` must be the name of some plugin that is listed in the `mysql.plugin` table. The server executes the plugin's deinitialization function and removes the row for the plugin from the `mysql.plugin`

table, so that subsequent server restarts will not load and initialize the plugin. `UNINSTALL PLUGIN` does not remove the plugin's shared library file.

You cannot uninstall a plugin if any table that uses it is open.

Plugin removal has implications for the use of associated tables. For example, if a full-text parser plugin is associated with a `FULLTEXT` index on the table, uninstalling the plugin makes the table unusable. Any attempt to access the table results in an error. The table cannot even be opened, so you cannot drop an index for which the plugin is used. This means that uninstalling a plugin is something to do with care unless you do not care about the table contents. If you are uninstalling a plugin with no intention of reinstalling it later and you care about the table contents, you should dump the table with `mysqldump` and remove the `WITH PARSER` clause from the dumped `CREATE TABLE` statement so that you can reload the table later. If you do not care about the table, `DROP TABLE` can be used even if any plugins associated with the table are missing.

For additional information about plugin loading, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

13.7.4 SET Syntax

The `SET` statement has several forms:

- `SET var_name = value` enables you to assign values to variables that affect the operation of the server or clients. See Section 13.7.4.1, "SET Syntax for Variable Assignment".

- `SET CHARACTER SET` and `SET NAMES` assign values to character set and collation variables associated with the current connection to the server. See Section 13.7.4.2, "SET CHARACTER SET Syntax", and Section 13.7.4.3, "SET NAMES Syntax".

- `SET PASSWORD` assigns account passwords. See Section 13.7.1.6, "SET PASSWORD Syntax".

- `SET TRANSACTION ISOLATION LEVEL` sets the isolation level for transaction processing. See Section 13.3.6, "SET TRANSACTION Syntax".

13.7.4.1 SET Syntax for Variable Assignment

```
SET variable_assignment [, variable_assignment] ...

variable_assignment:
      user_var_name = expr
    | param_name = expr
    | local_var_name = expr
    | [GLOBAL | SESSION]
        system_var_name = expr
    | [@@global. | @@session. | @@]
        system_var_name = expr

SET ONE_SHOT system_var_name = expr
```

`SET` syntax for variable assignment enables you to assign values to different types of variables that affect the operation of the server or clients:

- System variables. See Section 5.1.4, "Server System Variables". System variables also can be set at server startup, as described in Section 5.1.5, "Using System Variables". (To *display* system variables names and values, use the `SHOW VARIABLES` statement; see Section 13.7.5.41, "SHOW VARIABLES Syntax".)

- User-defined variables. See Section 9.4, "User-Defined Variables".

- Stored procedure and function parameters, and stored program local variables. See Section 13.6.4, "Variables in Stored Programs".

Older versions of MySQL employed SET OPTION, but this syntax is deprecated in favor of SET without OPTION.

A SET statement that assigns variable values is not written to the binary log, so it affects only the host on which you execute it in replication scenarios. To affect all replication hosts, execute the statement on each one.

The following discussion shows the different SET syntaxes for setting variables. The examples use the = assignment operator, but the := assignment operator is also permitted for this purpose.

A user variable is written as @var_name and can be set as follows:

```
SET @var_name = expr;
```

Examples:

```
SET @name = 43;
SET @total_tax = (SELECT SUM(tax) FROM taxable_transactions);
```

The expr can range from simple (a literal value) to more complex (the value returned by a scalar subquery).

SET applies to parameters and local variables within the context of the stored object within which they are defined. The following procedure uses the counter local variable as a loop counter:

```
CREATE PROCEDURE p()
BEGIN
  DECLARE counter INT DEFAULT 0;
  WHILE counter < 10 DO
    -- ... do work ...
    SET counter = counter + 1;
  END WHILE;
END;
```

Many system variables are dynamic and can be changed at runtime by using the SET statement. For a list, see Section 5.1.5.2, "Dynamic System Variables". To change a system variable with SET, refer to it by name, optionally preceded by a modifier:

- To indicate that a variable is a global variable, precede its name by the GLOBAL keyword or the @@global. qualifier:

```
SET GLOBAL max_connections = 1000;
SET @@global.max_connections = 1000;
```

The SUPER privilege is required to set global variables.

- To indicate that a variable is a session variable, precede its name by the SESSION keyword or either the @@session. or @@ qualifier:

```
SET SESSION sql_mode = 'TRADITIONAL';
SET @@session.sql_mode = 'TRADITIONAL';
SET @@sql_mode = 'TRADITIONAL';
```

Setting a session variable normally requires no special privilege, although there are exceptions that require the SUPER privilege (such as sql_log_bin). A client can change its own session variables, but not those of any other client.

- LOCAL and @@local. are synonyms for SESSION and @@session..

- If no modifier is present, SET changes the session variable. If the variable has no session value, an error occurs.

```
mysql> SET max_connections = 1000;
ERROR 1229 (HY000): Variable 'max_connections' is a
GLOBAL variable and should be set with SET GLOBAL
```

- An error occurs if you:

  - Use SET GLOBAL (or @@global.) when setting a variable that has only a session value

  - Omit GLOBAL (or @@global.) or PERSIST (or @@persist.) when setting a variable that has only a global value

  - Use SET SESSION (or @@SESSION.) when setting a variable that has only a global value

The preceding modifiers apply only to system variables. It is not permitted to apply them to user-defined variables, stored procedure or function parameters, or stored program local variables. An error occurs for such attempts.

A SET statement can contain multiple variable assignments, separated by commas. This statement assigns values to a user-defined variable and a system variable:

```
SET @x = 1, SESSION sql_mode = '';
```

If you set multiple system variables, the most recent GLOBAL or SESSION modifier in the statement is used for following assignments that have no modifier specified.

Examples of multiple-variable assignment:

```
SET GLOBAL sort_buffer_size = 1000000, SESSION sort_buffer_size = 1000000;
SET @@global.sort_buffer_size = 1000000, @@local.sort_buffer_size = 1000000;
SET GLOBAL max_connections = 1000, sort_buffer_size = 1000000;
```

If any variable assignment in a SET statement fails, the entire statement fails and no variables are changed.

If you change a session system variable, the value remains in effect within your session until you change the variable to a different value or the session ends. The change has no effect on other sessions.

If you change a global system variable, the value is remembered and used for new connections until you change the variable to a different value or the server restarts. The change is visible to any client that accesses the global variable. However, the change affects the corresponding session variable only for clients that connect after the change. The global variable change does not affect the session variable for any client that is currently connected (not even the session within which the SET GLOBAL statement occurred).

To make a global system variable setting permanent so that it applies across server restarts, you should also set it in an option file.

To set a GLOBAL value to the compiled-in MySQL default value or a SESSION variable to the current corresponding GLOBAL value, set the variable to the value DEFAULT. For example, the following two statements are identical in setting the session value of max_join_size to the current global value:

```
SET @@session.max_join_size=DEFAULT;
SET @@session.max_join_size=@@global.max_join_size;
```

Not all system variables can be set to DEFAULT. In such cases, assigning DEFAULT results in an error.

It is not permitted to assign DEFAULT to user-defined variables, and not supported for stored procedure or function parameters or stored program local variables. This results in an error for user-defined variables, and the results are undefined for parameters or local variables.

To refer to the value of a system variable in expressions, use one of the @@-modifiers. For example, you can retrieve values in a SELECT statement like this:

```
SELECT @@global.sql_mode, @@session.sql_mode, @@sql_mode;
```

When you refer to a system variable in an expression as @@var_name (that is, when you do not specify @@global. or @@session.), MySQL returns the session value if it exists and the global value otherwise. This differs from SET @@var_name = value, which always refers to the session value.

The SET ONE_SHOT syntax is *only* for internal use for replication: mysqlbinlog uses SET ONE_SHOT to modify temporarily the values of character set, collation, and time zone variables to reflect at rollforward what they were originally. ONE_SHOT is for internal use only and is deprecated for MySQL 5.0 and up.

ONE_SHOT is intended for use only with the permitted set of variables. With other variables, an error occurs:

```
mysql> SET ONE_SHOT max_allowed_packet = 1;
ERROR 1382 (HY000): The 'SET ONE_SHOT' syntax is reserved for purposes
internal to the MySQL server
```

If ONE_SHOT is used with the permitted variables, it changes the variables as requested, but only for the next non-SET statement. After that, the server resets all character set, collation, and time zone-related system variables to their previous values. Example:

```
mysql> SET ONE_SHOT character_set_connection = latin5;

mysql> SET ONE_SHOT collation_connection = latin5_turkish_ci;

mysql> SHOW VARIABLES LIKE '%_connection';
+--------------------------+-------------------+
| Variable_name            | Value             |
+--------------------------+-------------------+
| character_set_connection | latin5            |
| collation_connection     | latin5_turkish_ci |
+--------------------------+-------------------+

mysql> SHOW VARIABLES LIKE '%_connection';
+--------------------------+-------------------+
| Variable_name            | Value             |
+--------------------------+-------------------+
| character_set_connection | latin1            |
| collation_connection     | latin1_swedish_ci |
+--------------------------+-------------------+
```

13.7.4.2 SET CHARACTER SET Syntax

```
SET {CHARACTER SET | CHARSET}
    {charset_name | DEFAULT}
```

This statement maps all strings sent between the server and the current client with the given mapping.
SET CHARACTER SET sets three session system variables: character_set_client and
character_set_results are set to the given character set, and character_set_connection to the
value of character_set_database. See Section 10.1.4, "Connection Character Sets and Collations".

The default character set mapping can be restored by using the value DEFAULT. The default depends on
the server configuration.

ucs2 cannot be used as a client character set, which means that it does not work for SET CHARACTER
SET.

13.7.4.3 SET NAMES Syntax

```
SET NAMES {'charset_name'
    [COLLATE 'collation_name'] | DEFAULT}
```

This statement sets the three session system variables character_set_client,
character_set_connection, and character_set_results to the given character set. Setting
character_set_connection to charset_name also sets collation_connection to the default
collation for charset_name. The optional COLLATE clause may be used to specify a collation explicitly.
See Section 10.1.4, "Connection Character Sets and Collations".

The default mapping can be restored by using a value of DEFAULT. The default depends on the server
configuration.

ucs2 cannot be used as a client character set, which means that it does not work for SET NAMES.

13.7.5 SHOW Syntax

SHOW has many forms that provide information about databases, tables, columns, or status information
about the server. This section describes those following:

```
SHOW AUTHORS
SHOW {BINARY | MASTER} LOGS
SHOW BINLOG EVENTS [IN 'log_name'] [FROM pos] [LIMIT [offset,] row_count]
SHOW CHARACTER SET [like_or_where]
SHOW COLLATION [like_or_where]
SHOW [FULL] COLUMNS FROM tbl_name [FROM db_name] [like_or_where]
SHOW CONTRIBUTORS
SHOW CREATE DATABASE db_name
SHOW CREATE EVENT event_name
SHOW CREATE FUNCTION func_name
SHOW CREATE PROCEDURE proc_name
SHOW CREATE TABLE tbl_name
SHOW CREATE TRIGGER trigger_name
SHOW CREATE VIEW view_name
SHOW DATABASES [like_or_where]
SHOW ENGINE engine_name {STATUS | MUTEX}
SHOW [STORAGE] ENGINES
SHOW ERRORS [LIMIT [offset,] row_count]
SHOW EVENTS
SHOW FUNCTION CODE func_name
SHOW FUNCTION STATUS [like_or_where]
SHOW GRANTS FOR user
```

```
SHOW INDEX FROM tbl_name [FROM db_name]
SHOW INNODB STATUS
SHOW MASTER STATUS
SHOW OPEN TABLES [FROM db_name] [like_or_where]
SHOW PLUGINS
SHOW PROCEDURE CODE proc_name
SHOW PROCEDURE STATUS [like_or_where]
SHOW PRIVILEGES
SHOW [FULL] PROCESSLIST
SHOW PROFILE [types] [FOR QUERY n] [OFFSET n] [LIMIT n]
SHOW PROFILES
SHOW SCHEDULER STATUS
SHOW SLAVE HOSTS
SHOW SLAVE STATUS
SHOW [GLOBAL | SESSION] STATUS [like_or_where]
SHOW TABLE STATUS [FROM db_name] [like_or_where]
SHOW [FULL] TABLES [FROM db_name] [like_or_where]
SHOW TRIGGERS [FROM db_name] [like_or_where]
SHOW [GLOBAL | SESSION] VARIABLES [like_or_where]
SHOW WARNINGS [LIMIT [offset,] row_count]

like_or_where:
    LIKE 'pattern'
  | WHERE expr
```

If the syntax for a given `SHOW` statement includes a `LIKE 'pattern'` part, `'pattern'` is a string that can contain the SQL "%" and "_" wildcard characters. The pattern is useful for restricting statement output to matching values.

Several `SHOW` statements also accept a `WHERE` clause that provides more flexibility in specifying which rows to display. See Section 20.27, "Extensions to SHOW Statements".

Many MySQL APIs (such as PHP) enable you to treat the result returned from a `SHOW` statement as you would a result set from a `SELECT`; see Chapter 21, *Connectors and APIs*, or your API documentation for more information. In addition, you can work in SQL with results from queries on tables in the `INFORMATION_SCHEMA` database, which you cannot easily do with results from `SHOW` statements. See Chapter 20, *INFORMATION_SCHEMA Tables*.

13.7.5.1 SHOW AUTHORS Syntax

```
SHOW AUTHORS
```

The `SHOW AUTHORS` statement displays information about the people who work on MySQL. For each author, it displays `Name`, `Location`, and `Comment` values.

This statement was added in MySQL 5.1.3.

13.7.5.2 SHOW BINARY LOGS Syntax

```
SHOW BINARY LOGS
SHOW MASTER LOGS
```

Lists the binary log files on the server. This statement is used as part of the procedure described in Section 13.4.1.1, "PURGE BINARY LOGS Syntax", that shows how to determine which logs can be purged.

```
mysql> SHOW BINARY LOGS;
+---------------+-----------+
```

```
| Log_name      | File_size |
+---------------+-----------+
| binlog.000015 |    724935 |
| binlog.000016 |    733481 |
+---------------+-----------+
```

SHOW MASTER LOGS is equivalent to SHOW BINARY LOGS.

In MySQL 5.1.63 and earlier, the SUPER privilege was required to use this statement. Starting with MySQL 5.1.64, a user with the REPLICATION CLIENT privilege may also execute this statement.

13.7.5.3 SHOW BINLOG EVENTS Syntax

```
SHOW BINLOG EVENTS
   [IN 'log_name'] [FROM pos] [LIMIT [offset,] row_count]
```

Shows the events in the binary log. If you do not specify `'log_name'`, the first binary log is displayed.

The LIMIT clause has the same syntax as for the SELECT statement. See Section 13.2.8, "SELECT Syntax".

> **Note**
>
> Issuing a SHOW BINLOG EVENTS with no LIMIT clause could start a very time- and resource-consuming process because the server returns to the client the complete contents of the binary log (which includes all statements executed by the server that modify data). As an alternative to SHOW BINLOG EVENTS, use the mysqlbinlog utility to save the binary log to a text file for later examination and analysis. See Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files".

> **Note**
>
> Some events relating to the setting of user and system variables are not included in the output from SHOW BINLOG EVENTS. To get complete coverage of events within a binary log, use mysqlbinlog.

13.7.5.4 SHOW CHARACTER SET Syntax

```
SHOW CHARACTER SET
    [LIKE 'pattern' | WHERE expr]
```

The SHOW CHARACTER SET statement shows all available character sets. The LIKE clause, if present, indicates which character set names to match. The WHERE clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements". For example:

```
mysql> SHOW CHARACTER SET LIKE 'latin%';
+---------+-----------------------------+-------------------+--------+
| Charset | Description                 | Default collation | Maxlen |
+---------+-----------------------------+-------------------+--------+
| latin1  | cp1252 West European        | latin1_swedish_ci |      1 |
| latin2  | ISO 8859-2 Central European | latin2_general_ci |      1 |
| latin5  | ISO 8859-9 Turkish          | latin5_turkish_ci |      1 |
| latin7  | ISO 8859-13 Baltic          | latin7_general_ci |      1 |
+---------+-----------------------------+-------------------+--------+
```

The Maxlen column shows the maximum number of bytes required to store one character.

The `filename` character set is for internal use only; consequently, `SHOW CHARACTER SET` does not display it.

13.7.5.5 SHOW COLLATION Syntax

```
SHOW COLLATION
    [LIKE 'pattern' | WHERE expr]
```

This statement lists collations supported by the server. By default, the output from `SHOW COLLATION` includes all available collations. The `LIKE` clause, if present, indicates which collation names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements". For example:

```
mysql> SHOW COLLATION WHERE Charset = 'latin1';
+-------------------+---------+----+---------+----------+---------+
| Collation         | Charset | Id | Default | Compiled | Sortlen |
+-------------------+---------+----+---------+----------+---------+
| latin1_german1_ci | latin1  |  5 |         | Yes      |       1 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       1 |
| latin1_danish_ci  | latin1  | 15 |         | Yes      |       1 |
| latin1_german2_ci | latin1  | 31 |         | Yes      |       2 |
| latin1_bin        | latin1  | 47 |         | Yes      |       1 |
| latin1_general_ci | latin1  | 48 |         | Yes      |       1 |
| latin1_general_cs | latin1  | 49 |         | Yes      |       1 |
| latin1_spanish_ci | latin1  | 94 |         | Yes      |       1 |
+-------------------+---------+----+---------+----------+---------+
```

The `Collation` and `Charset` columns indicate the names of the collation and the character set with which it is associated. `Id` is the collation ID. `Default` indicates whether the collation is the default for its character set. `Compiled` indicates whether the character set is compiled into the server. `Sortlen` is related to the amount of memory required to sort strings expressed in the character set.

To see the default collation for each character set, use the following statement. `Default` is a reserved word, so to use it as an identifier, it must be quoted as such:

```
mysql> SHOW COLLATION WHERE `Default` = 'Yes';
+-------------------+---------+----+---------+----------+---------+
| Collation         | Charset | Id | Default | Compiled | Sortlen |
+-------------------+---------+----+---------+----------+---------+
| big5_chinese_ci   | big5    |  1 | Yes     | Yes      |       1 |
| dec8_swedish_ci   | dec8    |  3 | Yes     | Yes      |       1 |
| cp850_general_ci  | cp850   |  4 | Yes     | Yes      |       1 |
| hp8_english_ci    | hp8     |  6 | Yes     | Yes      |       1 |
| koi8r_general_ci  | koi8r   |  7 | Yes     | Yes      |       1 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       1 |
...
```

13.7.5.6 SHOW COLUMNS Syntax

```
SHOW [FULL] COLUMNS {FROM | IN} tbl_name [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW COLUMNS` displays information about the columns in a given table. It also works for views. The `LIKE` clause, if present, indicates which column names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

```
mysql> SHOW COLUMNS FROM City;
+------------+----------+------+-----+---------+----------------+
```

```
| Field      | Type      | Null | Key | Default | Extra          |
+------------+-----------+------+-----+---------+----------------+
| Id         | int(11)   | NO   | PRI | NULL    | auto_increment |
| Name       | char(35)  | NO   |     |         |                |
| Country    | char(3)   | NO   | UNI |         |                |
| District   | char(20)  | YES  | MUL |         |                |
| Population | int(11)   | NO   |     | 0       |                |
+------------+-----------+------+-----+---------+----------------+
5 rows in set (0.00 sec)
```

If the data types differ from what you expect them to be based on a `CREATE TABLE` statement, note that MySQL sometimes changes data types when you create or alter a table. The conditions under which this occurs are described in Section 13.1.17.4, "Silent Column Specification Changes".

The `FULL` keyword causes the output to include the column collation and comments, as well as the privileges you have for each column.

You can use `db_name.tbl_name` as an alternative to the `tbl_name FROM db_name` syntax. In other words, these two statements are equivalent:

```
mysql> SHOW COLUMNS FROM mytable FROM mydb;
mysql> SHOW COLUMNS FROM mydb.mytable;
```

`SHOW COLUMNS` displays the following values for each table column:

`Field` indicates the column name.

`Type` indicates the column data type.

`Collation` indicates the collation for nonbinary string columns, or `NULL` for other columns. This value is displayed only if you use the `FULL` keyword.

The `Null` field contains `YES` if `NULL` values can be stored in the column, `NO` if not.

The `Key` field indicates whether the column is indexed:

* If `Key` is empty, the column either is not indexed or is indexed only as a secondary column in a multiple-column, nonunique index.

* If `Key` is `PRI`, the column is a `PRIMARY KEY` or is one of the columns in a multiple-column `PRIMARY KEY`.

* If `Key` is `UNI`, the column is the first column of a `UNIQUE` index. (A `UNIQUE` index permits multiple `NULL` values, but you can tell whether the column permits `NULL` by checking the `Null` field.)

* If `Key` is `MUL`, the column is the first column of a nonunique index in which multiple occurrences of a given value are permitted within the column.

If more than one of the `Key` values applies to a given column of a table, `Key` displays the one with the highest priority, in the order `PRI`, `UNI`, `MUL`.

A `UNIQUE` index may be displayed as `PRI` if it cannot contain `NULL` values and there is no `PRIMARY KEY` in the table. A `UNIQUE` index may display as `MUL` if several columns form a composite `UNIQUE` index; although the combination of the columns is unique, each column can still hold multiple occurrences of a given value.

The `Default` field indicates the default value that is assigned to the column. This is `NULL` if the column has an explicit default of `NULL`. As of MySQL 5.1.23, `Default` is also `NULL` if the column definition has no `DEFAULT` clause.

The `Extra` field contains any additional information that is available about a given column. The value is nonempty in these cases: `auto_increment` for columns that have the `AUTO_INCREMENT` attribute; as of MySQL 5.1.23, `on update CURRENT_TIMESTAMP` for `TIMESTAMP` columns that have the `ON UPDATE CURRENT_TIMESTAMP` attribute.

`Privileges` indicates the privileges you have for the column. This value is displayed only if you use the `FULL` keyword.

`Comment` indicates any comment the column has. This value is displayed only if you use the `FULL` keyword.

`SHOW FIELDS` is a synonym for `SHOW COLUMNS`. You can also list a table's columns with the `mysqlshow db_name tbl_name` command.

The `DESCRIBE` statement provides information similar to `SHOW COLUMNS`. See Section 13.8.1, "DESCRIBE Syntax".

The `SHOW CREATE TABLE`, `SHOW TABLE STATUS`, and `SHOW INDEX` statements also provide information about tables. See Section 13.7.5, "SHOW Syntax".

13.7.5.7 SHOW CONTRIBUTORS Syntax

```
SHOW CONTRIBUTORS
```

The `SHOW CONTRIBUTORS` statement displays information about the people who contribute to MySQL source or to causes that we support. For each contributor, it displays `Name`, `Location`, and `Comment` values.

This statement was added in MySQL 5.1.12.

13.7.5.8 SHOW CREATE DATABASE Syntax

```
SHOW CREATE {DATABASE | SCHEMA} [IF NOT EXISTS] db_name
```

Shows the `CREATE DATABASE` statement that creates the named database. If the `SHOW` statement includes an `IF NOT EXISTS` clause, the output too includes such a clause. `SHOW CREATE SCHEMA` is a synonym for `SHOW CREATE DATABASE`.

```
mysql> SHOW CREATE DATABASE test\G
*************************** 1. row ***************************
       Database: test
Create Database: CREATE DATABASE `test`
                 /*!40100 DEFAULT CHARACTER SET latin1 */

mysql> SHOW CREATE SCHEMA test\G
*************************** 1. row ***************************
       Database: test
Create Database: CREATE DATABASE `test`
                 /*!40100 DEFAULT CHARACTER SET latin1 */
```

`SHOW CREATE DATABASE` quotes table and column names according to the value of the `sql_quote_show_create` option. See Section 5.1.4, "Server System Variables".

13.7.5.9 SHOW CREATE EVENT Syntax

```
SHOW CREATE EVENT event_name
```

This statement displays the CREATE EVENT statement needed to re-create a given event. It requires the EVENT privilege for the database from which the event is to be shown. For example (using the same event e_daily defined and then altered in Section 13.7.5.19, "SHOW EVENTS Syntax"):

```
mysql> SHOW CREATE EVENT test.e_daily\G
*************************** 1. row ***************************
               Event: e_daily
            sql_mode:
           time_zone: SYSTEM
        Create Event: CREATE EVENT `e_daily`
                        ON SCHEDULE EVERY 1 DAY
                        STARTS CURRENT_TIMESTAMP + INTERVAL 6 HOUR
                        ON COMPLETION NOT PRESERVE
                        ENABLE
                        COMMENT 'Saves total number of sessions then
                              clears the table each day'
                        DO BEGIN
                          INSERT INTO site_activity.totals (time, total)
                            SELECT CURRENT_TIMESTAMP, COUNT(*)
                            FROM site_activity.sessions;
                          DELETE FROM site_activity.sessions;
                        END
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

character_set_client is the session value of the character_set_client system variable when the event was created. collation_connection is the session value of the collation_connection system variable when the event was created. Database Collation is the collation of the database with which the event is associated. These columns were added in MySQL 5.1.21.

Note that the output reflects the current status of the event (ENABLE) rather than the status with which it was created.

This statement was implemented in MySQL 5.1.6.

13.7.5.10 SHOW CREATE FUNCTION Syntax

```
SHOW CREATE FUNCTION func_name
```

This statement is similar to SHOW CREATE PROCEDURE but for stored functions. See Section 13.7.5.11, "SHOW CREATE PROCEDURE Syntax".

13.7.5.11 SHOW CREATE PROCEDURE Syntax

```
SHOW CREATE PROCEDURE proc_name
```

This statement is a MySQL extension. It returns the exact string that can be used to re-create the named stored procedure. A similar statement, SHOW CREATE FUNCTION, displays information about stored functions (see Section 13.7.5.10, "SHOW CREATE FUNCTION Syntax").

To use either statement, you must be the user named in the routine DEFINER clause or have SELECT access to the mysql.proc table. If you do not have privileges for the routine itself, the value displayed for the Create Procedure or Create Function field will be NULL.

```
mysql> SHOW CREATE PROCEDURE test.simpleproc\G
*************************** 1. row ***************************
           Procedure: simpleproc
            sql_mode:
    Create Procedure: CREATE PROCEDURE `simpleproc`(OUT param1 INT)
                      BEGIN
                      SELECT COUNT(*) INTO param1 FROM t;
                      END
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci

mysql> SHOW CREATE FUNCTION test.hello\G
*************************** 1. row ***************************
            Function: hello
            sql_mode:
     Create Function: CREATE FUNCTION `hello`(s CHAR(20))
                      RETURNS CHAR(50)
                      RETURN CONCAT('Hello, ',s,'!')
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

character_set_client is the session value of the character_set_client system variable when
the routine was created. collation_connection is the session value of the collation_connection
system variable when the routine was created. Database Collation is the collation of the database
with which the routine is associated. These columns were added in MySQL 5.1.21.

13.7.5.12 SHOW CREATE TABLE Syntax

```
SHOW CREATE TABLE tbl_name
```

Shows the CREATE TABLE statement that creates the named table. To use this statement, you must have
some privilege for the table. This statement also works with views.

```
mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
      Table: t
Create Table: CREATE TABLE t (
  id INT(11) default NULL auto_increment,
  s char(60) default NULL,
  PRIMARY KEY (id)
) ENGINE=MyISAM
```

SHOW CREATE TABLE quotes table and column names according to the value of the
sql_quote_show_create option. See Section 5.1.4, "Server System Variables".

13.7.5.13 SHOW CREATE TRIGGER Syntax

```
SHOW CREATE TRIGGER trigger_name
```

This statement shows the CREATE TRIGGER statement that creates the named trigger. This statement
requires the TRIGGER privilege for the table associated with the trigger.

```
mysql> SHOW CREATE TRIGGER ins_sum\G
*************************** 1. row ***************************
               Trigger: ins_sum
              sql_mode:
```

```
SQL Original Statement: CREATE DEFINER=`me`@`localhost` TRIGGER ins_sum
                        BEFORE INSERT ON account
                        FOR EACH ROW SET @sum = @sum + NEW.amount
  character_set_client: latin1
  collation_connection: latin1_swedish_ci
    Database Collation: latin1_swedish_ci
```

`SHOW CREATE TRIGGER` output has the following columns:

- `Trigger`: The trigger name.

- `sql_mode`: The SQL mode in effect when the trigger executes.

- `SQL Original Statement`: The `CREATE TRIGGER` statement that defines the trigger.

- `character_set_client`: The session value of the `character_set_client` system variable when the trigger was created.

- `collation_connection`: The session value of the `collation_connection` system variable when the trigger was created.

- `Database Collation`: The collation of the database with which the trigger is associated.

`SHOW CREATE TRIGGER` output has the following columns:

- `Trigger`: The trigger name.

- `sql_mode`: The SQL mode in effect when the trigger executes.

- `SQL Original Statement`: The statement to be executed when the trigger activates.

- `character_set_client`: The session value of the `character_set_client` system variable when the trigger was created.

- `collation_connection`: The session value of the `collation_connection` system variable when the trigger was created.

- `Database Collation`: The collation of the database with which the trigger is associated.

`SHOW CREATE TRIGGER` was added in MySQL 5.1.21.

You can also obtain information about trigger objects from `INFORMATION_SCHEMA`, which contains a `TRIGGERS` table. See Section 20.23, "The INFORMATION_SCHEMA TRIGGERS Table".

13.7.5.14 SHOW CREATE VIEW Syntax

```
SHOW CREATE VIEW view_name
```

This statement shows the `CREATE VIEW` statement that creates the named view.

```
mysql> SHOW CREATE VIEW v\G
*************************** 1. row ***************************
               View: v
        Create View: CREATE ALGORITHM=UNDEFINED
                     DEFINER=`bob`@`localhost`
                     SQL SECURITY DEFINER VIEW
                     `v` AS select 1 AS `a`,2 AS `b`
character_set_client: latin1
collation_connection: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the view was created. `collation_connection` is the session value of the `collation_connection` system variable when the view was created. These columns were added in MySQL 5.1.21.

Use of `SHOW CREATE VIEW` requires the `SHOW VIEW` privilege and the `SELECT` privilege for the view in question.

You can also obtain information about view objects from `INFORMATION_SCHEMA`, which contains a `VIEWS` table. See Section 20.25, "The INFORMATION_SCHEMA VIEWS Table".

MySQL lets you use different `sql_mode` settings to tell the server the type of SQL syntax to support. For example, you might use the `ANSI` SQL mode to ensure MySQL correctly interprets the standard SQL concatenation operator, the double bar (`||`), in your queries. If you then create a view that concatenates items, you might worry that changing the `sql_mode` setting to a value different from `ANSI` could cause the view to become invalid. But this is not the case. No matter how you write out a view definition, MySQL always stores it the same way, in a canonical form. Here is an example that shows how the server changes a double bar concatenation operator to a `CONCAT()` function:

```
mysql> SET sql_mode = 'ANSI';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE VIEW test.v AS SELECT 'a' || 'b' as col1;
Query OK, 0 rows affected (0.01 sec)

mysql> SHOW CREATE VIEW test.v\G
*************************** 1. row ***************************
            View: v
     Create View: CREATE VIEW "v" AS select concat('a','b') AS "col1"
...
1 row in set (0.00 sec)
```

The advantage of storing a view definition in canonical form is that changes made later to the value of `sql_mode` will not affect the results from the view. However an additional consequence is that comments prior to `SELECT` are stripped from the definition by the server.

13.7.5.15 SHOW DATABASES Syntax

```
SHOW {DATABASES | SCHEMAS}
    [LIKE 'pattern' | WHERE expr]
```

`SHOW DATABASES` lists the databases on the MySQL server host. `SHOW SCHEMAS` is a synonym for `SHOW DATABASES`. The `LIKE` clause, if present, indicates which database names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

You see only those databases for which you have some kind of privilege, unless you have the global `SHOW DATABASES` privilege. You can also get this list using the `mysqlshow` command.

If the server was started with the `--skip-show-database` option, you cannot use this statement at all unless you have the `SHOW DATABASES` privilege.

MySQL implements databases as directories in the data directory, so this statement simply lists directories in that location. However, the output may include names of directories that do not correspond to actual databases.

13.7.5.16 SHOW ENGINE Syntax

```
SHOW ENGINE engine_name {STATUS | MUTEX}
```

`SHOW ENGINE` displays operational information about a storage engine. It requires the `PROCESS` privilege. The statement has these variants:

```
SHOW ENGINE INNODB STATUS
SHOW ENGINE INNODB MUTEX
SHOW ENGINE {NDB | NDBCLUSTER} STATUS
```

Older (and now deprecated) synonyms are `SHOW INNODB STATUS` for `SHOW ENGINE INNODB STATUS` and `SHOW MUTEX STATUS` for `SHOW ENGINE INNODB MUTEX`. `SHOW INNODB STATUS` and `SHOW MUTEX STATUS` are removed in MySQL 5.5.

In MySQL 5.0, `SHOW ENGINE INNODB MUTEX` is invoked as `SHOW MUTEX STATUS`. The latter statement displays similar information but in a somewhat different output format.

`SHOW ENGINE BDB LOGS` formerly displayed status information about `BDB` log files. As of MySQL 5.1.12, the `BDB` storage engine is not supported, and this statement produces a warning.

`SHOW ENGINE INNODB STATUS` displays extensive information from the standard `InnoDB` Monitor about the state of the `InnoDB` storage engine. For information about the standard monitor and other `InnoDB` Monitors that provide information about `InnoDB` processing, see Section 14.6.9, "InnoDB Monitors".

`SHOW ENGINE INNODB MUTEX` displays `InnoDB` mutex statistics. From MySQL 5.1.2 to 5.1.14, the statement displays the following output fields:

- `Type`

  Always `InnoDB`.

- `Name`

  The mutex name and the source file where it is implemented. Example: `&pool->mutex:mem0pool.c`

  The mutex name indicates its purpose. For example, the `log_sys` mutex is used by the `InnoDB` logging subsystem and indicates how intensive logging activity is. The `buf_pool` mutex protects the `InnoDB` buffer pool.

- `Status`

  The mutex status. The fields contains several values:

  - `count` indicates how many times the mutex was requested.

  - `spin_waits` indicates how many times the spinlock had to run.

  - `spin_rounds` indicates the number of spinlock rounds. (`spin_rounds` divided by `spin_waits` provides the average round count.)

  - `os_waits` indicates the number of operating system waits. This occurs when the spinlock did not work (the mutex was not locked during the spinlock and it was necessary to yield to the operating system and wait).

  - `os_yields` indicates the number of times a thread trying to lock a mutex gave up its timeslice and yielded to the operating system (on the presumption that permitting other threads to run will free the mutex so that it can be locked).

- `os_wait_times` indicates the amount of time (in ms) spent in operating system waits, if the `timed_mutexes` system variable is 1 (`ON`). If `timed_mutexes` is 0 (`OFF`), timing is disabled, so `os_wait_times` is 0. `timed_mutexes` is off by default.

From MySQL 5.1.15 on, the statement displays the following output fields:

- `Type`

  Always `InnoDB`.

- `Name`

  The source file where the mutex is implemented, and the line number in the file where the mutex is created. The line number is specific to your version of MySQL.

- `Status`

  This field displays the same values as previously described (`count`, `spin_waits`, `spin_rounds`, `os_waits`, `os_yields`, `os_wait_times`), but only if `UNIV_DEBUG` was defined at MySQL compilation time (for example, in `include/univ.i` in the `InnoDB` part of the MySQL source tree). If `UNIV_DEBUG` was not defined, the statement displays only the `os_waits` value. In the latter case (without `UNIV_DEBUG`), the information on which the output is based is insufficient to distinguish regular mutexes and mutexes that protect rw-locks (which permit multiple readers or a single writer). Consequently, the output may appear to contain multiple rows for the same mutex.

Information from this statement can be used to diagnose system problems. For example, large values of `spin_waits` and `spin_rounds` may indicate scalability problems.

If the server has the `NDBCLUSTER` storage engine enabled, `SHOW ENGINE NDB STATUS` displays cluster status information such as the number of connected data nodes, the cluster connectstring, and cluster binary log epochs, as well as counts of various Cluster API objects created by the MySQL Server when connected to the cluster. Sample output from this statement is shown here:

```
mysql> SHOW ENGINE NDB STATUS;
+------------+----------------------+--------------------------------------------------+
| Type       | Name                 | Status                                           |
+------------+----------------------+--------------------------------------------------+
| ndbcluster | connection           | cluster_node_id=7,                               |
  connected_host=192.168.0.103, connected_port=1186, number_of_data_nodes=4,
  number_of_ready_data_nodes=3, connect_count=0                                          |
| ndbcluster | NdbTransaction       | created=6, free=0, sizeof=212                    |
| ndbcluster | NdbOperation         | created=8, free=8, sizeof=660                    |
| ndbcluster | NdbIndexScanOperation | created=1, free=1, sizeof=744                   |
| ndbcluster | NdbIndexOperation    | created=0, free=0, sizeof=664                    |
| ndbcluster | NdbRecAttr           | created=1285, free=1285, sizeof=60               |
| ndbcluster | NdbApiSignal         | created=16, free=16, sizeof=136                  |
| ndbcluster | NdbLabel             | created=0, free=0, sizeof=196                    |
| ndbcluster | NdbBranch            | created=0, free=0, sizeof=24                     |
| ndbcluster | NdbSubroutine        | created=0, free=0, sizeof=68                     |
| ndbcluster | NdbCall              | created=0, free=0, sizeof=16                     |
| ndbcluster | NdbBlob              | created=1, free=1, sizeof=264                    |
| ndbcluster | NdbReceiver          | created=4, free=0, sizeof=68                     |
| ndbcluster | binlog               | latest_epoch=155467, latest_trans_epoch=148126, |
  latest_received_binlog_epoch=0, latest_handled_binlog_epoch=0,
  latest_applied_binlog_epoch=0                                                          |
+------------+----------------------+--------------------------------------------------+
```

The rows with `connection` and `binlog` in the `Name` column were added to the output of this statement in MySQL 5.1. The `Status` column in each of these rows provides information about the MySQL server's

connection to the cluster and about the cluster binary log's status, respectively. The `Status` information is in the form of comma-delimited set of name/value pairs.

The `connection` row's `Status` column contains the name/value pairs described in the following table.

Name	Value
`cluster_node_id`	The node ID of the MySQL server in the cluster
`connected_host`	The host name or IP address of the cluster management server to which the MySQL server is connected
`connected_port`	The port used by the MySQL server to connect to the management server (`connected_host`)
`number_of_data_nodes`	The number of data nodes configured for the cluster (that is, the number of `[ndbd]` sections in the cluster `config.ini` file)
`number_of_ready_data_nodes`	The number of data nodes in the cluster that are actually running
`connect_count`	The number of times this `mysqld` has connected or reconnected to cluster data nodes

The `binlog` row's `Status` column contains information relating to MySQL Cluster Replication. The name/value pairs it contains are described in the following table.

Name	Value
`latest_epoch`	The most recent epoch most recently run on this MySQL server (that is, the sequence number of the most recent transaction run on the server)
`latest_trans_epoch`	The most recent epoch processed by the cluster's data nodes
`latest_received_binlog_epoch`	The most recent epoch received by the binary log thread
`latest_handled_binlog_epoch`	The most recent epoch processed by the binary log thread (for writing to the binary log)
`latest_applied_binlog_epoch`	The most recent epoch actually written to the binary log

See Section 17.6, "MySQL Cluster Replication", for more information.

The remaining rows from the output of `SHOW ENGINE NDB STATUS` which are most likely to prove useful in monitoring the cluster are listed here by `Name`:

- `NdbTransaction`: The number and size of `NdbTransaction` objects that have been created. An `NdbTransaction` is created each time a table schema operation (such as `CREATE TABLE` or `ALTER TABLE`) is performed on an `NDB` table.

- `NdbOperation`: The number and size of `NdbOperation` objects that have been created.

- `NdbIndexScanOperation`: The number and size of `NdbIndexScanOperation` objects that have been created.

- `NdbIndexOperation`: The number and size of `NdbIndexOperation` objects that have been created.

- `NdbRecAttr`: The number and size of `NdbRecAttr` objects that have been created. In general, one of these is created each time a data manipulation statement is performed by an SQL node.

- `NdbBlob`: The number and size of `NdbBlob` objects that have been created. An `NdbBlob` is created for each new operation involving a `BLOB` column in an `NDB` table.

- `NdbReceiver`: The number and size of any `NdbReceiver` object that have been created. The number in the `created` column is the same as the number of data nodes in the cluster to which the MySQL server has connected.

> **Note**
>
> `SHOW ENGINE NDB STATUS` returns an empty result if no operations involving `NDB` tables have been performed during the current session by the MySQL client accessing the SQL node on which this statement is run.

13.7.5.17 SHOW ENGINES Syntax

```
SHOW [STORAGE] ENGINES
```

`SHOW ENGINES` displays status information about the server's storage engines. This is particularly useful for checking whether a storage engine is supported, or to see what the default engine is. This information can also be obtained from the `INFORMATION_SCHEMA ENGINES` table. See Section 20.6, "The INFORMATION_SCHEMA ENGINES Table".

`SHOW TABLE TYPES` is a synonym, but is deprecated and is removed in MySQL 5.5.

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
      Engine: MEMORY
     Support: YES
     Comment: Hash based, stored in memory, useful for temporary tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 2. row ***************************
      Engine: MyISAM
     Support: DEFAULT
     Comment: Default engine as of MySQL 3.23 with great performance
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 3. row ***************************
      Engine: InnoDB
     Support: YES
     Comment: Supports transactions, row-level locking, and foreign keys
Transactions: YES
          XA: YES
  Savepoints: YES
*************************** 4. row ***************************
      Engine: EXAMPLE
     Support: YES
     Comment: Example storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 5. row ***************************
      Engine: ARCHIVE
     Support: YES
     Comment: Archive storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 6. row ***************************
```

```
      Engine: CSV
     Support: YES
     Comment: CSV storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 7. row ***************************
      Engine: BLACKHOLE
     Support: YES
     Comment: /dev/null storage engine (anything you write »
              to it disappears)
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 8. row ***************************
      Engine: FEDERATED
     Support: YES
     Comment: Federated MySQL storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 9. row ***************************
      Engine: MRG_MYISAM
     Support: YES
     Comment: Collection of identical MyISAM tables
Transactions: NO
          XA: NO
  Savepoints: NO
```

The output from `SHOW ENGINES` may vary according to the MySQL version used and other factors. The values shown in the `Support` column indicate the server's level of support for the storage engine, as shown in the following table.

Value	Meaning
`YES`	The engine is supported and is active
`DEFAULT`	Like `YES`, plus this is the default engine
`NO`	The engine is not supported
`DISABLED`	The engine is supported but has been disabled

A value of `NO` means that the server was compiled without support for the engine, so it cannot be enabled at runtime.

A value of `DISABLED` occurs either because the server was started with an option that disables the engine, or because not all options required to enable it were given. In the latter case, the error log file should contain a reason indicating why the option is disabled. See Section 5.4.2, "The Error Log".

You might also see `DISABLED` for a storage engine if the server was compiled to support it, but was started with a `--skip-engine_name` option. For the `NDBCLUSTER` storage engine, `DISABLED` means the server was compiled with support for MySQL Cluster, but was not started with the `--ndbcluster` option.

All MySQL servers support `MyISAM` tables, because `MyISAM` is the default storage engine. It is not possible to disable `MyISAM`.

The `Transactions`, `XA`, and `Savepoints` columns were added in MySQL 5.1.2. They indicate whether the storage engine supports transactions, XA transactions, and savepoints, respectively.

13.7.5.18 SHOW ERRORS Syntax

```
SHOW ERRORS [LIMIT [offset,] row_count]
SHOW COUNT(*) ERRORS
```

SHOW ERRORS is a diagnostic statement that is similar to SHOW WARNINGS, except that it displays information only for errors, rather than for errors, warnings, and notes.

The LIMIT clause has the same syntax as for the SELECT statement. See Section 13.2.8, "SELECT Syntax".

The SHOW COUNT(*) ERRORS statement displays the number of errors. You can also retrieve this number from the error_count variable:

```
SHOW COUNT(*) ERRORS;
SELECT @@error_count;
```

SHOW ERRORS and error_count apply only to errors, not warnings or notes. In other respects, they are similar to SHOW WARNINGS and warning_count. In particular, SHOW ERRORS cannot display information for more than max_error_count messages, and error_count can exceed the value of max_error_count if the number of errors exceeds max_error_count.

For more information, see Section 13.7.5.42, "SHOW WARNINGS Syntax".

13.7.5.19 SHOW EVENTS Syntax

```
SHOW EVENTS [{FROM | IN} schema_name]
    [LIKE 'pattern' | WHERE expr]
```

This statement displays information about Event Manager events. It requires the EVENT privilege for the database from which the events are to be shown.

In its simplest form, SHOW EVENTS lists all of the events in the current schema:

```
mysql> SELECT CURRENT_USER(), SCHEMA();
+----------------+----------+
| CURRENT_USER() | SCHEMA() |
+----------------+----------+
| jon@ghidora    | myschema |
+----------------+----------+
1 row in set (0.00 sec)

mysql> SHOW EVENTS\G
*************************** 1. row ***************************
                  Db: myschema
                Name: e_daily
             Definer: jon@ghidora
           Time zone: SYSTEM
                Type: RECURRING
          Execute at: NULL
      Interval value: 10
      Interval field: SECOND
              Starts: 2006-02-09 10:41:23
                Ends: NULL
              Status: ENABLED
          Originator: 0
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

To see events for a specific schema, use the `FROM` clause. For example, to see events for the `test` schema, use the following statement:

```
SHOW EVENTS FROM test;
```

The `LIKE` clause, if present, indicates which event names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

`SHOW EVENTS` output has the following columns:

- `Db`: The schema (database) on which the event is defined.

- `Name`: The name of the event.

- `Time zone`: The event time zone, which is the time zone used for scheduling the event and that is in effect within the event as it executes. The default value is `SYSTEM`.

  This column was added in MySQL 5.1.17. See the Release Notes for MySQL 5.1.17 for important information if you are using the Event Scheduler and are upgrading to MySQL 5.1.17 or later from an earlier version.

- `Definer`: The account of the user who created the event, in `'user_name'@'host_name'` format.

- `Type`: The event repetition type, either `ONE TIME` (transient) or `RECURRING` (repeating).

- `Execute At`: The date and time when a transient event is set to execute. Shown as a `DATETIME` value.

  For a recurring event, the value of this column is always `NULL`.

- `Interval Value`: For a recurring event, the number of intervals to wait between event executions.

  For a transient event, the value of this column is always `NULL`.

- `Interval Field`: The time units used for the interval which a recurring event waits before repeating.

  For a transient event, the value of this column is always `NULL`.

- `Starts`: The start date and time for a recurring event. This is displayed as a `DATETIME` value, and is `NULL` if no start date and time are defined for the event. (Prior to MySQL 5.1.8, it defaulted to `'0000-00-00 00:00:00'` in such cases.)

  For a transient event, this column is always `NULL`.

- `Ends`: The end date and time for a recurring event. This is displayed as a `DATETIME` value, and defaults to `NULL` if no end date and time is defined for the event.

  For a transient event, this column is always `NULL`.

- `Status`: The event status. One of `ENABLED`, `DISABLED`, or `SLAVESIDE_DISABLED`.

  `SLAVESIDE_DISABLED` was added in MySQL 5.1.18. This value indicates that the creation of the event occurred on another MySQL server acting as a replication master and replicated to the current MySQL server which is acting as a slave, but the event is not presently being executed on the slave.

- `Originator`: The server ID of the MySQL server on which the event was created. Defaults to 0. This column was added in MySQL 5.1.18.

- `character_set_client` is the session value of the `character_set_client` system variable when the routine was created. `collation_connection` is the session value of the `collation_connection` system variable when the routine was created. `Database Collation` is the collation of the database with which the routine is associated. These columns were added in MySQL 5.1.21.

For more information about `SLAVE_DISABLED` and the `Originator` column, see Section 16.4.1.12, "Replication of Invoked Features".

The event action statement is not shown in the output of `SHOW EVENTS`. Use `SHOW CREATE EVENT` or the `INFORMATION_SCHEMA.EVENTS` table.

Times displayed by `SHOW EVENTS` are given in the event time zone (or UTC prior to MySQL 5.1.17), as discussed in Section 19.4.4, "Event Metadata".

The columns in the output of `SHOW EVENTS` are similar to, but not identical to the columns in the `INFORMATION_SCHEMA.EVENTS` table. See Section 20.7, "The INFORMATION_SCHEMA EVENTS Table".

`SHOW EVENTS` was added in MySQL 5.1.6.

> **Note**
>
> In MySQL 5.1.11 and earlier, `SHOW EVENTS` displayed only those events for which the current user was the definer, and the `SHOW FULL EVENTS` statement was used for viewing events defined by all users on a given schema. `SHOW FULL EVENTS` was removed in MySQL 5.1.12.

13.7.5.20 SHOW FUNCTION CODE Syntax

```
SHOW FUNCTION CODE func_name
```

This statement is similar to `SHOW PROCEDURE CODE` but for stored functions. See Section 13.7.5.29, "SHOW PROCEDURE CODE Syntax".

13.7.5.21 SHOW FUNCTION STATUS Syntax

```
SHOW FUNCTION STATUS
    [LIKE 'pattern' | WHERE expr]
```

This statement is similar to `SHOW PROCEDURE STATUS` but for stored functions. See Section 13.7.5.30, "SHOW PROCEDURE STATUS Syntax".

13.7.5.22 SHOW GRANTS Syntax

```
SHOW GRANTS [FOR user]
```

This statement displays the `GRANT` statement or statements that must be issued to duplicate the privileges that are granted to a MySQL user account. `SHOW GRANTS` requires the `SELECT` privilege for the `mysql` database, except to see the privileges for the current user.

To name the account, use the same format as for the `GRANT` statement; for example, `'jeffrey'@'localhost'`. If you specify only the user name part of the account name, a host name part

of `'%'` is used. For additional information about specifying account names, see Section 13.7.1.3, "GRANT Syntax".

```
mysql> SHOW GRANTS FOR 'root'@'localhost';
+---------------------------------------------------------------+
| Grants for root@localhost                                     |
+---------------------------------------------------------------+
| GRANT ALL PRIVILEGES ON *.* TO 'root'@'localhost' WITH GRANT OPTION |
+---------------------------------------------------------------+
```

To display the privileges granted to the account that you are using to connect to the server, you can use any of the following statements:

```
SHOW GRANTS;
SHOW GRANTS FOR CURRENT_USER;
SHOW GRANTS FOR CURRENT_USER();
```

As of MySQL 5.1.12, if `SHOW GRANTS FOR CURRENT_USER` (or any of the equivalent syntaxes) is used in `DEFINER` context, such as within a stored procedure that is defined with `SQL SECURITY DEFINER`), the grants displayed are those of the definer and not the invoker.

`SHOW GRANTS` displays only the privileges granted explicitly to the named account. Other privileges that might be available to the account are not displayed. For example, if an anonymous account exists, the named account might be able to use its privileges, but `SHOW GRANTS` will not display them.

13.7.5.23 SHOW INDEX Syntax

```
SHOW {INDEX | INDEXES | KEYS}
    {FROM | IN} tbl_name
    [{FROM | IN} db_name]
    [WHERE expr]
```

`SHOW INDEX` returns table index information. The format resembles that of the `SQLStatistics` call in ODBC.

`SHOW INDEX` returns the following fields:

- `Table`

  The name of the table.

- `Non_unique`

  0 if the index cannot contain duplicates, 1 if it can.

- `Key_name`

  The name of the index. If the index is the primary key, the name is always `PRIMARY`.

- `Seq_in_index`

  The column sequence number in the index, starting with 1.

- `Column_name`

  The column name.

- `Collation`

How the column is sorted in the index. In MySQL, this can have values "A" (Ascending) or NULL (Not sorted).

- Cardinality

  An estimate of the number of unique values in the index. This is updated by running ANALYZE TABLE or myisamchk -a. Cardinality is counted based on statistics stored as integers, so the value is not necessarily exact even for small tables. The higher the cardinality, the greater the chance that MySQL uses the index when doing joins.

- Sub_part

  The index prefix. That is, the number of indexed characters if the column is only partly indexed, NULL if the entire column is indexed.

  > **Note**
  >
  > Prefix limits are measured in bytes, whereas the prefix length in CREATE TABLE, ALTER TABLE, and CREATE INDEX statements is interpreted as number of characters for nonbinary string types (CHAR, VARCHAR, TEXT) and number of bytes for binary string types (BINARY, VARBINARY, BLOB). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

  For additional information about index prefixes, see Section 13.1.13, "CREATE INDEX Syntax".

- Packed

  Indicates how the key is packed. NULL if it is not.

- Null

  Contains YES if the column may contain NULL values and '' if not.

- Index_type

  The index method used (BTREE, FULLTEXT, HASH, RTREE).

- Comment

  Information about the index not described in its own column, such as disabled if the index is disabled.

You can use db_name.tbl_name as an alternative to the tbl_name FROM db_name syntax. These two statements are equivalent:

```
SHOW INDEX FROM mytable FROM mydb;
SHOW INDEX FROM mydb.mytable;
```

The WHERE clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

You can also list a table's indexes with the mysqlshow -k db_name tbl_name command.

13.7.5.24 SHOW INNODB STATUS Syntax

```
SHOW INNODB STATUS
```

In MySQL 5.1, this is a deprecated synonym for `SHOW ENGINE INNODB STATUS`. See Section 13.7.5.16, "SHOW ENGINE Syntax". `SHOW INNODB STATUS` is removed in MySQL 5.5.

13.7.5.25 SHOW MASTER STATUS Syntax

```
SHOW MASTER STATUS
```

This statement provides status information about the binary log files of the master. It requires either the `SUPER` or `REPLICATION CLIENT` privilege.

Example:

```
mysql> SHOW MASTER STATUS;
+---------------+----------+--------------+------------------+
| File          | Position | Binlog_Do_DB | Binlog_Ignore_DB |
+---------------+----------+--------------+------------------+
| mysql-bin.003 | 73       | test         | manual,mysql     |
+---------------+----------+--------------+------------------+
```

13.7.5.26 SHOW OPEN TABLES Syntax

```
SHOW OPEN TABLES [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW OPEN TABLES` lists the non-`TEMPORARY` tables that are currently open in the table cache. See Section 8.4.3.1, "How MySQL Opens and Closes Tables". The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

The `FROM` and `LIKE` clauses may be used beginning with MySQL 5.1.24. The `LIKE` clause, if present, indicates which table names to match. The `FROM` clause, if present, restricts the tables shown to those present in the `db_name` database.

`SHOW OPEN TABLES` output has the following columns:

- `Database`

  The database containing the table.

- `Table`

  The table name.

- `In_use`

  The number of table locks or lock requests there are for the table. For example, if one client acquires a lock for a table using `LOCK TABLE t1 WRITE`, `In_use` will be 1. If another client issues `LOCK TABLE t1 WRITE` while the table remains locked, the client will block waiting for the lock, but the lock request causes `In_use` to be 2. If the count is zero, the table is open but not currently being used. `In_use` is also increased by the `HANDLER ... OPEN` statement and decreased by `HANDLER ... CLOSE`.

- `Name_locked`

  Whether the table name is locked. Name locking is used for operations such as dropping or renaming tables.

13.7.5.27 SHOW PLUGINS Syntax

```
SHOW PLUGINS
```

`SHOW PLUGINS` displays information about server plugins. Plugin information is also available in the `INFORMATION_SCHEMA.PLUGINS` table. See Section 20.12, "The INFORMATION_SCHEMA PLUGINS Table".

Example of `SHOW PLUGINS` output:

```
mysql> SHOW PLUGINS\G
*************************** 1. row ***************************
   Name: binlog
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
*************************** 2. row ***************************
   Name: CSV
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
*************************** 3. row ***************************
   Name: MEMORY
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
*************************** 4. row ***************************
   Name: MyISAM
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
...
```

`SHOW PLUGINS` output has the following columns:

- `Name`: The name used to refer to the plugin in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`.

- `Status`: The plugin status, one of `ACTIVE`, `INACTIVE`, `DISABLED`, or `DELETED`.

- `Type`: The type of plugin, such as `STORAGE ENGINE` or `INFORMATION_SCHEMA`.

- `Library`: The name of the plugin shared object file. This is the name used to refer to the plugin file in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`. This file is located in the directory named by the `plugin_dir` system variable. If the library name is `NULL`, the plugin is compiled in and cannot be uninstalled with `UNINSTALL PLUGIN`.

- `License`: How the plugin is licensed; for example, `GPL`.

For plugins installed with `INSTALL PLUGIN`, the `Name` and `Library` values are also registered in the `mysql.plugin` table.

For information about plugin data structures that form the basis of the information displayed by `SHOW PLUGINS`, see Section 22.2, "The MySQL Plugin API".

`SHOW PLUGIN` was added in MySQL 5.1.5 and renamed to `SHOW PLUGINS` in 5.1.9. `SHOW PLUGIN` is deprecated as of 5.1.9 and generates a warning, and is removed in MySQL 5.5.)

13.7.5.28 SHOW PRIVILEGES Syntax

```
SHOW PRIVILEGES
```

`SHOW PRIVILEGES` shows the list of system privileges that the MySQL server supports. The exact list of privileges depends on the version of your server.

```
mysql> SHOW PRIVILEGES\G
*************************** 1. row ***************************
Privilege: Alter
  Context: Tables
  Comment: To alter the table
*************************** 2. row ***************************
Privilege: Alter routine
  Context: Functions,Procedures
  Comment: To alter or drop stored functions/procedures
*************************** 3. row ***************************
Privilege: Create
  Context: Databases,Tables,Indexes
  Comment: To create new databases and tables
*************************** 4. row ***************************
Privilege: Create routine
  Context: Databases
  Comment: To use CREATE FUNCTION/PROCEDURE
*************************** 5. row ***************************
Privilege: Create temporary tables
  Context: Databases
  Comment: To use CREATE TEMPORARY TABLE
...
```

Privileges belonging to a specific user are displayed by the `SHOW GRANTS` statement. See Section 13.7.5.22, "SHOW GRANTS Syntax", for more information.

13.7.5.29 SHOW PROCEDURE CODE Syntax

```
SHOW PROCEDURE CODE proc_name
```

This statement is a MySQL extension that is available only for servers that have been built with debugging support. It displays a representation of the internal implementation of the named stored procedure. A similar statement, `SHOW FUNCTION CODE`, displays information about stored functions (see Section 13.7.5.20, "SHOW FUNCTION CODE Syntax").

To use either statement, you must be the owner of the routine or have `SELECT` access to the `mysql.proc` table.

If the named routine is available, each statement produces a result set. Each row in the result set corresponds to one "instruction" in the routine. The first column is `Pos`, which is an ordinal number beginning with 0. The second column is `Instruction`, which contains an SQL statement (usually changed from the original source), or a directive which has meaning only to the stored-routine handler.

```
mysql> DELIMITER //
mysql> CREATE PROCEDURE p1 ()
    -> BEGIN
    ->   DECLARE fanta INT DEFAULT 55;
    ->   DROP TABLE t2;
    ->   LOOP
    ->     INSERT INTO t3 VALUES (fanta);
```

```
    ->      END LOOP;
    ->    END//
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW PROCEDURE CODE p1//
+-----+--------------------------------------+
| Pos | Instruction                          |
+-----+--------------------------------------+
|   0 | set fanta@0 55                       |
|   1 | stmt 9 "DROP TABLE t2"               |
|   2 | stmt 5 "INSERT INTO t3 VALUES (fanta)" |
|   3 | jump 2                               |
+-----+--------------------------------------+
4 rows in set (0.00 sec)
```

In this example, the nonexecutable `BEGIN` and `END` statements have disappeared, and for the `DECLARE variable_name` statement, only the executable part appears (the part where the default is assigned). For each statement that is taken from source, there is a code word `stmt` followed by a type (9 means `DROP`, 5 means `INSERT`, and so on). The final row contains an instruction `jump 2`, meaning `GOTO instruction #2`.

These statements were added in MySQL 5.1.3.

13.7.5.30 SHOW PROCEDURE STATUS Syntax

```
SHOW PROCEDURE STATUS
    [LIKE 'pattern' | WHERE expr]
```

This statement is a MySQL extension. It returns characteristics of a stored procedure, such as the database, name, type, creator, creation and modification dates, and character set information. A similar statement, `SHOW FUNCTION STATUS`, displays information about stored functions (see Section 13.7.5.21, "SHOW FUNCTION STATUS Syntax").

The `LIKE` clause, if present, indicates which procedure or function names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

```
mysql> SHOW PROCEDURE STATUS LIKE 'sp1'\G
*************************** 1. row ***************************
                 Db: test
               Name: sp1
               Type: PROCEDURE
            Definer: testuser@localhost
           Modified: 2004-08-03 15:29:37
            Created: 2004-08-03 15:29:37
      Security_type: DEFINER
            Comment:
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the routine was created. `collation_connection` is the session value of the `collation_connection` system variable when the routine was created. `Database Collation` is the collation of the database with which the routine is associated. These columns were added in MySQL 5.1.21.

You can also get information about stored routines from the `ROUTINES` table in `INFORMATION_SCHEMA`. See Section 20.16, "The INFORMATION_SCHEMA ROUTINES Table".

13.7.5.31 SHOW PROCESSLIST Syntax

```
SHOW [FULL] PROCESSLIST
```

SHOW PROCESSLIST shows you which threads are running. You can also get this information from the INFORMATION_SCHEMA PROCESSLIST table or the mysqladmin processlist command. If you have the PROCESS privilege, you can see all threads. Otherwise, you can see only your own threads (that is, threads associated with the MySQL account that you are using). If you do not use the FULL keyword, only the first 100 characters of each statement are shown in the Info field.

This statement is very useful if you get the "too many connections" error message and want to find out what is going on. MySQL reserves one extra connection to be used by accounts that have the SUPER privilege, to ensure that administrators should always be able to connect and check the system (assuming that you are not giving this privilege to all your users).

Threads can be killed with the KILL statement. See Section 13.7.6.4, "KILL Syntax".

Here is an example of SHOW PROCESSLIST output:

```
mysql> SHOW FULL PROCESSLIST\G
*************************** 1. row ***************************
Id: 1
User: system user
Host:
db: NULL
Command: Connect
Time: 1030455
State: Waiting for master to send event
Info: NULL
*************************** 2. row ***************************
Id: 2
User: system user
Host:
db: NULL
Command: Connect
Time: 1004
State: Has read all relay log; waiting for the slave
      I/O thread to update it
Info: NULL
*************************** 3. row ***************************
Id: 3112
User: replikator
Host: artemis:2204
db: NULL
Command: Binlog Dump
Time: 2144
State: Has sent all binlog to slave; waiting for binlog to be updated
Info: NULL
*************************** 4. row ***************************
Id: 3113
User: replikator
Host: iconnect2:45781
db: NULL
Command: Binlog Dump
Time: 2086
State: Has sent all binlog to slave; waiting for binlog to be updated
Info: NULL
*************************** 5. row ***************************
Id: 3123
User: stefan
Host: localhost
db: apollon
```

```
Command: Query
Time: 0
State: NULL
Info: SHOW FULL PROCESSLIST
5 rows in set (0.00 sec)
```

The columns produced by `SHOW PROCESSLIST` have the following meanings:

- `Id`

  The connection identifier. This is the same type of value displayed in the `ID` column of the `INFORMATION_SCHEMA.PROCESSLIST` table and returned by the `CONNECTION_ID()` function.

- `User`

  The MySQL user who issued the statement. If this is `system user`, it refers to a nonclient thread spawned by the server to handle tasks internally. This could be the I/O or SQL thread used on replication slaves or a delayed-row handler. `unauthenticated user` refers to a thread that has become associated with a client connection but for which authentication of the client user has not yet been done. `event_scheduler` refers to the thread that monitors scheduled events. For `system user`, there is no host specified in the `Host` column.

- `Host`

  The host name of the client issuing the statement (except for `system user` where there is no host). `SHOW PROCESSLIST` reports the host name for TCP/IP connections in `host_name:client_port` format to make it easier to determine which client is doing what.

- `db`

  The default database, if one is selected, otherwise `NULL`.

- `Command`

  The type of command the thread is executing. For descriptions for thread commands, see Section 8.14, "Examining Thread Information". The value of this column corresponds to the `COM_xxx` commands of the client/server protocol and `Com_xxx` status variables. See Section 5.1.6, "Server Status Variables"

- `Time`

  The time in seconds that the thread has been in its current state. For a slave SQL thread, the value is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. See Section 16.2.1, "Replication Implementation Details".

- `State`

  An action, event, or state that indicates what the thread is doing. Descriptions for `State` values can be found at Section 8.14, "Examining Thread Information".

  Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.

  For the `SHOW PROCESSLIST` statement, the value of `State` is `NULL`.

- `Info`

  The statement the thread is executing, or `NULL` if it is not executing any statement. The statement might be the one sent to the server, or an innermost statement if the statement executes other statements. For

example, if a `CALL` statement executes a stored procedure that is executing a `SELECT` statement, the `Info` value shows the `SELECT` statement.

13.7.5.32 SHOW PROFILE Syntax

```
SHOW PROFILE [type [, type] ... ]
    [FOR QUERY n]
    [LIMIT row_count [OFFSET offset]]

type:
    ALL
  | BLOCK IO
  | CONTEXT SWITCHES
  | CPU
  | IPC
  | MEMORY
  | PAGE FAULTS
  | SOURCE
  | SWAPS
```

The `SHOW PROFILE` and `SHOW PROFILES` statements display profiling information that indicates resource usage for statements executed during the course of the current session.

Profiling is controlled by the `profiling` session variable, which has a default value of 0 (`OFF`). Profiling is enabled by setting `profiling` to 1 or `ON`:

```
mysql> SET profiling = 1;
```

`SHOW PROFILES` displays a list of the most recent statements sent to the server. The size of the list is controlled by the `profiling_history_size` session variable, which has a default value of 15. The maximum value is 100. Setting the value to 0 has the practical effect of disabling profiling.

All statements are profiled except `SHOW PROFILE` and `SHOW PROFILES`, so you will find neither of those statements in the profile list. Malformed statements are profiled. For example, `SHOW PROFILING` is an illegal statement, and a syntax error occurs if you try to execute it, but it will show up in the profiling list.

`SHOW PROFILE` displays detailed information about a single statement. Without the `FOR QUERY n` clause, the output pertains to the most recently executed statement. If `FOR QUERY n` is included, `SHOW PROFILE` displays information for statement n. The values of n correspond to the `Query_ID` values displayed by `SHOW PROFILES`.

The `LIMIT row_count` clause may be given to limit the output to `row_count` rows. If `LIMIT` is given, `OFFSET offset` may be added to begin the output `offset` rows into the full set of rows.

By default, `SHOW PROFILE` displays `Status` and `Duration` columns. The `Status` values are like the `State` values displayed by `SHOW PROCESSLIST`, although there might be some minor differences in interpretation for the two statements for some status values (see Section 8.14, "Examining Thread Information").

Optional `type` values may be specified to display specific additional types of information:

- `ALL` displays all information

- `BLOCK IO` displays counts for block input and output operations

- `CONTEXT SWITCHES` displays counts for voluntary and involuntary context switches

- `CPU` displays user and system CPU usage times

- `IPC` displays counts for messages sent and received

- `MEMORY` is not currently implemented

- `PAGE FAULTS` displays counts for major and minor page faults

- `SOURCE` displays the names of functions from the source code, together with the name and line number of the file in which the function occurs

- `SWAPS` displays swap counts

Profiling is enabled per session. When a session ends, its profiling information is lost.

```
mysql> SELECT @@profiling;
+-------------+
| @@profiling |
+-------------+
|           0 |
+-------------+
1 row in set (0.00 sec)

mysql> SET profiling = 1;
Query OK, 0 rows affected (0.00 sec)

mysql> DROP TABLE IF EXISTS t1;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> CREATE TABLE T1 (id INT);
Query OK, 0 rows affected (0.01 sec)

mysql> SHOW PROFILES;
+----------+----------+-------------------------+
| Query_ID | Duration | Query                   |
+----------+----------+-------------------------+
|        0 | 0.000088 | SET PROFILING = 1       |
|        1 | 0.000136 | DROP TABLE IF EXISTS t1 |
|        2 | 0.011947 | CREATE TABLE t1 (id INT) |
+----------+----------+-------------------------+
3 rows in set (0.00 sec)

mysql> SHOW PROFILE;
+----------------------+----------+
| Status               | Duration |
+----------------------+----------+
| checking permissions | 0.000040 |
| creating table       | 0.000056 |
| After create         | 0.011363 |
| query end            | 0.000375 |
| freeing items        | 0.000089 |
| logging slow query   | 0.000019 |
| cleaning up          | 0.000005 |
+----------------------+----------+
7 rows in set (0.00 sec)

mysql> SHOW PROFILE FOR QUERY 1;
+--------------------+----------+
| Status             | Duration |
+--------------------+----------+
| query end          | 0.000107 |
| freeing items      | 0.000008 |
| logging slow query | 0.000015 |
| cleaning up        | 0.000006 |
```

```
+--------------------+----------+
4 rows in set (0.00 sec)

mysql> SHOW PROFILE CPU FOR QUERY 2;
+----------------------+----------+----------+------------+
| Status               | Duration | CPU_user | CPU_system |
+----------------------+----------+----------+------------+
| checking permissions | 0.000040 | 0.000038 |   0.000002 |
| creating table       | 0.000056 | 0.000028 |   0.000028 |
| After create         | 0.011363 | 0.000217 |   0.001571 |
| query end            | 0.000375 | 0.000013 |   0.000028 |
| freeing items        | 0.000089 | 0.000010 |   0.000014 |
| logging slow query   | 0.000019 | 0.000009 |   0.000010 |
| cleaning up          | 0.000005 | 0.000003 |   0.000002 |
+----------------------+----------+----------+------------+
7 rows in set (0.00 sec)
```

Note

Profiling is only partially functional on some architectures. For values that depend on the `getrusage()` system call, `NULL` is returned on systems such as Windows that do not support the call. In addition, profiling is per process and not per thread. This means that activity on threads within the server other than your own may affect the timing information that you see.

SHOW PROFILES and SHOW PROFILE were added in MySQL 5.1.24 (but were not added to binary distributions by default until 5.1.28).

You can also get profiling information from the PROFILING table in INFORMATION_SCHEMA. See Section 20.14, "The INFORMATION_SCHEMA PROFILING Table". For example, the following queries produce the same result:

```
SHOW PROFILE FOR QUERY 2;

SELECT STATE, FORMAT(DURATION, 6) AS DURATION
FROM INFORMATION_SCHEMA.PROFILING
WHERE QUERY_ID = 2 ORDER BY SEQ;
```

13.7.5.33 SHOW PROFILES Syntax

```
SHOW PROFILES
```

The SHOW PROFILES statement, together with SHOW PROFILE, displays profiling information that indicates resource usage for statements executed during the course of the current session. For more information, see Section 13.7.5.32, "SHOW PROFILE Syntax".

13.7.5.34 SHOW SCHEDULER STATUS Syntax

```
SHOW SCHEDULER STATUS
```

This statement provides debugging information regarding the Event Scheduler's state. It is supported only in -debug builds of MySQL 5.1.11, and was removed in 5.1.12 and subsequent releases.

Sample output is shown here:

```
+-------------------------------+---------------------+
```

```
| Name                           | Value               |
+--------------------------------+---------------------+
| scheduler state                | INITIALIZED         |
| thread_id                      | NULL                |
| scheduler last locked at       | init_scheduler::313 |
| scheduler last unlocked at     | init_scheduler::318 |
| scheduler waiting on condition | 0                   |
| scheduler workers count        | 0                   |
| scheduler executed events      | 0                   |
| scheduler data locked          | 0                   |
| queue element count            | 1                   |
| queue data locked              | 0                   |
| queue data attempting lock     | 0                   |
| queue last locked at           | create_event::218   |
| queue last unlocked at         | create_event::222   |
| queue last attempted lock at   | ::0                 |
| queue waiting on condition     | 0                   |
| next activation at             |    0-00-00 00:00:00 |
+--------------------------------+---------------------+
```

In MySQL 5.1.12 and later, this information can be obtained using `mysqladmin debug`. (See
Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".) For more information about
obtaining Event Scheduler status information, see Section 19.4.5, "Event Scheduler Status".

13.7.5.35 SHOW SLAVE HOSTS Syntax

```
SHOW SLAVE HOSTS
```

Displays a list of replication slaves currently registered with the master. Only slaves started with the `--report-host=host_name` option are visible in this list.

`SHOW SLAVE HOSTS` should be executed on a server that acts as a replication master. The statement
displays information about servers that are or have been connected as replication slaves, with each row of
the result corresponding to one slave server, as shown here:

```
mysql> SHOW SLAVE HOSTS;
+-----------+----------+------+-----------+
| Server_id | Host     | Port | Master_id |
+-----------+----------+------+-----------+
|  192168010 | iconnect2 | 3306 | 192168011 |
| 1921680101 | athena    | 3306 | 192168011 |
+-----------+----------+------+-----------+
```

- `Server_id`: The unique server ID of the slave server, as configured in the slave server's option file, or
  on the command line with `--server-id=value`.

- `Host`: The host name of the slave server as specified on the slave with the `--report-host` option.
  This can differ from the machine name as configured in the operating system.

- `User`: The slave server user name as, specified on the slave with the `--report-user` option.
  Statement output includes this column only if the master server is started with the `--show-slave-auth-info` option.

- `Password`: The slave server password as, specified on the slave with the `--report-password` option.
  Statement output includes this column only if the master server is started with the `--show-slave-auth-info` option.

- `Port`: The port on the master to which the slave server is listening, as specified on the slave with the `--report-port` option.

- `Master_id`: The unique server ID of the master server that the slave server is replicating from. This is the server ID of the server on which `SHOW SLAVE HOSTS` is executed, so this same value is listed for each row in the result.

Some MySQL versions report another variable, `Rpl_recovery_rank`. This variable was never used, and was eventually removed. (Bug #13963)

13.7.5.36 SHOW SLAVE STATUS Syntax

```
SHOW SLAVE STATUS
```

This statement provides status information on essential parameters of the slave threads. It requires either the `SUPER` or `REPLICATION CLIENT` privilege.

If you issue this statement using the `mysql` client, you can use a `\G` statement terminator rather than a semicolon to obtain a more readable vertical layout:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
               Slave_IO_State: Waiting for master to send event
                  Master_Host: localhost
                  Master_User: root
                  Master_Port: 3306
                Connect_Retry: 3
              Master_Log_File: gbichot-bin.005
          Read_Master_Log_Pos: 79
               Relay_Log_File: gbichot-relay-bin.005
                Relay_Log_Pos: 548
        Relay_Master_Log_File: gbichot-bin.005
             Slave_IO_Running: Yes
            Slave_SQL_Running: Yes
              Replicate_Do_DB:
          Replicate_Ignore_DB:
           Replicate_Do_Table:
       Replicate_Ignore_Table:
      Replicate_Wild_Do_Table:
  Replicate_Wild_Ignore_Table:
                   Last_Errno: 0
                   Last_Error:
                 Skip_Counter: 0
          Exec_Master_Log_Pos: 79
              Relay_Log_Space: 552
              Until_Condition: None
               Until_Log_File:
                Until_Log_Pos: 0
           Master_SSL_Allowed: No
           Master_SSL_CA_File:
           Master_SSL_CA_Path:
              Master_SSL_Cert:
            Master_SSL_Cipher:
               Master_SSL_Key:
        Seconds_Behind_Master: 8
Master_SSL_Verify_Server_Cert: No
                Last_IO_Errno: 0
                Last_IO_Error:
               Last_SQL_Errno: 0
               Last_SQL_Error:
```

The following list describes the fields returned by `SHOW SLAVE STATUS`. For additional information about interpreting their meanings, see Section 16.1.4.1, "Checking Replication Status".

- `Slave_IO_State`

A copy of the `State` field of the `SHOW PROCESSLIST` output for the slave I/O thread. This tells you what the thread is doing: trying to connect to the master, waiting for events from the master, reconnecting to the master, and so on. For a listing of possible states, see Section 8.14.6, "Replication Slave I/O Thread States".

- `Master_Host`

  The master host that the slave is connected to.

- `Master_User`

  The user name of the account used to connect to the master.

- `Master_Port`

  The port used to connect to the master.

- `Connect_Retry`

  The number of seconds between connect retries (default 60). This can be set with the `CHANGE MASTER TO` statement or `--master-connect-retry` option.

- `Master_Log_File`

  The name of the master binary log file from which the I/O thread is currently reading.

- `Read_Master_Log_Pos`

  The position in the current master binary log file up to which the I/O thread has read.

- `Relay_Log_File`

  The name of the relay log file from which the SQL thread is currently reading and executing.

- `Relay_Log_Pos`

  The position in the current relay log file up to which the SQL thread has read and executed.

- `Relay_Master_Log_File`

  The name of the master binary log file containing the most recent event executed by the SQL thread.

- `Slave_IO_Running`

  Whether the I/O thread is started and has connected successfully to the master. Internally, the state of this thread is represented by one of the following three values:

  - **MYSQL_SLAVE_NOT_RUN.** The slave I/O thread is not running. For this state, `Slave_IO_Running` is `No`.

  - **MYSQL_SLAVE_RUN_NOT_CONNECT.** The slave I/O thread is running, but is not connected to a replication master. For this state, `Slave_IO_Running` depends on the server version as shown in the following table.

MySQL Version	`Slave_IO_Running`
4.1 (4.1.13 and earlier); 5.0 (5.0.11 and earlier)	`Yes`
4.1 (4.1.14 and later); 5.0 (5.0.12 and later)	`No`

MySQL Version	`Slave_IO_Running`
5.1 (5.1.45 and earlier)	`No`
5.1 (5.1.46 and later); 5.5	`Connecting`

- **MYSQL_SLAVE_RUN_CONNECT.** The slave I/O thread is running, and is connected to a replication master. For this state, `Slave_IO_Running` is `Yes`.

Beginning with MySQL 5.1.46, the value of the `Slave_running` system status variable corresponds with this value. (Bug #30703)

- `Slave_SQL_Running`

Whether the SQL thread is started.

- `Replicate_Do_DB`, `Replicate_Ignore_DB`

The lists of databases that were specified with the `--replicate-do-db` and `--replicate-ignore-db` options, if any.

- `Replicate_Do_Table`, `Replicate_Ignore_Table`, `Replicate_Wild_Do_Table`, `Replicate_Wild_Ignore_Table`

The lists of tables that were specified with the `--replicate-do-table`, `--replicate-ignore-table`, `--replicate-wild-do-table`, and `--replicate-wild-ignore-table` options, if any.

- `Last_Errno`, `Last_Error`

As of MySQL 5.1.20, these columns are aliases for `Last_SQL_Errno` and `Last_SQL_Error`. Before 5.1.20, they indicate the error number and error message returned by the most recently executed statement. An error number of 0 and message of the empty string mean "no error." If the `Last_Error` value is not empty, the error values also appear in the slave's error log.

Beginning with MySQL 5.1.37, and with MySQL Cluster NDB 6.2.17, MySQL Cluster NDB 6.3.23, and MySQL Cluster NDB 6.4.3: Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns. (Bug #34654, Bug #44270)

> **Note**
>
> When the slave SQL thread receives an error, it reports the error first, then stops the SQL thread. This means that there is a small window of time during which `SHOW SLAVE STATUS` shows a nonzero value for `Last_SQL_Errno` even though `Slave_SQL_Running` still displays `Yes`.

- `Skip_Counter`

The current value of the `sql_slave_skip_counter` system variable. See Section 13.4.2.6, "SET GLOBAL sql_slave_skip_counter Syntax".

- `Exec_Master_Log_Pos`

The position in the current master binary log file to which the SQL thread has read and executed, marking the start of the next transaction or event to be processed. You can use this value with the `CHANGE MASTER TO` statement's `MASTER_LOG_POS` option when starting a new slave from an existing slave, so that the new slave reads from this point. The coordinates given by (`Relay_Master_Log_File`, `Exec_Master_Log_Pos`) in the master's binary log correspond to the coordinates given by (`Relay_Log_File`, `Relay_Log_Pos`) in the relay log.

- `Relay_Log_Space`

  The total combined size of all existing relay log files.

- `Until_Condition`, `Until_Log_File`, `Until_Log_Pos`

  The values specified in the `UNTIL` clause of the `START SLAVE` statement.

  `Until_Condition` has these values:

  - `None` if no `UNTIL` clause was specified

  - `Master` if the slave is reading until a given position in the master's binary log

  - `Relay` if the slave is reading until a given position in its relay log

  `Until_Log_File` and `Until_Log_Pos` indicate the log file name and position that define the coordinates at which the SQL thread stops executing.

- `Master_SSL_Allowed`, `Master_SSL_CA_File`, `Master_SSL_CA_Path`, `Master_SSL_Cert`, `Master_SSL_Cipher`, `Master_SSL_Key`, `Master_SSL_Verify_Server_Cert`

  These fields show the SSL parameters used by the slave to connect to the master, if any.

  `Master_SSL_Allowed` has these values:

  - `Yes` if an SSL connection to the master is permitted

  - `No` if an SSL connection to the master is not permitted

  - `Ignored` if an SSL connection is permitted but the slave server does not have SSL support enabled

  The values of the other SSL-related fields correspond to the values of the `MASTER_SSL_CA`, `MASTER_SSL_CAPATH`, `MASTER_SSL_CERT`, `MASTER_SSL_CIPHER`, `MASTER_SSL_KEY`, and `MASTER_SSL_VERIFY_SERVER_CERT` options to the `CHANGE MASTER TO` statement. See Section 13.4.2.1, "CHANGE MASTER TO Syntax". `MASTER_SSL_VERIFY_SERVER_CERT` was added in MySQL 5.1.18.

- `Seconds_Behind_Master`

  This field is an indication of how "late" the slave is:

  - When the slave is actively processing updates, this field shows the difference between the current timestamp on the slave and the original timestamp logged on the master for the event currently being processed on the slave.

  - When no event is currently being processed on the slave, this value is 0.

  In essence, this field measures the time difference in seconds between the slave SQL thread and the slave I/O thread. If the network connection between master and slave is fast, the slave I/O thread is very close to the master, so this field is a good approximation of how late the slave SQL thread is compared to the master. If the network is slow, this is *not* a good approximation; the slave SQL thread may quite often be caught up with the slow-reading slave I/O thread, so `Seconds_Behind_Master` often shows a value of 0, even if the I/O thread is late compared to the master. In other words, *this column is useful only for fast networks*.

  This time difference computation works even if the master and slave do not have identical clock times, provided that the difference, computed when the slave I/O thread starts, remains constant from then

on. Any changes—including NTP updates—can lead to clock skews that can make calculation of `Seconds_Behind_Master` less reliable.

This field is `NULL` (undefined or unknown) if the slave SQL thread is not running, or if the slave I/O thread is not running or is not connected to the master. For example, if the slave I/O thread is running but is not connected to the master and is sleeping for the number of seconds given by the `CHANGE MASTER TO` statement or `--master-connect-retry` option (default 60) before reconnecting, the value is `NULL`. This is because the slave cannot know what the master is doing, and so cannot say reliably how late it is.

The value of `Seconds_Behind_Master` is based on the timestamps stored in events, which are preserved through replication. This means that if a master M1 is itself a slave of M0, any event from M1's binary log that originates from M0's binary log has M0's timestamp for that event. This enables MySQL to replicate `TIMESTAMP` successfully. However, the problem for `Seconds_Behind_Master` is that if M1 also receives direct updates from clients, the `Seconds_Behind_Master` value randomly fluctuates because sometimes the last event from M1 originates from M0 and sometimes is the result of a direct update on M1.

- `Last_IO_Errno`, `Last_IO_Error`

  The error number and error message of the most recent error that caused the I/O thread to stop. An error number of 0 and message of the empty string mean "no error." If the `Last_IO_Error` value is not empty, the error values also appear in the slave's error log. These columns were added in MySQL 5.1.20.

  MySQL Cluster. Beginning with MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3: Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns. This applies to MySQL Cluster only. (Bug #34654)

- `Last_SQL_Errno`, `Last_SQL_Error`

  The error number and error message of the most recent error that caused the SQL thread to stop. An error number of 0 and message of the empty string mean "no error." If the `Last_SQL_Error` value is not empty, the error values also appear in the slave's error log. These columns were added in MySQL 5.1.20.

  Example:

```
Last_SQL_Errno: 1051
Last_SQL_Error: error 'Unknown table 'z'' on query 'drop table z'
```

  The message indicates that the table `z` existed on the master and was dropped there, but it did not exist on the slave, so `DROP TABLE` failed on the slave. (This might occur, for example, if you forget to copy the table to the slave when setting up replication.)

  MySQL Cluster. Beginning with MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3: Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns. This applies to MySQL Cluster only. (Bug #34654)

- `Replicate_Ignore_Server_Ids` (MySQL Cluster only)

  Beginning with MySQL Cluster NDB 6.1.29, MySQL Cluster NDB 6.3.31, MySQL Cluster NDB 7.0.11, and MySQL Cluster NDB 7.1.0, you can tell a slave to ignore events from 0 or more masters using the `IGNORE_SERVER_IDS` option in a `CHANGE MASTER TO` statement. (See Bug #47037.) This is normally of interest only when using a circular or other multi-master replication setup.

The message shown for `Replicate_Ignore_Server_Ids` consists of a space-delimited list of one or more numbers, the first value indicating the number of servers to be ignored; if not 0 (the default), this server-count value is followed by the actual server IDs. For example, if a `CHANGE MASTER TO` statement containing the `IGNORE_SERVER_IDS = (2,6,9)` option has been issued to tell a slave to ignore masters having the server ID 2, 6, or 9, that information appears as shown here:

```
Replicate_Ignore_Server_Ids: 3 2 6 9
```

`Replicate_Ignore_Server_Ids` filtering is performed by the I/O thread, rather than by the SQL thread, which means that events which are filtered out are not written to the relay log. This differs from the filtering actions taken by server options such `--replicate-do-table`, which apply to the SQL thread.

13.7.5.37 SHOW STATUS Syntax

```
SHOW [GLOBAL | SESSION] STATUS
    [LIKE 'pattern' | WHERE expr]
```

`SHOW STATUS` provides server status information (see Section 5.1.6, "Server Status Variables"). This statement does not require any privilege. It requires only the ability to connect to the server.

Status variable information is also available from these sources:

- The `GLOBAL_STATUS` and `SESSION_STATUS` tables. See Section 20.8, "The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables".

- The `mysqladmin extended-status` command. See Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".

For `SHOW STATUS`, a `LIKE` clause, if present, indicates which variable names to match. A `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

`SHOW STATUS` accepts an optional `GLOBAL` or `SESSION` variable scope modifier:

- With a `GLOBAL` modifier, the statement displays the global status values. A global status variable may represent status for some aspect of the server itself (for example, `Aborted_connects`), or the aggregated status over all connections to MySQL (for example, `Bytes_received` and `Bytes_sent`). If a variable has no global value, the session value is displayed.

- With a `SESSION` modifier, the statement displays the status variable values for the current connection. If a variable has no session value, the global value is displayed. `LOCAL` is a synonym for `SESSION`.

- If no modifier is present, the default is `SESSION`.

The scope for each status variable is listed at Section 5.1.6, "Server Status Variables".

Each invocation of the `SHOW STATUS` statement uses an internal temporary table and increments the global `Created_tmp_tables` value.

Partial output is shown here. The list of names and values may differ for your server. The meaning of each variable is given in Section 5.1.6, "Server Status Variables".

```
mysql> SHOW STATUS;
+------------------------+------------+
| Variable_name          | Value      |
+------------------------+------------+
| Aborted_clients        | 0          |
| Aborted_connects       | 0          |
| Bytes_received         | 155372598  |
| Bytes_sent             | 1176560426 |
| Connections            | 30023      |
| Created_tmp_disk_tables| 0          |
| Created_tmp_tables     | 8340       |
| Created_tmp_files      | 60         |
...
| Open_tables            | 1          |
| Open_files             | 2          |
| Open_streams           | 0          |
| Opened_tables          | 44600      |
| Questions              | 2026873    |
...
| Table_locks_immediate  | 1920382    |
| Table_locks_waited     | 0          |
| Threads_cached         | 0          |
| Threads_created        | 30022      |
| Threads_connected      | 1          |
| Threads_running        | 1          |
| Uptime                 | 80380      |
+------------------------+------------+
```

With a `LIKE` clause, the statement displays only rows for those variables with names that match the pattern:

```
mysql> SHOW STATUS LIKE 'Key%';
+--------------------+----------+
| Variable_name      | Value    |
+--------------------+----------+
| Key_blocks_used    | 14955    |
| Key_read_requests  | 96854827 |
| Key_reads          | 162040   |
| Key_write_requests | 7589728  |
| Key_writes         | 3813196  |
+--------------------+----------+
```

13.7.5.38 SHOW TABLE STATUS Syntax

```
SHOW TABLE STATUS [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW TABLE STATUS` works likes `SHOW TABLES`, but provides a lot of information about each non-`TEMPORARY` table. You can also get this list using the `mysqlshow --status db_name` command. The `LIKE` clause, if present, indicates which table names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

This statement also displays information about views.

`SHOW TABLE STATUS` output has the following columns:

- `Name`

  The name of the table.

- `Engine`

The storage engine for the table. See Chapter 14, *Storage Engines*.

- `Version`

  The version number of the table's `.frm` file.

- `Row_format`

  The row-storage format (`Fixed`, `Dynamic`, `Compressed`, `Redundant`, `Compact`). For `MyISAM` tables, (`Dynamic` corresponds to what `myisamchk -dvv` reports as `Packed`. The format of `InnoDB` tables is reported as `Redundant` or `Compact`. For the `Barracuda` file format of the `InnoDB Plugin`, the format may be `Compressed` or `Dynamic`.

- `Rows`

  The number of rows. Some storage engines, such as `MyISAM`, store the exact count. For other storage engines, such as `InnoDB`, this value is an approximation, and may vary from the actual value by as much as 40 to 50%. In such cases, use `SELECT COUNT(*)` to obtain an accurate count.

  The `Rows` value is `NULL` for tables in the `INFORMATION_SCHEMA` database.

- `Avg_row_length`

  The average row length.

  Refer to the notes at the end of this section for related information.

- `Data_length`

  For `MyISAM`, `Data_length` is the length of the data file, in bytes.

  For `InnoDB`, `Data_length` is the approximate amount of memory allocated for the clustered index, in bytes. Specifically, it is the clustered index size, in pages, multiplied by the `InnoDB` page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- `Max_data_length`

  For `MyISAM`, `Max_data_length` is maximum length of the data file. This is the total number of bytes of data that can be stored in the table, given the data pointer size used.

  Unused for `InnoDB`.

  Refer to the notes at the end of this section for information regarding other storage engines.

- `Index_length`

  For `MyISAM`, `Index_length` is the length of the index file, in bytes.

  For `InnoDB`, `Index_length` is the approximate amount of memory allocated for non-clustered indexes, in bytes. Specifically, it is the sum of non-clustered index sizes, in pages, multiplied by the `InnoDB` page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- `Data_free`

  The number of allocated but unused bytes.

Beginning with MySQL 5.1.24, this information is also shown for `InnoDB` tables (previously, it was in the `Comment` value). `InnoDB` tables report the free space of the tablespace to which the table belongs. For a table located in the shared tablespace, this is the free space of the shared tablespace. If you are using multiple tablespaces and the table has its own tablespace, the free space is for only that table. Free space means the number of bytes in completely free extents minus a safety margin. Even if free space displays as 0, it may be possible to insert rows as long as new extents need not be allocated.

For partitioned tables, this value is only an estimate and may not be absolutely correct. A more accurate method of obtaining this information in such cases is to query the `INFORMATION_SCHEMA.PARTITIONS` table, as shown in this example:

```
SELECT    SUM(DATA_FREE)
    FROM  INFORMATION_SCHEMA.PARTITIONS
    WHERE TABLE_SCHEMA = 'mydb'
    AND   TABLE_NAME   = 'mytable';
```

For more information, see Section 20.11, "The INFORMATION_SCHEMA PARTITIONS Table".

- `Auto_increment`

  The next `AUTO_INCREMENT` value.

- `Create_time`

  When the table was created.

- `Update_time`

  When the data file was last updated. For some storage engines, this value is `NULL`. For example, `InnoDB` stores multiple tables in its system tablespace and the data file timestamp does not apply. Even with file-per-table mode with each `InnoDB` table in a separate `.ibd` file, change buffering can delay the write to the data file, so the file modification time is different from the time of the last insert, update, or delete. For `MyISAM`, the data file timestamp is used; however, on Windows the timestamp is not updated by updates so the value is inaccurate.

- `Check_time`

  When the table was last checked. Not all storage engines update this time, in which case the value is always `NULL`.

- `Collation`

  The table's character set and collation.

- `Checksum`

  The live checksum value (if any).

- `Create_options`

  Extra options used with `CREATE TABLE`. The original options supplied when `CREATE TABLE` is called are retained and the options reported here may differ from the active table settings and options.

- `Comment`

  The comment used when creating the table (or information as to why MySQL could not access the table information).

Before MySQL 5.1.24, free space for `InnoDB` tables is reported in the comment. As of 5.1.24, it is reported in the `Data_free` column.

Notes:

- For `MEMORY` tables, the `Data_length`, `Max_data_length`, and `Index_length` values approximate the actual amount of allocated memory. The allocation algorithm reserves memory in large amounts to reduce the number of allocation operations.

- For `NDBCLUSTER` tables, the output of this statement shows appropriate values for the `Avg_row_length` and `Data_length` columns, with the exception that `BLOB` columns are not taken into account. Prior to MySQL 5.1.21, the number of MySQL Cluster replicas was shown in the `Comment` column as `number_of_replicas` (Bug #11379).

- For views, all the fields displayed by `SHOW TABLE STATUS` are `NULL` except that `Name` indicates the view name and `Comment` says `view`.

13.7.5.39 SHOW TABLES Syntax

```
SHOW [FULL] TABLES [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW TABLES` lists the non-`TEMPORARY` tables in a given database. You can also get this list using the `mysqlshow db_name` command. The `LIKE` clause, if present, indicates which table names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

Matching performed by the `LIKE` clause is dependent on the setting of the `lower_case_table_names` system variable.

This statement also lists any views in the database. The `FULL` modifier is supported such that `SHOW FULL TABLES` displays a second output column. Values for the second column are `BASE TABLE` for a table and `VIEW` for a view.

If you have no privileges for a base table or view, it does not show up in the output from `SHOW TABLES` or `mysqlshow db_name`.

13.7.5.40 SHOW TRIGGERS Syntax

```
SHOW TRIGGERS [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW TRIGGERS` lists the triggers currently defined for tables in a database (the default database unless a `FROM` clause is given). This statement returns results only for databases and tables for which you have the `TRIGGER` privilege, or (prior to MySQL 5.1.23) if you have the `SUPER` privilege). The `LIKE` clause, if present, indicates which table names to match (not trigger names) and causes the statement to display triggers for those tables. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

For the trigger `ins_sum` as defined in Section 19.3, "Using Triggers", the output of this statement is as shown here:

```
mysql> SHOW TRIGGERS LIKE 'acc%'\G
```

```
*************************** 1. row ***************************
           Trigger: ins_sum
             Event: INSERT
             Table: account
         Statement: SET @sum = @sum + NEW.amount
            Timing: BEFORE
           Created: NULL
          sql_mode:
           Definer: me@localhost
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

`SHOW TRIGGERS` output has the following columns:

- `Trigger`: The trigger name.

- `Event`: The type of operation that causes trigger activation. The value is `'INSERT'`, `'UPDATE'`, or `'DELETE'`.

- `Table`: The table for which the trigger is defined.

- `Statement`: The trigger body; that is, the statement executed when the trigger activates.

- `Timing`: Whether the trigger activates before or after the triggering event. The value is `'BEFORE'` or `'AFTER'`.

- `Created`: The value of this column is always `NULL`.

- `sql_mode`: The SQL mode in effect when the trigger executes.

- `Definer`: The account of the user who created the trigger, in `'user_name'@'host_name'` format.

- `character_set_client`: The session value of the `character_set_client` system variable when the trigger was created. This column was added in MySQL 5.1.21.

- `collation_connection`: The session value of the `collation_connection` system variable when the trigger was created. This column was added in MySQL 5.1.21.

- `Database Collation`: The collation of the database with which the trigger is associated. This column was added in MySQL 5.1.21.

You can also obtain information about trigger objects from `INFORMATION_SCHEMA`, which contains a `TRIGGERS` table. See Section 20.23, "The INFORMATION_SCHEMA TRIGGERS Table".

13.7.5.41 SHOW VARIABLES Syntax

```
SHOW [GLOBAL | SESSION] VARIABLES
    [LIKE 'pattern' | WHERE expr]
```

`SHOW VARIABLES` shows the values of MySQL system variables (see Section 5.1.4, "Server System Variables"). This statement does not require any privilege. It requires only the ability to connect to the server.

System variable information is also available from these sources:

- The `GLOBAL_VARIABLES` and `SESSION_VARIABLES` tables. See Section 20.9, "The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables".

- The `mysqladmin variables` command. See Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".

For `SHOW VARIABLES`, a `LIKE` clause, if present, indicates which variable names to match. A `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 20.27, "Extensions to SHOW Statements".

`SHOW VARIABLES` accepts an optional `GLOBAL` or `SESSION` variable scope modifier:

- With a `GLOBAL` modifier, the statement displays global system variable values. These are the values used to initialize the corresponding session variables for new connections to MySQL. If a variable has no global value, the session value is displayed.

- With a `SESSION` modifier, the statement displays the system varaible values that are in effect for the current connection. If a variable has no session value, the global value is displayed. `LOCAL` is a synonym for `SESSION`.

- If no modifier is present, the default is `SESSION`.

The scope for each system variable is listed at Section 5.1.4, "Server System Variables".

`SHOW VARIABLES` is subject to a version-dependent display-width limit. For variables with very long values that are not completely displayed, use `SELECT` as a workaround. For example:

```
SELECT @@GLOBAL.innodb_data_file_path;
```

Most system variables can be set at server startup (read-only variables such as `version_comment` are exceptions). Many can be changed at runtime with the `SET` statement. See Section 5.1.5, "Using System Variables", and Section 13.7.4.1, "SET Syntax for Variable Assignment".

Partial output is shown here. The list of names and values may differ for your server. Section 5.1.4, "Server System Variables", describes the meaning of each variable, and Section 8.12.2, "Tuning Server Parameters", provides information about tuning them.

```
mysql> SHOW VARIABLES;
+--------------------------------+--------------------------+
| Variable_name                  | Value                    |
+--------------------------------+--------------------------+
| auto_increment_increment       | 1                        |
| auto_increment_offset          | 1                        |
| automatic_sp_privileges        | ON                       |
| back_log                       | 50                       |
| basedir                        | /home/jon/bin/mysql-5.1/ |
| binlog_cache_size              | 32768                    |
| bulk_insert_buffer_size        | 8388608                  |
| character_set_client           | latin1                   |
| character_set_connection       | latin1                   |
...
| max_user_connections           | 0                        |
| max_write_lock_count           | 4294967295               |
| multi_range_count              | 256                      |
| myisam_data_pointer_size       | 6                        |
| myisam_max_sort_file_size      | 2147483647               |
| myisam_recover_options         | OFF                      |
| myisam_repair_threads          | 1                        |
| myisam_sort_buffer_size        | 8388608                  |
| ndb_autoincrement_prefetch_sz  | 32                       |
| ndb_cache_check_time           | 0                        |
| ndb_force_send                 | ON                       |
...
```

```
| time_zone                      | SYSTEM                   |
| timed_mutexes                  | OFF                      |
| tmp_table_size                 | 33554432                 |
| tmpdir                         |                          |
| transaction_alloc_block_size   | 8192                     |
| transaction_prealloc_size      | 4096                     |
| tx_isolation                   | REPEATABLE-READ          |
| updatable_views_with_limit     | YES                      |
| version                        | 5.1.6-alpha-log          |
| version_comment                | Source distribution      |
| version_compile_machine        | i686                     |
| version_compile_os             | suse-linux               |
| wait_timeout                   | 28800                    |
+--------------------------------+--------------------------+
```

With a `LIKE` clause, the statement displays only rows for those variables with names that match the pattern. To obtain the row for a specific variable, use a `LIKE` clause as shown:

```
SHOW VARIABLES LIKE 'max_join_size';
SHOW SESSION VARIABLES LIKE 'max_join_size';
```

To get a list of variables whose name match a pattern, use the "`%`" wildcard character in a `LIKE` clause:

```
SHOW VARIABLES LIKE '%size%';
SHOW GLOBAL VARIABLES LIKE '%size%';
```

Wildcard characters can be used in any position within the pattern to be matched. Strictly speaking, because "`_`" is a wildcard that matches any single character, you should escape it as "`\_`" to match it literally. In practice, this is rarely necessary.

13.7.5.42 SHOW WARNINGS Syntax

```
SHOW WARNINGS [LIMIT [offset,] row_count]
SHOW COUNT(*) WARNINGS
```

`SHOW WARNINGS` is a diagnostic statement that displays information about the conditions (errors, warnings, and notes) resulting from executing a statement in the current session. Warnings are generated for DML statements such as `INSERT`, `UPDATE`, and `LOAD DATA INFILE` as well as DDL statements such as `CREATE TABLE` and `ALTER TABLE`.

The `LIMIT` clause has the same syntax as for the `SELECT` statement. See Section 13.2.8, "SELECT Syntax".

`SHOW WARNINGS` is also used following `EXPLAIN EXTENDED`, to display the extra information generated by `EXPLAIN` when the `EXTENDED` keyword is used. See Section 8.8.3, "EXPLAIN EXTENDED Output Format".

`SHOW WARNINGS` displays information about the conditions resulting from the most recent statement in the current session that generated messages. It shows nothing if the most recent statement used a table and generated no messages. (That is, statements that use a table but generate no messages clear the message list.) Statements that do not use tables and do not generate messages have no effect on the message list.

The `SHOW COUNT(*) WARNINGS` diagnostic statement displays the total number of errors, warnings, and notes. You can also retrieve this number from the `warning_count` system variable:

```
SHOW COUNT(*) WARNINGS;
```

```
SELECT @@warning_count;
```

A related diagnostic statement, SHOW ERRORS, shows only error conditions (it excludes warnings and notes), and SHOW COUNT(*) ERRORS statement displays the total number of errors. See Section 13.7.5.18, "SHOW ERRORS Syntax".

Here is a simple example that shows data-conversion warnings for INSERT:

```
mysql> CREATE TABLE t1 (a TINYINT NOT NULL, b CHAR(4));
Query OK, 0 rows affected (0.05 sec)

mysql> INSERT INTO t1 VALUES(10,'mysql'), (NULL,'test'), (300,'xyz');
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1265
Message: Data truncated for column 'b' at row 1
*************************** 2. row ***************************
  Level: Warning
   Code: 1048
Message: Column 'a' cannot be null
*************************** 3. row ***************************
  Level: Warning
   Code: 1264
Message: Out of range value for column 'a' at row 3
3 rows in set (0.00 sec)
```

The max_error_count system variable controls the maximum number of error, warning, and note messages for which the server stores information, and thus the number of messages that SHOW WARNINGS displays. To change the number of messages the server can store, change the value of max_error_count. The default is 64.

max_error_count controls only how many messages are stored, not how many are counted. The value of warning_count is not limited by max_error_count, even if the number of messages generated exceeds max_error_count. The following example demonstrates this. The ALTER TABLE statement produces three warning messages (strict SQL mode is disabled for the example to prevent an error from occuring after a single conversion issue). Only one message is stored and displayed because max_error_count has been set to 1, but all three are counted (as shown by the value of warning_count):

```
mysql> SHOW VARIABLES LIKE 'max_error_count';
+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
| max_error_count | 64    |
+-----------------+-------+
1 row in set (0.00 sec)

mysql> SET max_error_count=1, sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> ALTER TABLE t1 MODIFY b CHAR;
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3

mysql> SHOW WARNINGS;
+---------+------+-------------------------------------+
| Level   | Code | Message                             |
+---------+------+-------------------------------------+
```

```
| Warning | 1263 | Data truncated for column 'b' at row 1 |
+---------+------+---------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @@warning_count;
+-----------------+
| @@warning_count |
+-----------------+
|               3 |
+-----------------+
1 row in set (0.01 sec)
```

To disable message storage, set `max_error_count` to 0. In this case, `warning_count` still indicates how many warnings occurred, but messages are not stored and cannot be displayed.

The `sql_notes` system variable controls whether note messages increment `warning_count` and whether the server stores them. By default, `sql_notes` is 1, but if set to 0, notes do not increment `warning_count` and the server does not store them:

```
mysql> SET sql_notes = 1;
mysql> DROP TABLE IF EXISTS test.no_such_table;
Query OK, 0 rows affected, 1 warning (0.00 sec)
mysql> SHOW WARNINGS;
+-------+------+------------------------------+
| Level | Code | Message                      |
+-------+------+------------------------------+
| Note  | 1051 | Unknown table 'no_such_table' |
+-------+------+------------------------------+
1 row in set (0.00 sec)

mysql> SET sql_notes = 0;
mysql> DROP TABLE IF EXISTS test.no_such_table;
Query OK, 0 rows affected (0.00 sec)
mysql> SHOW WARNINGS;
Empty set (0.00 sec)
```

The MySQL server sends to each client a count indicating the total number of errors, warnings, and notes resulting from the most recent statement executed by that client. From the C API, this value can be obtained by calling `mysql_warning_count()`. See Section 21.8.7.72, "mysql_warning_count()".

In the `mysql` client, you can enable and disable automatic warnings display using the `warnings` and `nowarning` commands, respectively, or their shortcuts, `\W` and `\w` (see Section 4.5.1.2, "mysql Commands"). For example:

```
mysql> \W
Show warnings enabled.
mysql> SELECT 1/0;
+------+
| 1/0  |
+------+
| NULL |
+------+
1 row in set, 1 warning (0.03 sec)

Warning (Code 1365): Division by 0
mysql> \w
Show warnings disabled.
```

13.7.6 Other Administrative Statements

13.7.6.1 BINLOG Syntax

```
BINLOG 'str'
```

BINLOG is an internal-use statement. It is generated by the mysqlbinlog program as the printable representation of certain events in binary log files. (See Section 4.6.7, "mysqlbinlog — Utility for Processing Binary Log Files".) The 'str' value is a base 64-encoded string the that server decodes to determine the data change indicated by the corresponding event. This statement requires the SUPER privilege. It was added in MySQL 5.1.5.

13.7.6.2 CACHE INDEX Syntax

```
CACHE INDEX
  tbl_index_list [, tbl_index_list] ...
  IN key_cache_name

tbl_index_list:
  tbl_name [[INDEX|KEY] (index_name[, index_name] ...)]
```

The CACHE INDEX statement assigns table indexes to a specific key cache. It is used only for MyISAM tables. After the indexes have been assigned, they can be preloaded into the cache if desired with LOAD INDEX INTO CACHE.

The following statement assigns indexes from the tables t1, t2, and t3 to the key cache named hot_cache:

```
mysql> CACHE INDEX t1, t2, t3 IN hot_cache;
+---------+--------------------+----------+----------+
| Table   | Op                 | Msg_type | Msg_text |
+---------+--------------------+----------+----------+
| test.t1 | assign_to_keycache | status   | OK       |
| test.t2 | assign_to_keycache | status   | OK       |
| test.t3 | assign_to_keycache | status   | OK       |
+---------+--------------------+----------+----------+
```

The syntax of CACHE INDEX enables you to specify that only particular indexes from a table should be assigned to the cache. The current implementation assigns all the table's indexes to the cache, so there is no reason to specify anything other than the table name.

The key cache referred to in a CACHE INDEX statement can be created by setting its size with a parameter setting statement or in the server parameter settings. For example:

```
mysql> SET GLOBAL keycache1.key_buffer_size=128*1024;
```

Key cache parameters can be accessed as members of a structured system variable. See Section 5.1.5.1, "Structured System Variables".

A key cache must exist before you can assign indexes to it:

```
mysql> CACHE INDEX t1 IN non_existent_cache;
ERROR 1284 (HY000): Unknown key cache 'non_existent_cache'
```

By default, table indexes are assigned to the main (default) key cache created at the server startup. When a key cache is destroyed, all indexes assigned to it become assigned to the default key cache again.

Index assignment affects the server globally: If one client assigns an index to a given cache, this cache is used for all queries involving the index, no matter which client issues the queries.

13.7.6.3 FLUSH Syntax

```
FLUSH [NO_WRITE_TO_BINLOG | LOCAL]
    flush_option [, flush_option] ...
```

The `FLUSH` statement has several variant forms that clear or reload various internal caches, flush tables, or acquire locks. To execute `FLUSH`, you must have the `RELOAD` privilege.

By default, the server writes `FLUSH` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

Note

> `FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, and `FLUSH TABLES WITH READ LOCK` are not written to the binary log in any case because they would cause problems if replicated to a slave.

Sending a `SIGHUP` signal to the server causes several flush operations to occur that are similar to various forms of the `FLUSH` statement. See Section 5.1.10, "Server Response to Signals".

The `FLUSH` statement causes an implicit commit. See Section 13.3.3, "Statements That Cause an Implicit Commit".

The `RESET` statement is similar to `FLUSH`. See Section 13.7.6.6, "RESET Syntax", for information about using the `RESET` statement with replication.

`flush_option` can be any of the following items:

- `DES_KEY_FILE`

  Reloads the DES keys from the file that was specified with the `--des-key-file` option at server startup time.

- `HOSTS`

  Empties the host cache. You should flush the host cache if some of your hosts change IP address or if the error message `Host 'host_name' is blocked` occurs. (See Section B.5.2.6, "Host 'host_name' is blocked".) When more than `max_connect_errors` errors occur successively for a given host while connecting to the MySQL server, MySQL assumes that something is wrong and blocks the host from further connection requests. Flushing the host cache enables further connection attempts from the host. The default value of `max_connect_errors` is 10. To avoid this error message, start the server with `max_connect_errors` set to a large value.

- `LOGS`

  Closes and reopens all log files. If binary logging is enabled, the sequence number of the binary log file is incremented by one relative to the previous file.

  Prior to MySQL 5.1.51, if you flush the logs using `FLUSH LOGS` and `mysqld` is writing the error log to a file (for example, if it was started with the `--log-error` option), log file renaming may occur, as described in Section 5.4.2, "The Error Log".

  `FLUSH LOGS` has no effect on tables used for the general query log or for the slow query log (see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations").

- `MASTER`

Deletes all binary logs, resets the binary log index file and creates a new binary log. `FLUSH MASTER` is deprecated in favor of `RESET MASTER`. `FLUSH MASTER` is still accepted in MySQL 5.1 for backward compatibility, but is removed in MySQL 5.6. See Section 13.4.1.2, "RESET MASTER Syntax".

- `PRIVILEGES`

  Reloads the privileges from the grant tables in the `mysql` database.

  The server caches information in memory as a result of `GRANT`, `CREATE USER`, `CREATE SERVER`, and `INSTALL PLUGIN` statements. This memory is not released by the corresponding `REVOKE`, `DROP USER`, `DROP SERVER`, and `UNINSTALL PLUGIN` statements, so for a server that executes many instances of the statements that cause caching, there will be an increase in memory use. This cached memory can be freed with `FLUSH PRIVILEGES`.

- `QUERY CACHE`

  Defragment the query cache to better utilize its memory. `FLUSH QUERY CACHE` does not remove any queries from the cache, unlike `FLUSH TABLES` or `RESET QUERY CACHE`.

- `SLAVE`

  Resets all replication slave parameters, including relay log files and replication position in the master's binary logs. `FLUSH SLAVE` is deprecated in favor of `RESET SLAVE`. `FLUSH SLAVE` is still accepted in MySQL 5.1 for backward compatibility, but is removed in MySQL 5.6. See Section 13.4.2.5, "RESET SLAVE Syntax".

- `STATUS`

  This option adds the current thread's session status variable values to the global values and resets the session values to zero. Some global variables may be reset to zero as well. It also resets the counters for key caches (default and named) to zero and sets `Max_used_connections` to the current number of open connections. This is something you should use only when debugging a query. See Section 1.7, "How to Report Bugs or Problems".

- `TABLES`

  `FLUSH TABLES` flushes tables, and, depending on the variant used, acquires locks. The permitted syntax is discussed later in this section.

- `USER_RESOURCES`

  Resets all per-hour user resources to zero. This enables clients that have reached their hourly connection, query, or update limits to resume activity immediately. `FLUSH USER_RESOURCES` does not apply to the limit on maximum simultaneous connections. See Section 6.3.4, "Setting Account Resource Limits".

The `mysqladmin` utility provides a command-line interface to some flush operations, using commands such as `flush-hosts`, `flush-logs`, `flush-privileges`, `flush-status`, and `flush-tables`. See Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server".

> **Note**
>
> It is not possible to issue `FLUSH` statements within stored functions or triggers. However, you may use `FLUSH` in stored procedures, so long as these are not called from stored functions or triggers. See Section C.1, "Restrictions on Stored Programs".

FLUSH TABLES Syntax

`FLUSH TABLES` has several forms, described following. `FLUSH TABLE` is a synonym for `FLUSH TABLES`, except that `TABLE` does not work with the `WITH READ LOCK` variant.

- `FLUSH TABLES`

  Closes all open tables, forces all tables in use to be closed, and flushes the query cache. `FLUSH TABLES` also removes all query results from the query cache, like the `RESET QUERY CACHE` statement.

- `FLUSH TABLES tbl_name [, tbl_name] ...`

  With a list of one or more comma-separated table names, this statement is like `FLUSH TABLES` with no names except that the server flushes only the named tables. No error occurs if a named table does not exist.

- `FLUSH TABLES WITH READ LOCK`

  Closes all open tables and locks all tables for all databases with a global read lock. This is a very convenient way to get backups if you have a file system such as Veritas or ZFS that can take snapshots in time. Use `UNLOCK TABLES` to release the lock.

  `FLUSH TABLES WITH READ LOCK` acquires a global read lock and not table locks, so it is not subject to the same behavior as `LOCK TABLES` and `UNLOCK TABLES` with respect to table locking and implicit commits:

  - `UNLOCK TABLES` implicitly commits any active transaction only if any tables currently have been locked with `LOCK TABLES`. The commit does not occur for `UNLOCK TABLES` following `FLUSH TABLES WITH READ LOCK` because the latter statement does not acquire table locks.

  - Beginning a transaction causes table locks acquired with `LOCK TABLES` to be released, as though you had executed `UNLOCK TABLES`. Beginning a transaction does not release a global read lock acquired with `FLUSH TABLES WITH READ LOCK`.

  `FLUSH TABLES WITH READ LOCK` does not prevent the server from inserting rows into the log tables (see Section 5.4.1, "Selecting General Query and Slow Query Log Output Destinations").

13.7.6.4 KILL Syntax

```
KILL [CONNECTION | QUERY] processlist_id
```

Each connection to `mysqld` runs in a separate thread. You can kill a thread with the `KILL processlist_id` statement.

Thread processlist identifiers can be determined from the `ID` column of the `INFORMATION_SCHEMA.PROCESSLIST` table and the `Id` column of `SHOW PROCESSLIST` output. The value for the current thread is returned by the `CONNECTION_ID()` function.

`KILL` permits an optional `CONNECTION` or `QUERY` modifier:

- `KILL CONNECTION` is the same as `KILL` with no modifier: It terminates the connection associated with the given `processlist_id`, after terminating any statement the connection is executing.

- `KILL QUERY` terminates the statement the connection is currently executing, but leaves the connection itself intact.

If you have the `PROCESS` privilege, you can see all threads. If you have the `SUPER` privilege, you can kill all threads and statements. Otherwise, you can see and kill only your own threads and statements.

You can also use the `mysqladmin processlist` and `mysqladmin kill` commands to examine and kill threads.

> **Note**
>
> You cannot use `KILL` with the Embedded MySQL Server library because the embedded server merely runs inside the threads of the host application. It does not create any connection threads of its own.

When you use `KILL`, a thread-specific kill flag is set for the thread. In most cases, it might take some time for the thread to die because the kill flag is checked only at specific intervals:

- During `SELECT` operations, for `ORDER BY` and `GROUP BY` loops, the flag is checked after reading a block of rows. If the kill flag is set, the statement is aborted.

- During `ALTER TABLE` operations, the kill flag is checked before each block of rows are read from the original table. If the kill flag was set, the statement is aborted and the temporary table is deleted.

- During `UPDATE` or `DELETE` operations, the kill flag is checked after each block read and after each updated or deleted row. If the kill flag is set, the statement is aborted. If you are not using transactions, the changes are not rolled back.

- `GET_LOCK()` aborts and returns `NULL`.

- An `INSERT DELAYED` thread quickly flushes (inserts) all rows it has in memory and then terminates.

- If the thread is in the table lock handler (state: `Locked`), the table lock is quickly aborted.

- If the thread is waiting for free disk space in a write call, the write is aborted with a "disk full" error message.

> **Warning**
>
> Killing a `REPAIR TABLE` or `OPTIMIZE TABLE` operation on a `MyISAM` table results in a table that is corrupted and unusable. Any reads or writes to such a table fail until you optimize or repair it again (without interruption).

13.7.6.5 LOAD INDEX INTO CACHE Syntax

```
LOAD INDEX INTO CACHE
  tbl_index_list [, tbl_index_list] ...

tbl_index_list:
  tbl_name
    [[INDEX|KEY] (index_name[, index_name] ...)]
    [IGNORE LEAVES]
```

The `LOAD INDEX INTO CACHE` statement preloads a table index into the key cache to which it has been assigned by an explicit `CACHE INDEX` statement, or into the default key cache otherwise. `LOAD INDEX INTO CACHE` is used only for `MyISAM` tables. It is not supported for tables having user-defined partitioning (see Section 18.5, "Restrictions and Limitations on Partitioning".)

The `IGNORE LEAVES` modifier causes only blocks for the nonleaf nodes of the index to be preloaded.

The following statement preloads nodes (index blocks) of indexes for the tables `t1` and `t2`:

```
mysql> LOAD INDEX INTO CACHE t1, t2 IGNORE LEAVES;
+---------+--------------+----------+----------+
| Table   | Op           | Msg_type | Msg_text |
+---------+--------------+----------+----------+
| test.t1 | preload_keys | status   | OK       |
| test.t2 | preload_keys | status   | OK       |
+---------+--------------+----------+----------+
```

This statement preloads all index blocks from `t1`. It preloads only blocks for the nonleaf nodes from `t2`.

The syntax of `LOAD INDEX INTO CACHE` enables you to specify that only particular indexes from a table should be preloaded. The current implementation preloads all the table's indexes into the cache, so there is no reason to specify anything other than the table name.

`LOAD INDEX INTO CACHE ... IGNORE LEAVES` fails unless all indexes in a table have the same block size. (Prior to MySQL 5.1.19, it fails even without `IGNORE LEAVES`.) You can determine index block sizes for a table by using `myisamchk -dv` and checking the `Blocksize` column.

13.7.6.6 RESET Syntax

```
RESET reset_option [, reset_option] ...
```

The `RESET` statement is used to clear the state of various server operations. You must have the `RELOAD` privilege to execute `RESET`.

`RESET` acts as a stronger version of the `FLUSH` statement. See Section 13.7.6.3, "FLUSH Syntax".

The `RESET` statement causes an implicit commit. See Section 13.3.3, "Statements That Cause an Implicit Commit".

`reset_option` can be any of the following:

- `MASTER`

  Deletes all binary logs listed in the index file, resets the binary log index file to be empty, and creates a new binary log file.

- `QUERY CACHE`

  Removes all query results from the query cache.

- `SLAVE`

  Makes the slave forget its replication position in the master binary logs. Also resets the relay log by deleting any existing relay log files and beginning a new one.

13.8 MySQL Utility Statements

13.8.1 DESCRIBE Syntax

The `DESCRIBE` and `EXPLAIN` statements are synonyms, used either to obtain information about table structure or query execution plans. For more information, see Section 13.7.5.6, "SHOW COLUMNS Syntax", and Section 13.8.2, "EXPLAIN Syntax".

13.8.2 EXPLAIN Syntax

```
{EXPLAIN | DESCRIBE | DESC}
    tbl_name [col_name | wild]

{EXPLAIN | DESCRIBE | DESC}
    [explain_type] SELECT select_options

explain_type: {EXTENDED | PARTITIONS}
```

The `DESCRIBE` and `EXPLAIN` statements are synonyms. In practice, the `DESCRIBE` keyword is more often used to obtain information about table structure, whereas `EXPLAIN` is used to obtain a query execution plan (that is, an explanation of how MySQL would execute a query). The following discussion uses the `DESCRIBE` and `EXPLAIN` keywords in accordance with those uses, but the MySQL parser treats them as completely synonymous.

Obtaining Table Structure Information

`DESCRIBE` provides information about the columns in a table:

```
mysql> DESCRIBE City;
+------------+----------+------+-----+---------+----------------+
| Field      | Type     | Null | Key | Default | Extra          |
+------------+----------+------+-----+---------+----------------+
| Id         | int(11)  | NO   | PRI | NULL    | auto_increment |
| Name       | char(35) | NO   |     |         |                |
| Country    | char(3)  | NO   | UNI |         |                |
| District   | char(20) | YES  | MUL |         |                |
| Population | int(11)  | NO   |     | 0       |                |
+------------+----------+------+-----+---------+----------------+
```

`DESCRIBE` is a shortcut for `SHOW COLUMNS`. These statements also display information for views. The description for `SHOW COLUMNS` provides more information about the output columns. See Section 13.7.5.6, "SHOW COLUMNS Syntax".

By default, `DESCRIBE` displays information about all columns in the table. `col_name`, if given, is the name of a column in the table. In this case, the statement displays information only for the named column. `wild`, if given, is a pattern string. It can contain the SQL "`%`" and "`_`" wildcard characters. In this case, the statement displays output only for the columns with names matching the string. There is no need to enclose the string within quotation marks unless it contains spaces or other special characters.

The `DESCRIBE` statement is provided for compatibility with Oracle.

The `SHOW CREATE TABLE`, `SHOW TABLE STATUS`, and `SHOW INDEX` statements also provide information about tables. See Section 13.7.5, "SHOW Syntax".

Obtaining Execution Plan Information

The `EXPLAIN` statement provides information about how MySQL executes statements:

- When you precede a `SELECT` statement with the keyword `EXPLAIN`, MySQL displays information from the optimizer about the statement execution plan. That is, MySQL explains how it would process the statement, including information about how tables are joined and in which order. For information about using `EXPLAIN` to obtain execution plan information, see Section 8.8.2, "EXPLAIN Output Format".

- `EXPLAIN EXTENDED` can be used to obtain additional execution plan information. See Section 8.8.3, "EXPLAIN EXTENDED Output Format".

- As of MySQL 5.1.5, `EXPLAIN PARTITIONS` is useful for examining queries involving partitioned tables. See Section 18.3.4, "Obtaining Information About Partitions".

 With the help of `EXPLAIN`, you can see where you should add indexes to tables so that the statement executes faster by using indexes to find rows. You can also use `EXPLAIN` to check whether the optimizer joins the tables in an optimal order. To give a hint to the optimizer to use a join order corresponding to the order in which the tables are named in a `SELECT` statement, begin the statement with `SELECT STRAIGHT_JOIN` rather than just `SELECT`. (See Section 13.2.8, "SELECT Syntax".)

If you have a problem with indexes not being used when you believe that they should be, run `ANALYZE TABLE` to update table statistics, such as cardinality of keys, that can affect the choices the optimizer makes. See Section 13.7.2.1, "ANALYZE TABLE Syntax".

13.8.3 HELP Syntax

```
HELP 'search_string'
```

The `HELP` statement returns online information from the MySQL Reference manual. Its proper operation requires that the help tables in the `mysql` database be initialized with help topic information (see Section 5.1.9, "Server-Side Help").

The `HELP` statement searches the help tables for the given search string and displays the result of the search. The search string is not case sensitive.

The search string can contain the wildcard characters "`%`" and "`_`". These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. For example, `HELP 'rep%'` returns a list of topics that begin with `rep`.

The HELP statement understands several types of search strings:

- At the most general level, use `contents` to retrieve a list of the top-level help categories:

```
HELP 'contents'
```

- For a list of topics in a given help category, such as `Data Types`, use the category name:

```
HELP 'data types'
```

- For help on a specific help topic, such as the `ASCII()` function or the `CREATE TABLE` statement, use the associated keyword or keywords:

```
HELP 'ascii'
HELP 'create table'
```

In other words, the search string matches a category, many topics, or a single topic. You cannot necessarily tell in advance whether a given search string will return a list of items or the help information for a single help topic. However, you can tell what kind of response `HELP` returned by examining the number of rows and columns in the result set.

The following descriptions indicate the forms that the result set can take. Output for the example statements is shown using the familiar "tabular" or "vertical" format that you see when using the `mysql` client, but note that `mysql` itself reformats `HELP` result sets in a different way.

- Empty result set

No match could be found for the search string.

- Result set containing a single row with three columns

  This means that the search string yielded a hit for the help topic. The result has three columns:

  - `name`: The topic name.

  - `description`: Descriptive help text for the topic.

  - `example`: Usage example or examples. This column might be blank.

  Example: `HELP 'replace'`

  Yields:

  ```
  name: REPLACE
  description: Syntax:
  REPLACE(str,from_str,to_str)

  Returns the string str with all occurrences of the string from_str
  replaced by the string to_str. REPLACE() performs a case-sensitive
  match when searching for from_str.
  example: mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
          -> 'WwWwWw.mysql.com'
  ```

- Result set containing multiple rows with two columns

  This means that the search string matched many help topics. The result set indicates the help topic names:

  - `name`: The help topic name.

  - `is_it_category`: `Y` if the name represents a help category, `N` if it does not. If it does not, the `name` value when specified as the argument to the `HELP` statement should yield a single-row result set containing a description for the named item.

  Example: `HELP 'status'`

  Yields:

  ```
  +-----------------------+----------------+
  | name                  | is_it_category |
  +-----------------------+----------------+
  | SHOW                  | N              |
  | SHOW ENGINE           | N              |
  | SHOW INNODB STATUS    | N              |
  | SHOW MASTER STATUS    | N              |
  | SHOW PROCEDURE STATUS | N              |
  | SHOW SLAVE STATUS     | N              |
  | SHOW STATUS           | N              |
  | SHOW TABLE STATUS     | N              |
  +-----------------------+----------------+
  ```

- Result set containing multiple rows with three columns

  This means the search string matches a category. The result set contains category entries:

  - `source_category_name`: The help category name.

- `name`: The category or topic name

- `is_it_category`: `Y` if the name represents a help category, `N` if it does not. If it does not, the `name` value when specified as the argument to the `HELP` statement should yield a single-row result set containing a description for the named item.

Example: `HELP 'functions'`

Yields:

```
+----------------------+------------------------+----------------+
| source_category_name | name                   | is_it_category |
+----------------------+------------------------+----------------+
| Functions            | CREATE FUNCTION        | N              |
| Functions            | DROP FUNCTION          | N              |
| Functions            | Bit Functions          | Y              |
| Functions            | Comparison operators   | Y              |
| Functions            | Control flow functions | Y              |
| Functions            | Date and Time Functions| Y              |
| Functions            | Encryption Functions   | Y              |
| Functions            | Information Functions   | Y              |
| Functions            | Logical operators      | Y              |
| Functions            | Miscellaneous Functions| Y              |
| Functions            | Numeric Functions      | Y              |
| Functions            | String Functions       | Y              |
+----------------------+------------------------+----------------+
```

Before MySQL 5.1.17, if you intend to use the `HELP` statement while other tables are locked with `LOCK TABLES`, you must also lock the required `mysql.help_xxx` tables. See Section 13.3.5, "LOCK TABLES and UNLOCK TABLES Syntax".

13.8.4 USE Syntax

```
USE db_name
```

The `USE db_name` statement tells MySQL to use the `db_name` database as the default (current) database for subsequent statements. The database remains the default until the end of the session or another `USE` statement is issued:

```
USE db1;
SELECT COUNT(*) FROM mytable;   # selects from db1.mytable
USE db2;
SELECT COUNT(*) FROM mytable;   # selects from db2.mytable
```

Making a particular database the default by means of the `USE` statement does not preclude you from accessing tables in other databases. The following example accesses the `author` table from the `db1` database and the `editor` table from the `db2` database:

```
USE db1;
SELECT author_name,editor_name FROM author,db2.editor
  WHERE author.editor_id = db2.editor.editor_id;
```

Chapter 14 Storage Engines

Table of Contents

MySQL supports several storage engines that act as handlers for different table types. MySQL storage engines include both those that handle transaction-safe tables and those that handle nontransaction-safe tables.

As of MySQL 5.1, MySQL Server uses a pluggable storage engine architecture that enables storage engines to be loaded into and unloaded from a running MySQL server.

> **Note**
>
> Prior to MySQL 5.1.38, the pluggable storage engine architecture is supported on Unix platforms only and pluggable storage engines are not supported on Windows.

To determine which storage engines your server supports by using the SHOW ENGINES statement. The value in the Support column indicates whether an engine can be used. A value of YES, NO, or DEFAULT indicates that an engine is available, not available, or available and currently set as the default storage engine.

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
      Engine: FEDERATED
     Support: NO
     Comment: Federated MySQL storage engine
Transactions: NULL
          XA: NULL
  Savepoints: NULL
*************************** 2. row ***************************
      Engine: MRG_MYISAM
     Support: YES
     Comment: Collection of identical MyISAM tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 3. row ***************************
      Engine: MyISAM
     Support: DEFAULT
     Comment: Default engine as of MySQL 3.23 with great performance
Transactions: NO
          XA: NO
  Savepoints: NO
...
```

This chapter describes each of the MySQL storage engines except for NDBCLUSTER, which is covered in Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*. It also contains a description of the pluggable storage engine architecture (see Section 14.4, "Overview of MySQL Storage Engine Architecture").

For information about storage engine support offered in commercial MySQL Server binaries, see *MySQL Enterprise Server 5.1*, on the MySQL Web site. The storage engines available might depend on which edition of Enterprise Server you are using.

For answers to some commonly asked questions about MySQL storage engines, see Section A.2, "MySQL 5.1 FAQ: Storage Engines".

MySQL 5.1 supported storage engines

- MyISAM: The default MySQL storage engine and the one that is used the most in Web, data warehousing, and other application environments. MyISAM is supported in all MySQL configurations, and is the default storage engine unless you have configured MySQL to use a different one by default.

- `InnoDB`: A transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data. `InnoDB` row-level locking (without escalation to coarser granularity locks) and Oracle-style consistent nonlocking reads increase multi-user concurrency and performance. `InnoDB` stores user data in clustered indexes to reduce I/O for common queries based on primary keys. To maintain data integrity, `InnoDB` also supports `FOREIGN KEY` referential-integrity constraints.

- `Memory`: Stores all data in RAM for extremely fast access in environments that require quick lookups of reference and other like data. This engine was formerly known as the `HEAP` engine.

- `Merge`: Enables a MySQL DBA or developer to logically group a series of identical `MyISAM` tables and reference them as one object. Good for VLDB environments such as data warehousing.

- `Archive`: Provides the perfect solution for storing and retrieving large amounts of seldom-referenced historical, archived, or security audit information.

- `Federated`: Offers the ability to link separate MySQL servers to create one logical database from many physical servers. Very good for distributed or data mart environments.

- `NDB` (also known as `NDBCLUSTER`)—This clustered database engine is particularly suited for applications that require the highest possible degree of uptime and availability.

  > **Note**
  >
  > The `NDB` storage engine is not supported in standard MySQL 5.1 releases. Currently supported MySQL Cluster releases include MySQL Cluster NDB 7.0 and MySQL Cluster NDB 7.1, which are based on MySQL 5.1, and MySQL Cluster NDB 7.2, which is based on MySQL 5.5. While based on MySQL Server, these releases also contain support for `NDB`.

- `CSV`: The CSV storage engine stores data in text files using comma-separated values format. You can use the CSV engine to easily exchange data between other software and applications that can import and export in CSV format.

- `Blackhole`: The Blackhole storage engine accepts but does not store data and retrievals always return an empty set. The functionality can be used in distributed database design where data is automatically replicated, but not stored locally.

- `Example`: The Example storage engine is "stub" engine that does nothing. You can create tables with this engine, but no data can be stored in them or retrieved from them. The purpose of this engine is to serve as an example in the MySQL source code that illustrates how to begin writing new storage engines. As such, it is primarily of interest to developers.

It is important to remember that you are not restricted to using the same storage engine for an entire server or schema: you can use a different storage engine for each table in your schema.

Choosing a Storage Engine

The various storage engines provided with MySQL are designed with different use cases in mind. To use the pluggable storage architecture effectively, it is good to have an idea of the advantages and disadvantages of the various storage engines. The following table provides an overview of some storage engines provided with MySQL:

Table 14.1 Storage Engine Features

Feature	MyISAM	Memory	InnoDB	Archive	NDB
Storage limits	256TB	RAM	64TB	None	384EB

Feature	MyISAM	Memory	InnoDB	Archive	NDB
Transactions	No	No	Yes	No	Yes
Locking granularity	Table	Table	Row	Row	Row
MVCC	No	No	Yes	No	No
Geospatial data type support	Yes	No	Yes	Yes	Yes
Geospatial indexing support	Yes	No	Yes[a]	No	No
B-tree indexes	Yes	Yes	Yes	No	No
T-tree indexes	No	No	No	No	Yes
Hash indexes	No	Yes	No[b]	No	Yes
Full-text search indexes	Yes	No	Yes[c]	No	No
Clustered indexes	No	No	Yes	No	No
Data caches	No	N/A	Yes	No	Yes
Index caches	Yes	N/A	Yes	No	Yes
Compressed data	Yes[d]	No	Yes[e]	Yes	No
Encrypted data[f]	Yes	Yes	Yes	Yes	Yes
Cluster database support	No	No	No	No	Yes
Replication support[g]	Yes	Yes	Yes	Yes	Yes
Foreign key support	No	No	Yes	No	No
Backup / point-in-time recovery[h]	Yes	Yes	Yes	Yes	Yes
Query cache support	Yes	Yes	Yes	Yes	Yes

Feature	MyISAM	Memory	InnoDB	Archive	NDB
Update statistics for data dictionary	Yes	Yes	Yes	Yes	Yes

[a]InnoDB support for geospatial indexing is available in MySQL 5.7.5 and higher.

[b]InnoDB utilizes hash indexes internally for its Adaptive Hash Index feature.

[c]InnoDB support for FULLTEXT indexes is available in MySQL 5.6.4 and higher.

[d]Compressed MyISAM tables are supported only when using the compressed row format. Tables using the compressed row format with MyISAM are read only.

[e]Compressed InnoDB tables require the InnoDB Barracuda file format.

[f]Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and higher.

[g]Implemented in the server, rather than in the storage engine.

[h]Implemented in the server, rather than in the storage engine.

14.1 Comparing Transaction and Nontransaction Engines

Transaction-safe tables (TSTs) have several advantages over nontransaction-safe tables (NTSTs):

- They are safer. Even if MySQL crashes or you get hardware problems, you can get your data back, either by automatic recovery or from a backup plus the transaction log.

- You can combine many statements and accept them all at the same time with the `COMMIT` statement (if autocommit is disabled).

- You can execute `ROLLBACK` to ignore your changes (if autocommit is disabled).

- If an update fails, all of your changes are reverted. (With nontransaction-safe tables, all changes that have taken place are permanent.)

- Transaction-safe storage engines can provide better concurrency for tables that get many updates concurrently with reads.

You can combine transaction-safe and nontransaction-safe tables in the same statements to get the best of both worlds. However, although MySQL supports several transaction-safe storage engines, for best results, you should not mix different storage engines within a transaction with autocommit disabled. For example, if you do this, changes to nontransaction-safe tables still are committed immediately and cannot be rolled back. For information about this and other problems that can occur in transactions that use mixed storage engines, see Section 13.3.1, "START TRANSACTION, COMMIT, and ROLLBACK Syntax".

Nontransaction-safe tables have several advantages of their own, all of which occur because there is no transaction overhead:

- Much faster

- Lower disk space requirements

- Less memory required to perform updates

14.2 Other Storage Engines

Other storage engines may be available from third parties and community members that have used the Custom Storage Engine interface.

Third party engines are not supported by MySQL. For further information, documentation, installation guides, bug reporting or for any help or assistance with these engines, please contact the developer of the engine directly.

For more information on developing a customer storage engine that can be used with the Pluggable Storage Engine Architecture, see MySQL Internals: Writing a Custom Storage Engine.

14.3 Setting the Storage Engine

When you create a new table, you can specify which storage engine to use by adding an `ENGINE` table option to the `CREATE TABLE` statement:

```
CREATE TABLE t (i INT) ENGINE = INNODB;
```

If you omit the `ENGINE` option, the default storage engine is used. Normally, this is `MyISAM`, but you can change it by using the `--default-storage-engine` server startup option, or by setting the `default-storage-engine` option in the `my.cnf` configuration file.

You can set the default storage engine to be used during the current session by setting the `storage_engine` variable:

```
SET storage_engine=MYISAM;
```

When MySQL is installed on Windows using the MySQL Configuration Wizard, the `InnoDB` or `MyISAM` storage engine can be selected as the default. See Section 2.3.5.5, "MySQL Server Instance Config Wizard: The Database Usage Dialog".

To convert a table from one storage engine to another, use an `ALTER TABLE` statement that indicates the new engine:

```
ALTER TABLE t ENGINE = MYISAM;
```

See Section 13.1.17, "CREATE TABLE Syntax", and Section 13.1.7, "ALTER TABLE Syntax".

If you try to use a storage engine that is not compiled in or that is compiled in but deactivated, MySQL instead creates a table using the default storage engine. This behavior is convenient when you want to copy tables between MySQL servers that support different storage engines. (For example, in a replication setup, perhaps your master server supports transactional storage engines for increased safety, but the slave servers use only nontransactional storage engines for greater speed.)

This automatic substitution of the default storage engine for unavailable engines can be confusing for new MySQL users. A warning is generated whenever a storage engine is automatically changed. To prevent this from happening if the desired engine is unavailable, enable the `NO_ENGINE_SUBSTITUTION` SQL mode. In this case, an error occurs instead of a warning and the table is not created or altered if the desired engine is unavailable. See Section 5.1.7, "Server SQL Modes".

For new tables, MySQL always creates an `.frm` file to hold the table and column definitions. The table's index and data may be stored in one or more other files, depending on the storage engine. The server creates the `.frm` file above the storage engine level. Individual storage engines create any additional files required for the tables that they manage. If a table name contains special characters, the names for the table files contain encoded versions of those characters as described in Section 9.2.3, "Mapping of Identifiers to File Names".

A database may contain tables of different types. That is, tables need not all be created with the same storage engine.

14.4 Overview of MySQL Storage Engine Architecture

The MySQL pluggable storage engine architecture enables a database professional to select a specialized storage engine for a particular application need while being completely shielded from the need to manage

any specific application coding requirements. The MySQL server architecture isolates the application programmer and DBA from all of the low-level implementation details at the storage level, providing a consistent and easy application model and API. Thus, although there are different capabilities across different storage engines, the application is shielded from these differences.

The pluggable storage engine architecture provides a standard set of management and support services that are common among all underlying storage engines. The storage engines themselves are the components of the database server that actually perform actions on the underlying data that is maintained at the physical server level.

This efficient and modular architecture provides huge benefits for those wishing to specifically target a particular application need—such as data warehousing, transaction processing, or high availability situations—while enjoying the advantage of utilizing a set of interfaces and services that are independent of any one storage engine.

The application programmer and DBA interact with the MySQL database through Connector APIs and service layers that are above the storage engines. If application changes bring about requirements that demand the underlying storage engine change, or that one or more storage engines be added to support new needs, no significant coding or process changes are required to make things work. The MySQL server architecture shields the application from the underlying complexity of the storage engine by presenting a consistent and easy-to-use API that applies across storage engines.

14.4.1 Pluggable Storage Engine Architecture

As of MySQL 5.1, MySQL Server uses a pluggable storage engine architecture that enables storage engines to be loaded into and unloaded from a running MySQL server.

Note

Prior to MySQL 5.1.38, the pluggable storage engine architecture is supported on Unix platforms only and pluggable storage engines are not supported on Windows.

Plugging in a Storage Engine

Before a storage engine can be used, the storage engine plugin shared library must be loaded into MySQL using the `INSTALL PLUGIN` statement. For example, if the `EXAMPLE` engine plugin is named `example` and the shared library is named `ha_example.so`, you load it with the following statement:

```
mysql> INSTALL PLUGIN example SONAME 'ha_example.so';
```

To install a pluggable storage engine, the plugin file must be located in the MySQL plugin directory, and the user issuing the `INSTALL PLUGIN` statement must have `INSERT` privilege for the `mysql.plugin` table.

The shared library must be located in the MySQL server plugin directory, the location of which is given by the `plugin_dir` system variable.

Unplugging a Storage Engine

To unplug a storage engine, use the `UNINSTALL PLUGIN` statement:

```
mysql> UNINSTALL PLUGIN example;
```

If you unplug a storage engine that is needed by existing tables, those tables become inaccessible, but will still be present on disk (where applicable). Ensure that there are no tables using a storage engine before you unplug the storage engine.

14.4.2 The Common Database Server Layer

A MySQL pluggable storage engine is the component in the MySQL database server that is responsible for performing the actual data I/O operations for a database as well as enabling and enforcing certain feature sets that target a specific application need. A major benefit of using specific storage engines is that you are only delivered the features needed for a particular application, and therefore you have less system overhead in the database, with the end result being more efficient and higher database performance. This is one of the reasons that MySQL has always been known to have such high performance, matching or beating proprietary monolithic databases in industry standard benchmarks.

From a technical perspective, what are some of the unique supporting infrastructure components that are in a storage engine? Some of the key feature differentiations include:

- *Concurrency*: Some applications have more granular lock requirements (such as row-level locks) than others. Choosing the right locking strategy can reduce overhead and therefore improve overall performance. This area also includes support for capabilities such as multi-version concurrency control or "snapshot" read.

- *Transaction Support*: Not every application needs transactions, but for those that do, there are very well defined requirements such as ACID compliance and more.

- *Referential Integrity*: The need to have the server enforce relational database referential integrity through DDL defined foreign keys.

- *Physical Storage*: This involves everything from the overall page size for tables and indexes as well as the format used for storing data to physical disk.

- *Index Support*: Different application scenarios tend to benefit from different index strategies. Each storage engine generally has its own indexing methods, although some (such as B-tree indexes) are common to nearly all engines.

- *Memory Caches*: Different applications respond better to some memory caching strategies than others, so although some memory caches are common to all storage engines (such as those used for user connections or MySQL's high-speed Query Cache), others are uniquely defined only when a particular storage engine is put in play.

- *Performance Aids*: This includes multiple I/O threads for parallel operations, thread concurrency, database checkpointing, bulk insert handling, and more.

- *Miscellaneous Target Features*: This may include support for geospatial operations, security restrictions for certain data manipulation operations, and other similar features.

Each set of the pluggable storage engine infrastructure components are designed to offer a selective set of benefits for a particular application. Conversely, avoiding a set of component features helps reduce unnecessary overhead. It stands to reason that understanding a particular application's set of requirements and selecting the proper MySQL storage engine can have a dramatic impact on overall system efficiency and performance.

14.5 The MyISAM Storage Engine

`MyISAM` is the default storage engine. It is based on the older (and no longer available) `ISAM` storage engine but has many useful extensions.

Table 14.2 `MyISAM` Storage Engine Features

Storage limits	256TB	Transactions	No	Locking granularity	Table

MVCC	No	Geospatial data type support	Yes	Geospatial indexing support	Yes
B-tree indexes	Yes	T-tree indexes	No	Hash indexes	No
Full-text search indexes	Yes	Clustered indexes	No	Data caches	No
Index caches	Yes	Compressed data	Yes[a]	Encrypted data[b]	Yes
Cluster database support	No	Replication support[c]	Yes	Foreign key support	No
Backup / point-in-time recovery[d]	Yes	Query cache support	Yes	Update statistics for data dictionary	Yes

[a]Compressed MyISAM tables are supported only when using the compressed row format. Tables using the compressed row format with MyISAM are read only.

[b]Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and higher.

[c]Implemented in the server, rather than in the storage engine.

[d]Implemented in the server, rather than in the storage engine.

Each `MyISAM` table is stored on disk in three files. The files have names that begin with the table name and have an extension to indicate the file type. An `.frm` file stores the table format. The data file has an `.MYD` (`MYData`) extension. The index file has an `.MYI` (`MYIndex`) extension.

To specify explicitly that you want a `MyISAM` table, indicate that with an `ENGINE` table option:

```
CREATE TABLE t (i INT) ENGINE = MYISAM;
```

Normally, it is unnecessary to use `ENGINE` to specify the `MyISAM` storage engine. `MyISAM` is the default engine unless the default has been changed. To ensure that `MyISAM` is used in situations where the default might have been changed, include the `ENGINE` option explicitly.

You can check or repair `MyISAM` tables with the `mysqlcheck` client or `myisamchk` utility. You can also compress `MyISAM` tables with `myisampack` to take up much less space. See Section 4.5.3, "`mysqlcheck` — A Table Maintenance Program", Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility", and Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables".

`MyISAM` tables have the following characteristics:

• All data values are stored with the low byte first. This makes the data machine and operating system independent. The only requirements for binary portability are that the machine uses two's-complement signed integers and IEEE floating-point format. These requirements are widely used among mainstream machines. Binary compatibility might not be applicable to embedded systems, which sometimes have peculiar processors.

  There is no significant speed penalty for storing data low byte first; the bytes in a table row normally are unaligned and it takes little more processing to read an unaligned byte in order than in reverse order. Also, the code in the server that fetches column values is not time critical compared to other code.

• All numeric key values are stored with the high byte first to permit better index compression.

• Large files (up to 63-bit file length) are supported on file systems and operating systems that support large files.

• There is a limit of 2^{32} (~4.295E+09) rows in a `MyISAM` table. If you build MySQL with the `--with-big-tables` option, the row limitation is increased to $(2^{32})^2$ (1.844E+19) rows. See Section 2.11.4, "MySQL Source-Configuration Options". Binary distributions for Unix and Linux are built with this option.

- The maximum number of indexes per `MyISAM` table is 64. This can be changed by recompiling. Beginning with MySQL 5.1.4, you can configure the build by invoking `configure` with the `--with-max-indexes=N` option, where `N` is the maximum number of indexes to permit per `MyISAM` table. `N` must be less than or equal to 128. Before MySQL 5.1.4, you must change the source.

  The maximum number of columns per index is 16.

- The maximum key length is 1000 bytes. This can also be changed by changing the source and recompiling. For the case of a key longer than 250 bytes, a larger key block size than the default of 1024 bytes is used.

- When rows are inserted in sorted order (as when you are using an `AUTO_INCREMENT` column), the index tree is split so that the high node only contains one key. This improves space utilization in the index tree.

- Internal handling of one `AUTO_INCREMENT` column per table is supported. `MyISAM` automatically updates this column for `INSERT` and `UPDATE` operations. This makes `AUTO_INCREMENT` columns faster (at least 10%). Values at the top of the sequence are not reused after being deleted. (When an `AUTO_INCREMENT` column is defined as the last column of a multiple-column index, reuse of values deleted from the top of a sequence does occur.) The `AUTO_INCREMENT` value can be reset with `ALTER TABLE` or `myisamchk`.

- Dynamic-sized rows are much less fragmented when mixing deletes with updates and inserts. This is done by automatically combining adjacent deleted blocks and by extending blocks if the next block is deleted.

- `MyISAM` supports concurrent inserts: If a table has no free blocks in the middle of the data file, you can `INSERT` new rows into it at the same time that other threads are reading from the table. A free block can occur as a result of deleting rows or an update of a dynamic length row with more data than its current contents. When all free blocks are used up (filled in), future inserts become concurrent again. See Section 8.11.3, "Concurrent Inserts".

- You can put the data file and index file in different directories on different physical devices to get more speed with the `DATA DIRECTORY` and `INDEX DIRECTORY` table options to `CREATE TABLE`. See Section 13.1.17, "CREATE TABLE Syntax".

- `BLOB` and `TEXT` columns can be indexed.

- `NULL` values are permitted in indexed columns. This takes 0 to 1 bytes per key.

- Each character column can have a different character set. See Section 10.1, "Character Set Support".

- There is a flag in the `MyISAM` index file that indicates whether the table was closed correctly. If `mysqld` is started with the `--myisam-recover` option, `MyISAM` tables are automatically checked when opened, and are repaired if the table wasn't closed properly.

- `myisamchk` marks tables as checked if you run it with the `--update-state` option. `myisamchk --fast` checks only those tables that don't have this mark.

- `myisamchk --analyze` stores statistics for portions of keys, as well as for entire keys.

- `myisampack` can pack `BLOB` and `VARCHAR` columns.

`MyISAM` also supports the following features:

- Support for a true `VARCHAR` type; a `VARCHAR` column starts with a length stored in one or two bytes.

- Tables with `VARCHAR` columns may have fixed or dynamic row length.

- The sum of the lengths of the `VARCHAR` and `CHAR` columns in a table may be up to 64KB.

- Arbitrary length `UNIQUE` constraints.

Additional Resources

- A forum dedicated to the `MyISAM` storage engine is available at http://forums.mysql.com/list.php?21.

14.5.1 MyISAM Startup Options

The following options to `mysqld` can be used to change the behavior of `MyISAM` tables. For additional information, see Section 5.1.3, "Server Command Options".

Table 14.3 MyISAM Option/Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
bulk_insert_buffer_size	Yes	Yes	Yes		Both	Yes
concurrent_insert	Yes	Yes	Yes		Global	Yes
delay-key-write	Yes	Yes			Global	Yes
- *Variable*: delay_key_write			Yes		Global	Yes
have_rtree_keys			Yes		Global	No
key_buffer_size	Yes	Yes	Yes		Global	Yes
log-isam	Yes	Yes				
myisam-block-size	Yes	Yes				
myisam_data_pointer_size	Yes	Yes	Yes		Global	Yes
myisam_max_sort_file_size	Yes	Yes	Yes		Global	Yes
myisam_mmap_size	Yes	Yes	Yes		Global	No
myisam-recover	Yes	Yes				
- *Variable*: myisam_recover_options						
myisam_recover_options			Yes		Global	No
myisam_repair_threads	Yes	Yes	Yes		Both	Yes
myisam_sort_buffer_size	Yes	Yes	Yes		Both	Yes
myisam_stats_method	Yes	Yes	Yes		Both	Yes
myisam_use_mmap	Yes	Yes	Yes		Global	Yes
skip-concurrent-insert	Yes	Yes				
- *Variable*: concurrent_insert						
tmp_table_size	Yes	Yes	Yes		Both	Yes

- `--myisam-recover=`*mode*

  Set the mode for automatic recovery of crashed `MyISAM` tables.

- `--delay-key-write=ALL`

Don't flush key buffers between writes for any `MyISAM` table.

> **Note**
>
> If you do this, you should not access `MyISAM` tables from another program (such as from another MySQL server or with `myisamchk`) when the tables are in use. Doing so risks index corruption. Using `--external-locking` does not eliminate this risk.

The following system variables affect the behavior of `MyISAM` tables. For additional information, see Section 5.1.4, "Server System Variables".

* `bulk_insert_buffer_size`

  The size of the tree cache used in bulk insert optimization.

  > **Note**
  >
  > This is a limit *per thread*!

* `myisam_max_sort_file_size`

  The maximum size of the temporary file that MySQL is permitted to use while re-creating a `MyISAM` index (during `REPAIR TABLE`, `ALTER TABLE`, or `LOAD DATA INFILE`). If the file size would be larger than this value, the index is created using the key cache instead, which is slower. The value is given in bytes.

* `myisam_sort_buffer_size`

  Set the size of the buffer used when recovering tables.

Automatic recovery is activated if you start `mysqld` with the `--myisam-recover` option. In this case, when the server opens a `MyISAM` table, it checks whether the table is marked as crashed or whether the open count variable for the table is not 0 and you are running the server with external locking disabled. If either of these conditions is true, the following happens:

* The server checks the table for errors.

* If the server finds an error, it tries to do a fast table repair (with sorting and without re-creating the data file).

* If the repair fails because of an error in the data file (for example, a duplicate-key error), the server tries again, this time re-creating the data file.

* If the repair still fails, the server tries once more with the old repair option method (write row by row without sorting). This method should be able to repair any type of error and has low disk space requirements.

If the recovery wouldn't be able to recover all rows from previously completed statements and you didn't specify `FORCE` in the value of the `--myisam-recover` option, automatic repair aborts with an error message in the error log:

```
Error: Couldn't repair table: test.g00pages
```

If you specify `FORCE`, a warning like this is written instead:

```
Warning: Found 344 of 354 rows when repairing ./test/g00pages
```

If the automatic recovery value includes `BACKUP`, the recovery process creates files with names of the form `tbl_name-datetime.BAK`. You should have a `cron` script that automatically moves these files from the database directories to backup media.

14.5.2 Space Needed for Keys

`MyISAM` tables use B-tree indexes. You can roughly calculate the size for the index file as `(key_length +4)/0.67`, summed over all keys. This is for the worst case when all keys are inserted in sorted order and the table doesn't have any compressed keys.

String indexes are space compressed. If the first index part is a string, it is also prefix compressed. Space compression makes the index file smaller than the worst-case figure if a string column has a lot of trailing space or is a `VARCHAR` column that is not always used to the full length. Prefix compression is used on keys that start with a string. Prefix compression helps if there are many strings with an identical prefix.

In `MyISAM` tables, you can also prefix compress numbers by specifying the `PACK_KEYS=1` table option when you create the table. Numbers are stored with the high byte first, so this helps when you have many integer keys that have an identical prefix.

14.5.3 MyISAM Table Storage Formats

`MyISAM` supports three different storage formats. Two of them, fixed and dynamic format, are chosen automatically depending on the type of columns you are using. The third, compressed format, can be created only with the `myisampack` utility (see Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables").

When you use `CREATE TABLE` or `ALTER TABLE` for a table that has no `BLOB` or `TEXT` columns, you can force the table format to `FIXED` or `DYNAMIC` with the `ROW_FORMAT` table option.

See Section 13.1.17, "CREATE TABLE Syntax", for information about `ROW_FORMAT`.

You can decompress (unpack) compressed `MyISAM` tables using `myisamchk --unpack`; see Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility", for more information.

14.5.3.1 Static (Fixed-Length) Table Characteristics

Static format is the default for `MyISAM` tables. It is used when the table contains no variable-length columns (`VARCHAR`, `VARBINARY`, `BLOB`, or `TEXT`). Each row is stored using a fixed number of bytes.

Of the three `MyISAM` storage formats, static format is the simplest and most secure (least subject to corruption). It is also the fastest of the on-disk formats due to the ease with which rows in the data file can be found on disk: To look up a row based on a row number in the index, multiply the row number by the row length to calculate the row position. Also, when scanning a table, it is very easy to read a constant number of rows with each disk read operation.

The security is evidenced if your computer crashes while the MySQL server is writing to a fixed-format `MyISAM` file. In this case, `myisamchk` can easily determine where each row starts and ends, so it can usually reclaim all rows except the partially written one. `MyISAM` table indexes can always be reconstructed based on the data rows.

> **Note**
>
> Fixed-length row format is only available for tables without `BLOB` or `TEXT` columns. Creating a table with these columns with an explicit `ROW_FORMAT` clause will not raise an error or warning; the format specification will be ignored.

Static-format tables have these characteristics:

- `CHAR` and `VARCHAR` columns are space-padded to the specified column width, although the column type is not altered. `BINARY` and `VARBINARY` columns are padded with `0x00` bytes to the column width.

- Very quick.

- Easy to cache.

- Easy to reconstruct after a crash, because rows are located in fixed positions.

- Reorganization is unnecessary unless you delete a huge number of rows and want to return free disk space to the operating system. To do this, use `OPTIMIZE TABLE` or `myisamchk -r`.

- Usually require more disk space than dynamic-format tables.

14.5.3.2 Dynamic Table Characteristics

Dynamic storage format is used if a `MyISAM` table contains any variable-length columns (`VARCHAR`, `VARBINARY`, `BLOB`, or `TEXT`), or if the table was created with the `ROW_FORMAT=DYNAMIC` table option.

Dynamic format is a little more complex than static format because each row has a header that indicates how long it is. A row can become fragmented (stored in noncontiguous pieces) when it is made longer as a result of an update.

You can use `OPTIMIZE TABLE` or `myisamchk -r` to defragment a table. If you have fixed-length columns that you access or change frequently in a table that also contains some variable-length columns, it might be a good idea to move the variable-length columns to other tables just to avoid fragmentation.

Dynamic-format tables have these characteristics:

- All string columns are dynamic except those with a length less than four.

- Each row is preceded by a bitmap that indicates which columns contain the empty string (for string columns) or zero (for numeric columns). This does not include columns that contain `NULL` values. If a string column has a length of zero after trailing space removal, or a numeric column has a value of zero, it is marked in the bitmap and not saved to disk. Nonempty strings are saved as a length byte plus the string contents.

- Much less disk space usually is required than for fixed-length tables.

- Each row uses only as much space as is required. However, if a row becomes larger, it is split into as many pieces as are required, resulting in row fragmentation. For example, if you update a row with information that extends the row length, the row becomes fragmented. In this case, you may have to run `OPTIMIZE TABLE` or `myisamchk -r` from time to time to improve performance. Use `myisamchk -ei` to obtain table statistics.

- More difficult than static-format tables to reconstruct after a crash, because rows may be fragmented into many pieces and links (fragments) may be missing.

- The expected row length for dynamic-sized rows is calculated using the following expression:

```
3
+ (number of columns + 7) / 8
+ (number of char columns)
+ (packed size of numeric columns)
+ (length of strings)
```

```
                      + (number of NULL columns + 7) / 8
```

There is a penalty of 6 bytes for each link. A dynamic row is linked whenever an update causes an enlargement of the row. Each new link is at least 20 bytes, so the next enlargement probably goes in the same link. If not, another link is created. You can find the number of links using `myisamchk -ed`. All links may be removed with `OPTIMIZE TABLE` or `myisamchk -r`.

14.5.3.3 Compressed Table Characteristics

Compressed storage format is a read-only format that is generated with the `myisampack` tool. Compressed tables can be uncompressed with `myisamchk`.

Compressed tables have the following characteristics:

- Compressed tables take very little disk space. This minimizes disk usage, which is helpful when using slow disks (such as CD-ROMs).

- Each row is compressed separately, so there is very little access overhead. The header for a row takes up one to three bytes depending on the biggest row in the table. Each column is compressed differently. There is usually a different Huffman tree for each column. Some of the compression types are:

  - Suffix space compression.

  - Prefix space compression.

  - Numbers with a value of zero are stored using one bit.

  - If values in an integer column have a small range, the column is stored using the smallest possible type. For example, a `BIGINT` column (eight bytes) can be stored as a `TINYINT` column (one byte) if all its values are in the range from `-128` to `127`.

  - If a column has only a small set of possible values, the data type is converted to `ENUM`.

  - A column may use any combination of the preceding compression types.

- Can be used for fixed-length or dynamic-length rows.

> **Note**
>
> While a compressed table is read only, and you cannot therefore update or add rows in the table, DDL (Data Definition Language) operations are still valid. For example, you may still use `DROP` to drop the table, and `TRUNCATE TABLE` to empty the table.

14.5.4 MyISAM Table Problems

The file format that MySQL uses to store data has been extensively tested, but there are always circumstances that may cause database tables to become corrupted. The following discussion describes how this can happen and how to handle it.

14.5.4.1 Corrupted MyISAM Tables

Even though the `MyISAM` table format is very reliable (all changes to a table made by an SQL statement are written before the statement returns), you can still get corrupted tables if any of the following events occur:

- The `mysqld` process is killed in the middle of a write.

- An unexpected computer shutdown occurs (for example, the computer is turned off).

- Hardware failures.

- You are using an external program (such as `myisamchk`) to modify a table that is being modified by the server at the same time.

- A software bug in the MySQL or `MyISAM` code.

Typical symptoms of a corrupt table are:

- You get the following error while selecting data from the table:

```
Incorrect key file for table: '...'. Try to repair it
```

- Queries don't find rows in the table or return incomplete results.

You can check the health of a `MyISAM` table using the `CHECK TABLE` statement, and repair a corrupted `MyISAM` table with `REPAIR TABLE`. When `mysqld` is not running, you can also check or repair a table with the `myisamchk` command. See Section 13.7.2.3, "CHECK TABLE Syntax", Section 13.7.2.6, "REPAIR TABLE Syntax", and Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility".

If your tables become corrupted frequently, you should try to determine why this is happening. The most important thing to know is whether the table became corrupted as a result of a server crash. You can verify this easily by looking for a recent `restarted mysqld` message in the error log. If there is such a message, it is likely that table corruption is a result of the server dying. Otherwise, corruption may have occurred during normal operation. This is a bug. You should try to create a reproducible test case that demonstrates the problem. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing", and Section 22.4, "Debugging and Porting MySQL".

14.5.4.2 Problems from Tables Not Being Closed Properly

Each `MyISAM` index file (`.MYI` file) has a counter in the header that can be used to check whether a table has been closed properly. If you get the following warning from `CHECK TABLE` or `myisamchk`, it means that this counter has gone out of sync:

```
clients are using or haven't closed the table properly
```

This warning doesn't necessarily mean that the table is corrupted, but you should at least check the table.

The counter works as follows:

- The first time a table is updated in MySQL, a counter in the header of the index files is incremented.

- The counter is not changed during further updates.

- When the last instance of a table is closed (because a `FLUSH TABLES` operation was performed or because there is no room in the table cache), the counter is decremented if the table has been updated at any point.

- When you repair the table or check the table and it is found to be okay, the counter is reset to zero.

- To avoid problems with interaction with other processes that might check the table, the counter is not decremented on close if it was zero.

In other words, the counter can become incorrect only under these conditions:

- A `MyISAM` table is copied without first issuing `LOCK TABLES` and `FLUSH TABLES`.

- MySQL has crashed between an update and the final close. (The table may still be okay because MySQL always issues writes for everything between each statement.)

- A table was modified by `myisamchk --recover` or `myisamchk --update-state` at the same time that it was in use by `mysqld`.

- Multiple `mysqld` servers are using the table and one server performed a `REPAIR TABLE` or `CHECK TABLE` on the table while it was in use by another server. In this setup, it is safe to use `CHECK TABLE`, although you might get the warning from other servers. However, `REPAIR TABLE` should be avoided because when one server replaces the data file with a new one, this is not known to the other servers.

  In general, it is a bad idea to share a data directory among multiple servers. See Section 5.5, "Running Multiple MySQL Instances on One Machine", for additional discussion.

14.6 The InnoDB Storage Engine

14.6.1 Introduction to InnoDB

Key Advantages of InnoDB

`InnoDB` is a high-reliability and high-performance storage engine for MySQL. Key advantages of `InnoDB` include:

- Its design follows the ACID model, with transactions featuring commit, rollback, and crash-recovery capabilities to protect user data.

- Row-level locking (without escalation to coarser granularity locks) and Oracle-style consistent reads increase multi-user concurrency and performance.

- `InnoDB` tables arrange your data on disk to optimize common queries based on primary keys. Each `InnoDB` table has a primary key index called the clustered index that organizes the data to minimize I/O for primary key lookups.

- To maintain data integrity, `InnoDB` also supports `FOREIGN KEY` referential-integrity constraints.

- You can freely mix `InnoDB` tables with tables from other MySQL storage engines, even within the same statement. For example, you can use a join operation to combine data from `InnoDB` and `MEMORY` tables in a single query.

- `InnoDB` has been designed for CPU efficiency and maximum performance when processing large data volumes.

To determine whether your server supports `InnoDB` use the `SHOW ENGINES` statement. See Section 13.7.5.17, "SHOW ENGINES Syntax".

Table 14.4 InnoDB Storage Engine Features

Storage limits	64TB	Transactions	Yes	Locking granularity	Row
MVCC	Yes	Geospatial data type support	Yes	Geospatial indexing support	Yes[a]
B-tree indexes	Yes	T-tree indexes	No	Hash indexes	No[b]
Full-text search indexes	Yes[c]	Clustered indexes	Yes	Data caches	Yes
Index caches	Yes	Compressed data	Yes[d]	Encrypted data[e]	Yes

Cluster database support	No	Replication support[f]	Yes	Foreign key support	Yes
Backup / point-in-time recovery[g]	Yes	Query cache support	Yes	Update statistics for data dictionary	Yes

[a]InnoDB support for geospatial indexing is available in MySQL 5.7.5 and higher.

[b]InnoDB utilizes hash indexes internally for its Adaptive Hash Index feature.

[c]InnoDB support for FULLTEXT indexes is available in MySQL 5.6.4 and higher.

[d]Compressed InnoDB tables require the InnoDB Barracuda file format.

[e]Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and higher.

[f]Implemented in the server, rather than in the storage engine.

[g]Implemented in the server, rather than in the storage engine.

The `InnoDB` storage engine maintains its own buffer pool for caching data and indexes in main memory. `InnoDB` stores its tables and indexes in a tablespace, which may consist of several files (or raw disk partitions). This is different from, for example, `MyISAM` tables where each table is stored using separate files. `InnoDB` tables can be very large even on operating systems where file size is limited to 2GB.

The Windows Essentials installer makes `InnoDB` the MySQL default storage engine on Windows, if the server being installed supports `InnoDB`.

To compare the features of `InnoDB` with other storage engines provided with MySQL, see the *Storage Engine Features* table in Chapter 14, *Storage Engines*.

The InnoDB Plugin for MySQL

- At the 2008 MySQL User Conference, Innobase announced availability of an `InnoDB` Plugin for MySQL. This plugin for MySQL exploits the "pluggable storage engine" architecture of MySQL, to permit users to replace the "built-in" version of `InnoDB` in MySQL 5.1.

- As of MySQL 5.1.38, the `InnoDB Plugin` is included in MySQL 5.1 releases, in addition to the built-in version of `InnoDB` that has been included in previous releases. MySQL 5.1.42 through 5.1.45 include `InnoDB Plugin` 1.0.6, which is considered of Release Candidate (RC) quality. MySQL 5.1.46 and up include `InnoDB Plugin` 1.0.7 or higher, which is considered of General Availability (GA) quality.

- Prior to MySQL Cluster NDB 7.1.11, MySQL Cluster was not compatible with the `InnoDB Plugin`.

- The `InnoDB Plugin` offers new features, improved performance and scalability, enhanced reliability and new capabilities for flexibility and ease of use. Among the features of the `InnoDB Plugin` are "Fast index creation," table and index compression, file format management, new `INFORMATION_SCHEMA` tables, capacity tuning, multiple background I/O threads, and group commit.

- The `InnoDB Plugin` is included in source and binary distributions, except RHEL3, RHEL4, SuSE 9 (x86, x86_64, ia64), and generic Linux RPM packages.

- For instructions on replacing the built-in version of `InnoDB` with `InnoDB Plugin`, see Section 14.6.2.1, "Using InnoDB Plugin Instead of the Built-In InnoDB".

MySQL Enterprise Backup and InnoDB

The MySQL Enterprise Backup product lets you back up a running MySQL database, including `InnoDB` and `MyISAM` tables, with minimal disruption to operations while producing a consistent snapshot of the database. When MySQL Enterprise Backup is copying `InnoDB` tables, reads and writes to both `InnoDB` and `MyISAM` tables can continue. During the copying of `MyISAM` and other non-InnoDB tables, reads (but not writes) to those tables are permitted. In addition, MySQL Enterprise Backup can create compressed backup files, and back up subsets of `InnoDB` tables. In conjunction with the MySQL binary log, you can

perform point-in-time recovery. MySQL Enterprise Backup is included as part of the MySQL Enterprise subscription.

For a more complete description of MySQL Enterprise Backup, see Section 23.2, "MySQL Enterprise Backup Overview".

Additional Resources

- For `InnoDB`-related terms and definitions, see MySQL Glossary.

- A forum dedicated to the `InnoDB` storage engine is available here: MySQL Forums::InnoDB.

- `InnoDB` is published under the same GNU GPL License Version 2 (of June 1991) as MySQL. For more information on MySQL licensing, see http://www.mysql.com/company/legal/licensing/.

14.6.2 InnoDB Configuration

The first decisions to make about InnoDB configuration involve how to lay out InnoDB data files, and how much memory to allocate for the InnoDB storage engine. You record these choices either by recording them in a configuration file that MySQL reads at startup, or by specifying them as command-line options in a startup script. The full list of options, descriptions, and allowed parameter values is at Section 14.6.8, "InnoDB Startup Options and System Variables".

Overview of InnoDB Tablespace and Log Files

Two important disk-based resources managed by the `InnoDB` storage engine are its tablespace data files and its log files. If you specify no `InnoDB` configuration options, MySQL creates an auto-extending data file, slightly larger than 10MB, named `ibdata1` and two log files named `ib_logfile0` and `ib_logfile1` in the MySQL data directory. Their size is given by the size of the `innodb_log_file_size` system variable. To get good performance, explicitly provide `InnoDB` parameters as discussed in the following examples. Naturally, edit the settings to suit your hardware and requirements.

The examples shown here are representative. See Section 14.6.8, "InnoDB Startup Options and System Variables" for additional information about `InnoDB`-related configuration parameters.

Considerations for Storage Devices

In some cases, database performance improves if the data is not all placed on the same physical disk. Putting log files on a different disk from data is very often beneficial for performance. The example illustrates how to do this. It places the two data files on different disks and places the log files on the third disk. `InnoDB` fills the tablespace beginning with the first data file. You can also use raw disk partitions (raw devices) as `InnoDB` data files, which may speed up I/O. See Section 14.6.5.3, "Using Raw Disk Partitions for the System Tablespace".

> **Caution**
>
> `InnoDB` is a transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data. **However, it cannot do so** if the underlying operating system or hardware does not work as advertised. Many operating systems or disk subsystems may delay or reorder write operations to improve performance. On some operating systems, the very `fsync()` system call that should wait until all unwritten data for a file has been flushed might actually return before the data has been flushed to stable storage. Because of this, an operating system crash or a power outage may destroy recently committed data, or in the worst case, even corrupt the database because of write operations having

been reordered. If data integrity is important to you, perform some "pull-the-plug" tests before using anything in production. On OS X 10.3 and higher, `InnoDB` uses a special `fcntl()` file flush method. Under Linux, it is advisable to **disable the write-back cache**.

On ATA/SATA disk drives, a command such `hdparm -W0 /dev/hda` may work to disable the write-back cache. **Beware that some drives or disk controllers may be unable to disable the write-back cache.**

With regard to `InnoDB` recovery capabilities that protect user data, `InnoDB` uses a file flush technique involving a structure called the doublewrite buffer, which is enabled by default (`innodb_doublewrite=ON`). The doublewrite buffer adds safety to recovery following a crash or power outage, and improves performance on most varieties of Unix by reducing the need for `fsync()` operations. It is recommended that the `innodb_doublewrite` option remains enabled if you are concerned with data integrity or possible failures. For additional information about the doublewrite buffer, see Section 14.6.7, "InnoDB Disk I/O and File Space Management".

Caution

If reliability is a consideration for your data, do not configure `InnoDB` to use data files or log files on NFS volumes. Potential problems vary according to OS and version of NFS, and include such issues as lack of protection from conflicting writes, and limitations on maximum file sizes.

Specifying the Location and Size for InnoDB Tablespace Files

To set up the `InnoDB` tablespace files, use the `innodb_data_file_path` option in the `[mysqld]` section of the `my.cnf` option file. On Windows, you can use `my.ini` instead. The value of `innodb_data_file_path` should be a list of one or more data file specifications. If you name more than one data file, separate them by semicolon ("`;`") characters:

```
innodb_data_file_path=datafile_spec1[;datafile_spec2]...
```

For example, the following setting explicitly creates a tablespace having the same characteristics as the default:

```
[mysqld]
innodb_data_file_path=ibdata1:10M:autoextend
```

This setting configures a single 10MB data file named `ibdata1` that is auto-extending. No location for the file is given, so by default, `InnoDB` creates it in the MySQL data directory.

Sizes are specified using `K`, `M`, or `G` suffix letters to indicate units of KB, MB, or GB.

A tablespace containing a fixed-size 50MB data file named `ibdata1` and a 50MB auto-extending file named `ibdata2` in the data directory can be configured like this:

```
[mysqld]
innodb_data_file_path=ibdata1:50M;ibdata2:50M:autoextend
```

The full syntax for a data file specification includes the file name, its size, and several optional attributes:

```
file_name:file_size[:autoextend[:max:max_file_size]]
```

The `autoextend` and `max` attributes can be used only for the last data file in the `innodb_data_file_path` line.

If you specify the `autoextend` option for the last data file, `InnoDB` extends the data file if it runs out of free space in the tablespace. The increment is 8MB at a time by default. To modify the increment, change the `innodb_autoextend_increment` system variable.

If the disk becomes full, you might want to add another data file on another disk. For tablespace reconfiguration instructions, see Section 14.6.5.1, "Resizing the InnoDB System Tablespace".

`InnoDB` is not aware of the file system maximum file size, so be cautious on file systems where the maximum file size is a small value such as 2GB. To specify a maximum size for an auto-extending data file, use the `max` attribute following the `autoextend` attribute. Use the `max` attribute only in cases where constraining disk usage is of critical importance, because exceeding the maximum size causes a fatal error, possibly including a crash. The following configuration permits `ibdata1` to grow up to a limit of 500MB:

```
[mysqld]
innodb_data_file_path=ibdata1:10M:autoextend:max:500M
```

`InnoDB` creates tablespace files in the MySQL data directory by default. To specify a location explicitly, use the `innodb_data_home_dir` option. For example, to use two files named `ibdata1` and `ibdata2` but create them in the `/ibdata` directory, configure `InnoDB` like this:

```
[mysqld]
innodb_data_home_dir = /ibdata
innodb_data_file_path=ibdata1:50M;ibdata2:50M:autoextend
```

> **Note**
>
> `InnoDB` does not create directories, so make sure that the `/ibdata` directory exists before you start the server. This is also true of any log file directories that you configure. Use the Unix or DOS `mkdir` command to create any necessary directories.
>
> Make sure that the MySQL server has the proper access rights to create files in the data directory. More generally, the server must have access rights in any directory where it needs to create data files or log files.

`InnoDB` forms the directory path for each data file by textually concatenating the value of `innodb_data_home_dir` to the data file name, adding a path name separator (slash or backslash) between values if necessary. If the `innodb_data_home_dir` option is not specified in `my.cnf` at all, the default value is the "dot" directory `./`, which means the MySQL data directory. (The MySQL server changes its current working directory to its data directory when it begins executing.)

If you specify `innodb_data_home_dir` as an empty string, you can specify absolute paths for the data files listed in the `innodb_data_file_path` value. The following example is equivalent to the preceding one:

```
[mysqld]
innodb_data_home_dir =
innodb_data_file_path=/ibdata/ibdata1:50M;/ibdata/ibdata2:50M:autoextend
```

Specifying InnoDB Configuration Options

Sample `my.cnf` file for small systems. Suppose that you have a computer with 512MB RAM and one hard disk. The following example shows possible configuration parameters in `my.cnf` or `my.ini` for

`InnoDB`, including the `autoextend` attribute. The example suits most users, both on Unix and Windows, who do not want to distribute `InnoDB` data files and log files onto several disks. It creates an auto-extending data file `ibdata1` and two `InnoDB` log files `ib_logfile0` and `ib_logfile1` in the MySQL data directory.

```
[mysqld]
# You can write your other MySQL server options here
# ...
# Data files must be able to hold your data and indexes.
# Make sure that you have enough free disk space.
innodb_data_file_path = ibdata1:10M:autoextend
#
# Set buffer pool size to 50-80% of your computer's memory
innodb_buffer_pool_size=256M
innodb_additional_mem_pool_size=20M
#
# Set the log file size to about 25% of the buffer pool size
innodb_log_file_size=64M
innodb_log_buffer_size=8M
#
innodb_flush_log_at_trx_commit=1
```

Note that data files must be less than 2GB in some file systems. The combined size of the log files must be less than 4GB. The combined size of data files must be at least slightly larger than 10MB.

Setting Up the InnoDB System Tablespace

When you create an `InnoDB` system tablespace for the first time, it is best that you start the MySQL server from the command prompt. `InnoDB` then prints the information about the database creation to the screen, so you can see what is happening. For example, on Windows, if `mysqld` is located in `C:\Program Files\MySQL\MySQL Server 5.1\bin`, you can start it like this:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld" --console
```

If you do not send server output to the screen, check the server's error log to see what `InnoDB` prints during the startup process.

Editing the MySQL Configuration File

You can place `InnoDB` options in the `[mysqld]` group of any option file that your server reads when it starts. The locations for option files are described in Section 4.2.6, "Using Option Files".

If you installed MySQL on Windows using the installation and configuration wizards, the option file will be the `my.ini` file located in your MySQL installation directory. See Section 2.3.5.1, "Starting the MySQL Server Instance Config Wizard".

If your PC uses a boot loader where the `C:` drive is not the boot drive, your only option is to use the `my.ini` file in your Windows directory (typically `C:\WINDOWS`). You can use the `SET` command at the command prompt in a console window to print the value of `WINDIR`:

```
C:\> SET WINDIR
windir=C:\WINDOWS
```

To make sure that `mysqld` reads options only from a specific file, use the `--defaults-file` option as the first option on the command line when starting the server:

```
mysqld --defaults-file=your_path_to_my_cnf
```

Sample `my.cnf` file for large systems. Suppose that you have a Linux computer with 2GB RAM and three 60GB hard disks at directory paths `/`, `/dr2` and `/dr3`. The following example shows possible configuration parameters in `my.cnf` for `InnoDB`.

```
[mysqld]
# You can write your other MySQL server options here
# ...
innodb_data_home_dir =
#
# Data files must be able to hold your data and indexes
innodb_data_file_path = /db/ibdata1:2000M;/dr2/db/ibdata2:2000M:autoextend
#
# Set buffer pool size to 50-80% of your computer's memory,
# but make sure on Linux x86 total memory usage is < 2GB
innodb_buffer_pool_size=1G
innodb_additional_mem_pool_size=20M
innodb_log_group_home_dir = /dr3/iblogs
#
# Set the log file size to about 25% of the buffer pool size
innodb_log_file_size=250M
innodb_log_buffer_size=8M
#
innodb_flush_log_at_trx_commit=1
innodb_lock_wait_timeout=50
#
# Uncomment the next line if you want to use it
#innodb_thread_concurrency=5
```

Determining the Maximum Memory Allocation for InnoDB

Warning

On 32-bit GNU/Linux x86, be careful not to set memory usage too high. `glibc` may permit the process heap to grow over thread stacks, which crashes your server. It is a risk if the value of the following expression is close to or exceeds 2GB:

```
innodb_buffer_pool_size
+ key_buffer_size
+ max_connections*(sort_buffer_size+read_buffer_size+binlog_cache_size)
+ max_connections*2MB
```

Each thread uses a stack (often 2MB, but only 256KB in MySQL binaries provided by Oracle Corporation.) and in the worst case also uses `sort_buffer_size + read_buffer_size` additional memory.

Tuning other `mysqld` server parameters. The following values are typical and suit most users:

```
[mysqld]
skip-external-locking
max_connections=200
read_buffer_size=1M
sort_buffer_size=1M
#
# Set key_buffer to 5 - 50% of your RAM depending on how much
# you use MyISAM tables, but keep key_buffer_size + InnoDB
# buffer pool size < 80% of your RAM
key_buffer_size=value
```

On Linux, if the kernel is enabled for large page support, `InnoDB` can use large pages to allocate memory for its buffer pool and additional memory pool. See Section 8.12.5.2, "Enabling Large Page Support".

Enabling the InnoDB Plugin

If you want to use `InnoDB Plugin` rather than the built-in version of `InnoDB`, to get the latest performance improvements and new features such as table compression and fast index creation, see Section 14.6.2.1, "Using InnoDB Plugin Instead of the Built-In InnoDB".

Turning Off InnoDB

If you do not want to use `InnoDB` tables, start the server with the `--innodb=OFF` or `--skip-innodb` option to disable the `InnoDB` storage engine. In this case, the server will not start if the default storage engine is set to `InnoDB`. Use `--default-storage-engine` to set the default to some other engine if necessary.

14.6.2.1 Using InnoDB Plugin Instead of the Built-In InnoDB

To use `InnoDB Plugin` in MySQL 5.1, you must disable the built-in version of `InnoDB` that is also included and instruct the server to use `InnoDB Plugin` instead. To accomplish this, use the following lines in your `my.cnf` file:

```
[mysqld]
ignore-builtin-innodb
plugin-load=innodb=ha_innodb_plugin.so
```

For the `plugin-load` option, `innodb` is the name to associate with the plugin and `ha_innodb_plugin.so` is the name of the shared object library that contains the plugin code. The extension of `.so` applies for Unix (and similar) systems. For HP-UX on HPPA (11.11) or Windows, the extension should be `.sl` or `.dll`, respectively, rather than `.so`.

If the server has problems finding the plugin when it starts up, specify the pathname to the plugin directory. For example, if plugins are located in the `lib/mysql/plugin` directory under the MySQL installation directory and you have installed MySQL at `/usr/local/mysql`, use these lines in your `my.cnf` file:

```
[mysqld]
ignore-builtin-innodb
plugin-load=innodb=ha_innodb_plugin.so
plugin_dir=/usr/local/mysql/lib/mysql/plugin
```

The previous examples show how to activate the storage engine part of `InnoDB Plugin,` but the plugin also implements several InnoDB-related `INFORMATION_SCHEMA` tables. (For information about these tables, see InnoDB INFORMATION_SCHEMA Tables.) To enable these tables, include additional `name=library` pairs in the value of the `plugin-load` option:

```
[mysqld]
ignore-builtin-innodb
plugin-load=innodb=ha_innodb_plugin.so
  ;innodb_trx=ha_innodb_plugin.so
  ;innodb_locks=ha_innodb_plugin.so
  ;innodb_lock_waits=ha_innodb_plugin.so
  ;innodb_cmp=ha_innodb_plugin.so
  ;innodb_cmp_reset=ha_innodb_plugin.so
  ;innodb_cmpmem=ha_innodb_plugin.so
  ;innodb_cmpmem_reset=ha_innodb_plugin.so
```

The `plugin-load` option value as shown here is formatted on multiple lines for display purposes but should be written in `my.cnf` using a single line without spaces in the option value. On Windows, substitute `.dll` for each instance of the `.so` extension.

After the server starts, verify that `InnoDB Plugin` has been loaded by using the `SHOW PLUGINS` statement. For example, if you have loaded the storage engine and the `INFORMATION_SCHEMA` tables, the output should include lines similar to these:

```
mysql> SHOW PLUGINS;
+---------------------+--------+-------------------+...
| Name                | Status | Type              |...
+---------------------+--------+-------------------+...
...
| InnoDB              | ACTIVE | STORAGE ENGINE    |...
| INNODB_TRX          | ACTIVE | INFORMATION SCHEMA |...
| INNODB_LOCKS        | ACTIVE | INFORMATION SCHEMA |...
| INNODB_LOCK_WAITS   | ACTIVE | INFORMATION SCHEMA |...
| INNODB_CMP          | ACTIVE | INFORMATION SCHEMA |...
| INNODB_CMP_RESET    | ACTIVE | INFORMATION SCHEMA |...
| INNODB_CMPMEM       | ACTIVE | INFORMATION SCHEMA |...
| INNODB_CMPMEM_RESET | ACTIVE | INFORMATION SCHEMA |...
+---------------------+--------+-------------------+...
```

An alternative to using the `plugin-load` option at server startup is to use the `INSTALL PLUGIN` statement at runtime. First start the server with the `ignore-builtin-innodb` option to disable the built-in version of `InnoDB`:

```
[mysqld]
ignore-builtin-innodb
```

Then issue an `INSTALL PLUGIN` statement for each plugin that you want to load:

```
mysql> INSTALL PLUGIN InnoDB SONAME 'ha_innodb_plugin.so';
mysql> INSTALL PLUGIN INNODB_TRX SONAME 'ha_innodb_plugin.so';
mysql> INSTALL PLUGIN INNODB_LOCKS SONAME 'ha_innodb_plugin.so';
...
```

`INSTALL PLUGIN` need be issued only once for each plugin. Installed plugins will be loaded automatically on subsequent server restarts.

If you build MySQL from a source distribution, `InnoDB Plugin` is one of the storage engines that is built by default. Build MySQL the way you normally do; for example, by using the instructions at Section 2.11, "Installing MySQL from Source". After the build completes, you should find the plugin shared object file under the `storage/innodb_plugin` directory, and `make install` should install it in the plugin directory. Configure MySQL to use `InnoDB Plugin` as described earlier for binary distributions.

If you use `gcc`, `InnoDB Plugin` cannot be compiled with `gcc` 3.x; you must use `gcc` 4.x instead.

> **Note**
>
> In MySQL 5.5, the `InnoDB Plugin` is also included, but it becomes the built-in version of `InnoDB` in MySQL Server, replacing the version previously included as the built-in `InnoDB` engine. This means that if you use `InnoDB Plugin` in MySQL 5.1 using the instructions just given, you will need to remove `ignore-builtin-innodb` and `plugin-load` from your startup options after an upgrade to MySQL 5.5 or the server will fail to start.

14.6.3 InnoDB Concepts and Architecture

14.6.3.1 InnoDB Multi-Versioning

`InnoDB` is a multi-versioned storage engine: it keeps information about old versions of changed rows, to support transactional features such as concurrency and rollback. This information is stored in the tablespace in a data structure called a rollback segment (after an analogous data structure in Oracle). `InnoDB` uses the information in the rollback segment to perform the undo operations needed in a transaction rollback. It also uses the information to build earlier versions of a row for a consistent read.

Internally, `InnoDB` adds three fields to each row stored in the database. A 6-byte `DB_TRX_ID` field indicates the transaction identifier for the last transaction that inserted or updated the row. Also, a deletion is treated internally as an update where a special bit in the row is set to mark it as deleted. Each row also contains a 7-byte `DB_ROLL_PTR` field called the roll pointer. The roll pointer points to an undo log record written to the rollback segment. If the row was updated, the undo log record contains the information necessary to rebuild the content of the row before it was updated. A 6-byte `DB_ROW_ID` field contains a row ID that increases monotonically as new rows are inserted. If `InnoDB` generates a clustered index automatically, the index contains row ID values. Otherwise, the `DB_ROW_ID` column does not appear in any index.

Undo logs in the rollback segment are divided into insert and update undo logs. Insert undo logs are needed only in transaction rollback and can be discarded as soon as the transaction commits. Update undo logs are used also in consistent reads, but they can be discarded only after there is no transaction present for which `InnoDB` has assigned a snapshot that in a consistent read could need the information in the update undo log to build an earlier version of a database row.

Commit your transactions regularly, including those transactions that issue only consistent reads. Otherwise, `InnoDB` cannot discard data from the update undo logs, and the rollback segment may grow too big, filling up your tablespace.

The physical size of an undo log record in the rollback segment is typically smaller than the corresponding inserted or updated row. You can use this information to calculate the space needed for your rollback segment.

In the `InnoDB` multi-versioning scheme, a row is not physically removed from the database immediately when you delete it with an SQL statement. `InnoDB` only physically removes the corresponding row and its index records when it discards the update undo log record written for the deletion. This removal operation is called a purge, and it is quite fast, usually taking the same order of time as the SQL statement that did the deletion.

If you insert and delete rows in smallish batches at about the same rate in the table, the purge thread can start to lag behind and the table can grow bigger and bigger because of all the "dead" rows, making everything disk-bound and very slow. In such a case, throttle new row operations, and allocate more resources to the purge thread by tuning the `innodb_max_purge_lag` system variable. See Section 14.6.8, "InnoDB Startup Options and System Variables" for more information.

Multi-Versioning and Secondary Indexes

`InnoDB` multiversion concurrency control (MVCC) treats secondary indexes differently than clustered indexes. Records in a clustered index are updated in-place, and their hidden system columns point undo log entries from which earlier versions of records can be reconstructed. Unlike clustered index records, secondary index records do not contain hidden system columns nor are they updated in-place.

When a secondary index column is updated, old secondary index records are delete-marked, new records are inserted, and delete-marked records are eventually purged. When a secondary index record is delete-marked or the secondary index page is updated by a newer transaction, `InnoDB` looks up the database record in the clustered index. In the clustered index, the record's `DB_TRX_ID` is checked, and the correct version of the record is retrieved from the undo log if the record was modified after the reading transaction was initiated.

If a secondary index record is marked for deletion or the secondary index page is updated by a newer transaction, the covering index technique is not used. Instead of returning values from the index structure, `InnoDB` looks up the record in the clustered index.

14.6.3.2 InnoDB Table and Index Structures

Role of the .frm File

MySQL stores its data dictionary information for tables in `.frm` files in database directories. This is true for all MySQL storage engines, but every `InnoDB` table also has its own entry in the `InnoDB` internal data dictionary inside the tablespace. When MySQL drops a table or a database, it has to delete one or more `.frm` files as well as the corresponding entries inside the `InnoDB` data dictionary. Consequently, you cannot move `InnoDB` tables between databases simply by moving the `.frm` files.

Clustered and Secondary Indexes

Every `InnoDB` table has a special index called the clustered index where the data for the rows is stored. Typically, the clustered index is synonymous with the primary key. To get the best performance from queries, inserts, and other database operations, you must understand how InnoDB uses the clustered index to optimize the most common lookup and DML operations for each table.

- If you define a `PRIMARY KEY` on your table, `InnoDB` uses it as the clustered index.

- If you do not define a `PRIMARY KEY` for your table, MySQL picks the first `UNIQUE` index that has only `NOT NULL` columns as the primary key and `InnoDB` uses it as the clustered index.

- If the table has no `PRIMARY KEY` or suitable `UNIQUE` index, `InnoDB` internally generates a hidden clustered index on a synthetic column containing row ID values. The rows are ordered by the ID that `InnoDB` assigns to the rows in such a table. The row ID is a 6-byte field that increases monotonically as new rows are inserted. Thus, the rows ordered by the row ID are physically in insertion order.

How the Clustered Index Speeds Up Queries

Accessing a row through the clustered index is fast because the row data is on the same page where the index search leads. If a table is large, the clustered index architecture often saves a disk I/O operation when compared to storage organizations that store row data using a different page from the index record. (For example, `MyISAM` uses one file for data rows and another for index records.)

How Secondary Indexes Relate to the Clustered Index

All indexes other than the clustered index are known as secondary indexes. In `InnoDB`, each record in a secondary index contains the primary key columns for the row, as well as the columns specified for the secondary index. `InnoDB` uses this primary key value to search for the row in the clustered index.

If the primary key is long, the secondary indexes use more space, so it is advantageous to have a short primary key.

Physical Structure of an InnoDB Index

All `InnoDB` indexes are B-trees where the index records are stored in the leaf pages of the tree. The default size of an index page is 16KB.

When new records are inserted into an `InnoDB` clustered index, `InnoDB` tries to leave 1/16 of the page free for future insertions and updates of the index records. If index records are inserted in a sequential order (ascending or descending), the resulting index pages are about 15/16 full. If records are inserted in a random order, the pages are from 1/2 to 15/16 full. If the fill factor of an index page drops below 1/2, `InnoDB` tries to contract the index tree to free the page.

Changing the `InnoDB` page size is not a supported operation and there is no guarantee that `InnoDB` will function normally with a page size other than 16KB. Problems compiling or running `InnoDB` may occur. In particular, `ROW_FORMAT=COMPRESSED` in the `InnoDB Plugin` assumes that the page size is at most 16KB and uses 14-bit pointers.

An instance using a particular `InnoDB` page size cannot use data files or log files from an instance that uses a different page size.

Insert Buffering

It is a common situation in database applications that the primary key is a unique identifier and new rows are inserted in the ascending order of the primary key. Thus, insertions into the clustered index do not require random reads from a disk.

On the other hand, secondary indexes are usually nonunique, and insertions into secondary indexes happen in a relatively random order. This would cause a lot of random disk I/O operations without a special mechanism used in `InnoDB`.

If an index record should be inserted into a nonunique secondary index, `InnoDB` checks whether the secondary index page is in the buffer pool. If that is the case, `InnoDB` does the insertion directly to the index page. If the index page is not found in the buffer pool, `InnoDB` inserts the record to a special insert buffer structure. The insert buffer is kept so small that it fits entirely in the buffer pool, and insertions can be done very fast.

Disk I/O for Flushing the Insert Buffer

Periodically, the insert buffer is merged into the secondary index trees in the database. Often, it is possible to merge several changes into the same page of the index tree, saving disk I/O operations. It has been measured that the insert buffer can speed up insertions into a table up to 15 times.

The insert buffer merging may continue to happen *after* the transaction has been committed. In fact, it may continue to happen after a server shutdown and restart (see Section 14.6.12.2, "Forcing InnoDB Recovery").

Insert buffer merging may take many hours when many secondary indexes must be updated and many rows have been inserted. During this time, disk I/O will be increased, which can cause significant slowdown on disk-bound queries. Another significant background I/O operation is the purge thread (see Section 14.6.3.1, "InnoDB Multi-Versioning").

Adaptive Hash Indexes

If a table fits almost entirely in main memory, the fastest way to perform queries on it is to use hash indexes. `InnoDB` has a mechanism that monitors index searches made to the indexes defined for a table. If `InnoDB` notices that queries could benefit from building a hash index, it does so automatically.

The hash index is always built based on an existing B-tree index on the table. `InnoDB` can build a hash index on a prefix of any length of the key defined for the B-tree, depending on the pattern of searches that `InnoDB` observes for the B-tree index. A hash index can be partial: It is not required that the whole B-tree index is cached in the buffer pool. `InnoDB` builds hash indexes on demand for those pages of the index that are often accessed.

In a sense, `InnoDB` tailors itself through the adaptive hash index mechanism to ample main memory, coming closer to the architecture of main-memory databases.

Physical Row Structure

The physical row structure for an `InnoDB` table depends on the row format specified when the table was created. For MySQL 5.1, `InnoDB` uses the `COMPACT` format by default, but the `REDUNDANT` format is

available to retain compatibility with older versions of MySQL. To check the row format of an `InnoDB` table, use `SHOW TABLE STATUS`.

The compact row format decreases row storage space by about 20% at the cost of increasing CPU use for some operations. If your workload is a typical one that is limited by cache hit rates and disk speed, compact format is likely to be faster. If the workload is a rare case that is limited by CPU speed, compact format might be slower.

Rows in `InnoDB` tables that use `REDUNDANT` row format have the following characteristics:

- Each index record contains a 6-byte header. The header is used to link together consecutive records, and also in row-level locking.

- Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte transaction ID field and a 7-byte roll pointer field.

- If no primary key was defined for a table, each clustered index record also contains a 6-byte row ID field.

- Each secondary index record also contains all the primary key fields defined for the clustered index key that are not in the secondary index.

- A record contains a pointer to each field of the record. If the total length of the fields in a record is less than 128 bytes, the pointer is one byte; otherwise, two bytes. The array of these pointers is called the record directory. The area where these pointers point is called the data part of the record.

- Internally, `InnoDB` stores fixed-length character columns such as `CHAR(10)` in a fixed-length format. `InnoDB` does not truncate trailing spaces from `VARCHAR` columns.

- An SQL `NULL` value reserves one or two bytes in the record directory. Besides that, an SQL `NULL` value reserves zero bytes in the data part of the record if stored in a variable length column. In a fixed-length column, it reserves the fixed length of the column in the data part of the record. Reserving the fixed space for `NULL` values enables an update of the column from `NULL` to a non-`NULL` value to be done in place without causing fragmentation of the index page.

Rows in `InnoDB` tables that use `COMPACT` row format have the following characteristics:

- Each index record contains a 5-byte header that may be preceded by a variable-length header. The header is used to link together consecutive records, and also in row-level locking.

- The variable-length part of the record header contains a bit vector for indicating `NULL` columns. If the number of columns in the index that can be `NULL` is N, the bit vector occupies `CEILING(`N`/8)` bytes. (For example, if there are anywhere from 9 to 15 columns that can be `NULL`, the bit vector uses two bytes.) Columns that are `NULL` do not occupy space other than the bit in this vector. The variable-length part of the header also contains the lengths of variable-length columns. Each length takes one or two bytes, depending on the maximum length of the column. If all columns in the index are `NOT NULL` and have a fixed length, the record header has no variable-length part.

- For each non-`NULL` variable-length field, the record header contains the length of the column in one or two bytes. Two bytes will only be needed if part of the column is stored externally in overflow pages or the maximum length exceeds 255 bytes and the actual length exceeds 127 bytes. For an externally stored column, the 2-byte length indicates the length of the internally stored part plus the 20-byte pointer to the externally stored part. The internal part is 768 bytes, so the length is 768+20. The 20-byte pointer stores the true length of the column.

- The record header is followed by the data contents of the non-`NULL` columns.

- Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte transaction ID field and a 7-byte roll pointer field.

- If no primary key was defined for a table, each clustered index record also contains a 6-byte row ID field.

- Each secondary index record also contains all the primary key fields defined for the clustered index key that are not in the secondary index. If any of these primary key fields are variable length, the record header for each secondary index will have a variable-length part to record their lengths, even if the secondary index is defined on fixed-length columns.

- Internally, `InnoDB` stores fixed-length character columns such as `CHAR(10)` in a fixed-length format. `InnoDB` does not truncate trailing spaces from `VARCHAR` columns.

- Internally, `InnoDB` attempts to store UTF-8 `CHAR(N)` columns in N bytes by trimming trailing spaces. (With `REDUNDANT` row format, such columns occupy 3 × N bytes.) Reserving the minimum space N in many cases enables column updates to be done in place without causing fragmentation of the index page.

14.6.4 InnoDB Transaction Model and Locking

To implement a large-scale, busy, or highly reliable database application, to port substantial code from a different database system, or to tune MySQL performance, you must understand the notions of transactions and locking as they relate to the InnoDB storage engine.

In the `InnoDB` transaction model, the goal is to combine the best properties of a multi-versioning database with traditional two-phase locking. `InnoDB` does locking on the row level and runs queries as nonlocking consistent reads by default, in the style of Oracle. The lock information in `InnoDB` is stored so space-efficiently that lock escalation is not needed: Typically, several users are permitted to lock every row in `InnoDB` tables, or any random subset of the rows, without causing `InnoDB` memory exhaustion.

In `InnoDB`, all user activity occurs inside a transaction. If autocommit mode is enabled, each SQL statement forms a single transaction on its own. By default, MySQL starts the session for each new connection with autocommit enabled, so MySQL does a commit after each SQL statement if that statement did not return an error. If a statement returns an error, the commit or rollback behavior depends on the error. See Section 14.6.12.4, "InnoDB Error Handling".

A session that has autocommit enabled can perform a multiple-statement transaction by starting it with an explicit `START TRANSACTION` or `BEGIN` statement and ending it with a `COMMIT` or `ROLLBACK` statement. See Section 13.3.1, "START TRANSACTION, COMMIT, and ROLLBACK Syntax".

If autocommit mode is disabled within a session with `SET autocommit = 0`, the session always has a transaction open. A `COMMIT` or `ROLLBACK` statement ends the current transaction and a new one starts.

A `COMMIT` means that the changes made in the current transaction are made permanent and become visible to other sessions. A `ROLLBACK` statement, on the other hand, cancels all modifications made by the current transaction. Both `COMMIT` and `ROLLBACK` release all `InnoDB` locks that were set during the current transaction.

In terms of the SQL:1992 transaction isolation levels, the default `InnoDB` level is `REPEATABLE READ`. `InnoDB` offers all four transaction isolation levels described by the SQL standard: `READ UNCOMMITTED`, `READ COMMITTED`, `REPEATABLE READ`, and `SERIALIZABLE`.

A user can change the isolation level for a single session or for all subsequent connections with the `SET TRANSACTION` statement. To set the server's default isolation level for all connections, use the `--transaction-isolation` option on the command line or in an option file. For detailed information about isolation levels and level-setting syntax, see Section 13.3.6, "SET TRANSACTION Syntax".

In row-level locking, `InnoDB` normally uses next-key locking. That means that besides index records, `InnoDB` can also lock the "gap" preceding an index record to block insertions by other sessions in the gap

immediately before the index record. A next-key lock refers to a lock that locks an index record and the gap before it. A gap lock refers to a lock that locks only the gap before some index record.

For more information about row-level locking, and the circumstances under which gap locking is disabled, see Section 14.6.4.2, "InnoDB Record, Gap, and Next-Key Locks".

14.6.4.1 InnoDB Lock Modes

`InnoDB` implements standard row-level locking where there are two types of locks, shared (S) locks and exclusive (X) locks. For information about record, gap, and next-key lock types, see Section 14.6.4.2, "InnoDB Record, Gap, and Next-Key Locks".

- A shared (S) lock permits a transaction to read a row.

- An exclusive (X) lock permits a transaction to update or delete a row.

If transaction `T1` holds a shared (S) lock on row `r`, then requests from some distinct transaction `T2` for a lock on row `r` are handled as follows:

- A request by `T2` for an S lock can be granted immediately. As a result, both `T1` and `T2` hold an S lock on `r`.

- A request by `T2` for an X lock cannot be granted immediately.

If a transaction `T1` holds an exclusive (X) lock on row `r`, a request from some distinct transaction `T2` for a lock of either type on `r` cannot be granted immediately. Instead, transaction `T2` has to wait for transaction `T1` to release its lock on row `r`.

Intention Locks

Additionally, `InnoDB` supports *multiple granularity locking* which permits coexistence of record locks and locks on entire tables. To make locking at multiple granularity levels practical, additional types of locks called *intention locks* are used. Intention locks are table locks in `InnoDB`. The idea behind intention locks is for a transaction to indicate which type of lock (shared or exclusive) it will require later for a row in that table. There are two types of intention locks used in `InnoDB` (assume that transaction `T` has requested a lock of the indicated type on table `t`):

- Intention shared (IS): Transaction `T` intends to set S locks on individual rows in table `t`.

- Intention exclusive (IX): Transaction `T` intends to set X locks on those rows.

For example, `SELECT ... LOCK IN SHARE MODE` sets an IS lock and `SELECT ... FOR UPDATE` sets an IX lock.

The intention locking protocol is as follows:

- Before a transaction can acquire an S lock on a row in table `t`, it must first acquire an IS or stronger lock on `t`.

- Before a transaction can acquire an X lock on a row, it must first acquire an IX lock on `t`.

These rules can be conveniently summarized by means of the following *lock type compatibility matrix*.

	X	*IX*	*S*	*IS*
X	Conflict	Conflict	Conflict	Conflict
IX	Conflict	Compatible	Conflict	Compatible
S	Conflict	Conflict	Compatible	Compatible
IS	Conflict	Compatible	Compatible	Compatible

A lock is granted to a requesting transaction if it is compatible with existing locks, but not if it conflicts with existing locks. A transaction waits until the conflicting existing lock is released. If a lock request conflicts with an existing lock and cannot be granted because it would cause deadlock, an error occurs.

Thus, intention locks do not block anything except full table requests (for example, `LOCK TABLES ... WRITE`). The main purpose of `IX` and `IS` locks is to show that someone is locking a row, or going to lock a row in the table.

Deadlock Example

The following example illustrates how an error can occur when a lock request would cause a deadlock. The example involves two clients, A and B.

First, client A creates a table containing one row, and then begins a transaction. Within the transaction, A obtains an `S` lock on the row by selecting it in share mode:

```
mysql> CREATE TABLE t (i INT) ENGINE = InnoDB;
Query OK, 0 rows affected (1.07 sec)

mysql> INSERT INTO t (i) VALUES(1);
Query OK, 1 row affected (0.09 sec)

mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT * FROM t WHERE i = 1 LOCK IN SHARE MODE;
+------+
| i    |
+------+
|    1 |
+------+
```

Next, client B begins a transaction and attempts to delete the row from the table:

```
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)

mysql> DELETE FROM t WHERE i = 1;
```

The delete operation requires an `X` lock. The lock cannot be granted because it is incompatible with the `S` lock that client A holds, so the request goes on the queue of lock requests for the row and client B blocks.

Finally, client A also attempts to delete the row from the table:

```
mysql> DELETE FROM t WHERE i = 1;
ERROR 1213 (40001): Deadlock found when trying to get lock;
try restarting transaction
```

Deadlock occurs here because client A needs an `X` lock to delete the row. However, that lock request cannot be granted because client B already has a request for an `X` lock and is waiting for client A to release its `S` lock. Nor can the `S` lock held by A be upgraded to an `X` lock because of the prior request by B for an `X` lock. As a result, `InnoDB` generates an error for one of the clients and releases its locks. The client returns this error:

```
ERROR 1213 (40001): Deadlock found when trying to get lock;
try restarting transaction
```

At that point, the lock request for the other client can be granted and it deletes the row from the table.

Note

If the `LATEST DETECTED DEADLOCK` section of InnoDB Monitor output includes a message stating, "`TOO DEEP OR LONG SEARCH IN THE LOCK TABLE WAITS-FOR GRAPH, WE WILL ROLL BACK FOLLOWING TRANSACTION`," this indicates that the number of transactions on the wait-for list has reached a limit of 200, which is defined by `LOCK_MAX_DEPTH_IN_DEADLOCK_CHECK`. A wait-for list that exceeds 200 transactions is treated as a deadlock and the transaction attempting to check the wait-for list is rolled back.

The same error may also occur if the locking thread must look at more than 1,000,000 locks owned by the transactions on the wait-for list. The limit of 1,000,000 locks is defined by `LOCK_MAX_N_STEPS_IN_DEADLOCK_CHECK`.

14.6.4.2 InnoDB Record, Gap, and Next-Key Locks

`InnoDB` has several types of record-level locks including record locks, gap locks, and next-key locks. For information about shared locks, exclusive locks, and intention locks, see Section 14.6.4.1, "InnoDB Lock Modes".

- Record lock: This is a lock on an index record.

- Gap lock: This is a lock on a gap between index records, or a lock on the gap before the first or after the last index record.

- Next-key lock: This is a combination of a record lock on the index record and a gap lock on the gap before the index record.

Record Locks

Record locks always lock index records, even if a table is defined with no indexes. For such cases, `InnoDB` creates a hidden clustered index and uses this index for record locking. See Clustered and Secondary Indexes.

Next-key Locks

By default, `InnoDB` operates in `REPEATABLE READ` transaction isolation level and with the `innodb_locks_unsafe_for_binlog` system variable disabled. In this case, `InnoDB` uses next-key locks for searches and index scans, which prevents phantom rows (see Section 14.6.4.3, "Avoiding the Phantom Problem Using Next-Key Locking").

Next-key locking combines index-row locking with gap locking. `InnoDB` performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are actually index-record locks. In addition, a next-key lock on an index record also affects the "gap" before that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record `R` in an index, another session cannot insert a new index record in the gap immediately before `R` in the index order.

Suppose that an index contains the values 10, 11, 13, and 20. The possible next-key locks for this index cover the following intervals, where a round bracket denotes exclusion of the interval endpoint and a square bracket denotes inclusion of the endpoint:

```
(negative infinity, 10]
(10, 11]
(11, 13]
(13, 20]
```

```
(20, positive infinity)
```

For the last interval, the next-key lock locks the gap above the largest value in the index and the "supremum" pseudo-record having a value higher than any value actually in the index. The supremum is not a real index record, so, in effect, this next-key lock locks only the gap following the largest index value.

Gap Locks

The next-key locking example in the previous section shows that a gap might span a single index value, multiple index values, or even be empty.

Gap locking is not needed for statements that lock rows using a unique index to search for a unique row. (This does not include the case that the search condition includes only some columns of a multiple-column unique index; in that case, gap locking does occur.) For example, if the id column has a unique index, the following statement uses only an index-record lock for the row having id value 100 and it does not matter whether other sessions insert rows in the preceding gap:

```
SELECT * FROM child WHERE id = 100;
```

If id is not indexed or has a nonunique index, the statement does lock the preceding gap.

It is also worth noting here that conflicting locks can be held on a gap by different transactions. For example, transaction A can hold a shared gap lock (gap S-lock) on a gap while transaction B holds an exclusive gap lock (gap X-lock) on the same gap. The reason conflicting gap locks are allowed is that if a record is purged from an index, the gap locks held on the record by different transactions must be merged.

Gap locks in InnoDB are "purely inhibitive", which means they only stop other transactions from inserting to the gap. They do not prevent different transactions from taking gap locks on the same gap. Thus, a gap X-lock has the same effect as a gap S-lock.

A type of gap lock called an **insert intention** gap lock is set by INSERT operations prior to row insertion. An insert intention lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. Suppose that there are index records with values of 4 and 7. Separate transactions that attempt to insert values of 5 and 6, respectively, both lock the gap between 4 and 7 with insert intention locks prior to obtaining the exclusive lock on the inserted row, but do not block each other because the rows are nonconflicting.

The following example demonstrates a transaction taking an insert intention lock prior to obtaining an exclusive lock on the inserted record. The example involves two clients, A and B.

Client A creates a table containing two index records (90 and 102) and then starts a transaction that places an exclusive lock on index records with an ID greater than 100. The exclusive lock includes a gap lock before record 102:

```
mysql> CREATE TABLE child (id int(11) NOT NULL, PRIMARY KEY(id)) ENGINE=InnoDB;
mysql> INSERT INTO child (id) values (90),(102);

mysql> START TRANSACTION;
mysql> SELECT * FROM child WHERE id > 100 FOR UPDATE;
+-----+
| id  |
+-----+
| 102 |
+-----+
```

Client B begins a transaction to insert a record into the gap. The transaction takes an insert intention lock while it waits to obtain an exclusive lock.

```
mysql> START TRANSACTION;
mysql> INSERT INTO child (id) VALUES (101);
```

To view data about the insert intention lock, run `SHOW ENGINE INNODB STATUS`. Data similar to the following appears under the `TRANSACTIONS` heading:

```
mysql> SHOW ENGINE INNODB STATUS\G
...
SHOW ENGINE INNODB STATUS
---TRANSACTION 8731, ACTIVE 7 sec inserting
mysql tables in use 1, locked 1
LOCK WAIT 2 lock struct(s), heap size 360, 1 row lock(s)
MySQL thread id 3, OS thread handle 0x7f996beac700, query id 30 localhost root update
INSERT INTO child (id) VALUES (101)
------- TRX HAS BEEN WAITING 7 SEC FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 31 page no 3 n bits 72 index `PRIMARY` of table `test`.`child`
trx id 8731 lock_mode X locks gap before rec insert intention waiting
Record lock, heap no 3 PHYSICAL RECORD: n_fields 3; compact format; info bits 0
 0: len 4; hex 80000066; asc     f;;
 1: len 6; hex 000000002215; asc      " ;;
 2: len 7; hex 9000000172011c; asc      r  ;;...
```

Disabling Gap Locking

Gap locking can be disabled explicitly. This occurs if you change the transaction isolation level to `READ COMMITTED` or enable the `innodb_locks_unsafe_for_binlog` system variable. Under these circumstances, gap locking is disabled for searches and index scans and is used only for foreign-key constraint checking and duplicate-key checking.

There are also other effects of using the `READ COMMITTED` isolation level or enabling `innodb_locks_unsafe_for_binlog`: Record locks for nonmatching rows are released after MySQL has evaluated the `WHERE` condition. For `UPDATE` statements, `InnoDB` does a "semi-consistent" read, such that it returns the latest committed version to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`.

14.6.4.3 Avoiding the Phantom Problem Using Next-Key Locking

The so-called *phantom* problem occurs within a transaction when the same query produces different sets of rows at different times. For example, if a `SELECT` is executed twice, but returns a row the second time that was not returned the first time, the row is a "phantom" row.

Suppose that there is an index on the `id` column of the `child` table and that you want to read and lock all rows from the table having an identifier value larger than 100, with the intention of updating some column in the selected rows later:

```
SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

The query scans the index starting from the first record where `id` is bigger than 100. Let the table contain rows having `id` values of 90 and 102. If the locks set on the index records in the scanned range do not lock out inserts made in the gaps (in this case, the gap between 90 and 102), another session can insert a new row into the table with an `id` of 101. If you were to execute the same `SELECT` within the same transaction, you would see a new row with an `id` of 101 (a "phantom") in the result set returned by the query. If we regard a set of rows as a data item, the new phantom child would violate the isolation principle of transactions that a transaction should be able to run so that the data it has read does not change during the transaction.

To prevent phantoms, `InnoDB` uses an algorithm called *next-key locking* that combines index-row locking with gap locking. `InnoDB` performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are

actually index-record locks. In addition, a next-key lock on an index record also affects the "gap" before that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record `R` in an index, another session cannot insert a new index record in the gap immediately before `R` in the index order.

When `InnoDB` scans an index, it can also lock the gap after the last record in the index. Just that happens in the preceding example: To prevent any insert into the table where `id` would be bigger than 100, the locks set by `InnoDB` include a lock on the gap following `id` value 102.

You can use next-key locking to implement a uniqueness check in your application: If you read your data in share mode and do not see a duplicate for a row you are going to insert, then you can safely insert your row and know that the next-key lock set on the successor of your row during the read prevents anyone meanwhile inserting a duplicate for your row. Thus, the next-key locking enables you to "lock" the nonexistence of something in your table.

Gap locking can be disabled as discussed in Section 14.6.4.2, "InnoDB Record, Gap, and Next-Key Locks". This may cause phantom problems because other sessions can insert new rows into the gaps when gap locking is disabled.

14.6.4.4 Consistent Nonlocking Reads

A consistent read means that `InnoDB` uses multi-versioning to present to a query a snapshot of the database at a point in time. The query sees the changes made by transactions that committed before that point of time, and no changes made by later or uncommitted transactions. The exception to this rule is that the query sees the changes made by earlier statements within the same transaction. This exception causes the following anomaly: If you update some rows in a table, a `SELECT` sees the latest version of the updated rows, but it might also see older versions of any rows. If other sessions simultaneously update the same table, the anomaly means that you might see the table in a state that never existed in the database.

If the transaction isolation level is `REPEATABLE READ` (the default level), all consistent reads within the same transaction read the snapshot established by the first such read in that transaction. You can get a fresher snapshot for your queries by committing the current transaction and after that issuing new queries.

With `READ COMMITTED` isolation level, each consistent read within a transaction sets and reads its own fresh snapshot.

Consistent read is the default mode in which `InnoDB` processes `SELECT` statements in `READ COMMITTED` and `REPEATABLE READ` isolation levels. A consistent read does not set any locks on the tables it accesses, and therefore other sessions are free to modify those tables at the same time a consistent read is being performed on the table.

Suppose that you are running in the default `REPEATABLE READ` isolation level. When you issue a consistent read (that is, an ordinary `SELECT` statement), `InnoDB` gives your transaction a timepoint according to which your query sees the database. If another transaction deletes a row and commits after your timepoint was assigned, you do not see the row as having been deleted. Inserts and updates are treated similarly.

> **Note**
>
> The snapshot of the database state applies to `SELECT` statements within a transaction, not necessarily to DML statements. If you insert or modify some rows and then commit that transaction, a `DELETE` or `UPDATE` statement issued from another concurrent `REPEATABLE READ` transaction could affect those just-committed rows, even though the session could not query them. If a transaction does update or delete rows committed by a different transaction, those changes do become visible to the current transaction. For example, you might encounter a situation like the following:

```
SELECT COUNT(c1) FROM t1 WHERE c1 = 'xyz'; -- Returns 0: no rows match.
DELETE FROM t1 WHERE c1 = 'xyz'; -- Deletes several rows recently committed by other tran

SELECT COUNT(c2) FROM t1 WHERE c2 = 'abc'; -- Returns 0: no rows match.
UPDATE t1 SET c2 = 'cba' WHERE c2 = 'abc'; -- Affects 10 rows: another txn just committed
SELECT COUNT(c2) FROM t1 WHERE c2 = 'cba'; -- Returns 10: this txn can now see the rows i
```

You can advance your timepoint by committing your transaction and then doing another SELECT or START
TRANSACTION WITH CONSISTENT SNAPSHOT.

This is called *multi-versioned concurrency control*.

In the following example, session A sees the row inserted by B only when B has committed the insert and
A has committed as well, so that the timepoint is advanced past the commit of B.

```
         Session A              Session B

         SET autocommit=0;      SET autocommit=0;
time
|        SELECT * FROM t;
|        empty set
|                               INSERT INTO t VALUES (1, 2);
|
v        SELECT * FROM t;
         empty set

                                COMMIT;

         SELECT * FROM t;
         empty set

         COMMIT;

         SELECT * FROM t;
         ---------------------
         |    1    |    2    |
         ---------------------
```

If you want to see the "freshest" state of the database, use either the READ COMMITTED isolation level or a
locking read:

```
SELECT * FROM t LOCK IN SHARE MODE;
```

With READ COMMITTED isolation level, each consistent read within a transaction sets and reads its own
fresh snapshot. With LOCK IN SHARE MODE, a locking read occurs instead: A SELECT blocks until the
transaction containing the freshest rows ends (see Section 14.6.4.5, "SELECT ... FOR UPDATE and
SELECT ... LOCK IN SHARE MODE Locking Reads").

Consistent read does not work over certain DDL statements:

• Consistent read does not work over DROP TABLE, because MySQL cannot use a table that has been
  dropped and InnoDB destroys the table.

• Consistent read does not work over ALTER TABLE, because that statement makes a temporary copy
  of the original table and deletes the original table when the temporary copy is built. When you reissue
  a consistent read within a transaction, rows in the new table are not visible because those rows did not
  exist when the transaction's snapshot was taken.

The type of read varies for selects in clauses like INSERT INTO ... SELECT, UPDATE ... (SELECT),
and CREATE TABLE ... SELECT that do not specify FOR UPDATE or LOCK IN SHARE MODE:

- By default, `InnoDB` uses stronger locks and the `SELECT` part acts like `READ COMMITTED`, where each consistent read, even within the same transaction, sets and reads its own fresh snapshot.

- To use a consistent read in such cases, enable the `innodb_locks_unsafe_for_binlog` option and set the isolation level of the transaction to `READ UNCOMMITTED`, `READ COMMITTED`, or `REPEATABLE READ` (that is, anything other than `SERIALIZABLE`). In this case, no locks are set on rows read from the selected table.

14.6.4.5 SELECT ... FOR UPDATE and SELECT ... LOCK IN SHARE MODE Locking Reads

If you query data and then insert or update related data within the same transaction, the regular `SELECT` statement does not give enough protection. Other transactions can update or delete the same rows you just queried. `InnoDB` supports two types of locking reads that offer extra safety:

- `SELECT ... LOCK IN SHARE MODE` sets a shared mode lock on any rows that are read. Other sessions can read the rows, but cannot modify them until your transaction commits. If any of these rows were changed by another transaction that has not yet committed, your query waits until that transaction ends and then uses the latest values.

- `SELECT ... FOR UPDATE` locks the rows and any associated index entries, the same as if you issued an `UPDATE` statement for those rows. Other transactions are blocked from updating those rows, from doing `SELECT ... LOCK IN SHARE MODE`, or from reading the data in certain transaction isolation levels. Consistent reads ignore any locks set on the records that exist in the read view. (Old versions of a record cannot be locked; they are reconstructed by applying undo logs on an in-memory copy of the record.)

These clauses are primarily useful when dealing with tree-structured or graph-structured data, either in a single table or split across multiple tables.

All locks set by `LOCK IN SHARE MODE` and `FOR UPDATE` queries are released when the transaction is committed or rolled back.

> **Note**
>
> Locking of rows for update using `SELECT FOR UPDATE` only applies when autocommit is disabled (either by beginning transaction with `START TRANSACTION` or by setting `autocommit` to 0. If autocommit is enabled, the rows matching the specification are not locked.

Usage Examples

Suppose that you want to insert a new row into a table `child`, and make sure that the child row has a parent row in table `parent`. Your application code can ensure referential integrity throughout this sequence of operations.

First, use a consistent read to query the table `PARENT` and verify that the parent row exists. Can you safely insert the child row to table `CHILD`? No, because some other session could delete the parent row in the moment between your `SELECT` and your `INSERT`, without you being aware of it.

To avoid this potential issue, perform the `SELECT` using `LOCK IN SHARE MODE`:

```
SELECT * FROM parent WHERE NAME = 'Jones' LOCK IN SHARE MODE;
```

After the `LOCK IN SHARE MODE` query returns the parent `'Jones'`, you can safely add the child record to the `CHILD` table and commit the transaction. Any transaction that tries to read or write to the applicable row in the `PARENT` table waits until you are finished, that is, the data in all tables is in a consistent state.

For another example, consider an integer counter field in a table `CHILD_CODES`, used to assign a unique identifier to each child added to table `CHILD`. Do not use either consistent read or a shared mode read to read the present value of the counter, because two users of the database could see the same value for the counter, and a duplicate-key error occurs if two transactions attempt to add rows with the same identifier to the `CHILD` table.

Here, `LOCK IN SHARE MODE` is not a good solution because if two users read the counter at the same time, at least one of them ends up in deadlock when it attempts to update the counter.

To implement reading and incrementing the counter, first perform a locking read of the counter using `FOR UPDATE`, and then increment the counter. For example:

```
SELECT counter_field FROM child_codes FOR UPDATE;
UPDATE child_codes SET counter_field = counter_field + 1;
```

A `SELECT ... FOR UPDATE` reads the latest available data, setting exclusive locks on each row it reads. Thus, it sets the same locks a searched SQL `UPDATE` would set on the rows.

The preceding description is merely an example of how `SELECT ... FOR UPDATE` works. In MySQL, the specific task of generating a unique identifier actually can be accomplished using only a single access to the table:

```
UPDATE child_codes SET counter_field = LAST_INSERT_ID(counter_field + 1);
SELECT LAST_INSERT_ID();
```

The `SELECT` statement merely retrieves the identifier information (specific to the current connection). It does not access any table.

14.6.4.6 Locks Set by Different SQL Statements in InnoDB

A locking read, an `UPDATE`, or a `DELETE` generally set record locks on every index record that is scanned in the processing of the SQL statement. It does not matter whether there are `WHERE` conditions in the statement that would exclude the row. `InnoDB` does not remember the exact `WHERE` condition, but only knows which index ranges were scanned. The locks are normally next-key locks that also block inserts into the "gap" immediately before the record. However, gap locking can be disabled explicitly, which causes next-key locking not to be used. For more information, see Section 14.6.4.2, "InnoDB Record, Gap, and Next-Key Locks". The transaction isolation level also can affect which locks are set; see Section 13.3.6, "SET TRANSACTION Syntax".

If a secondary index is used in a search and index record locks to be set are exclusive, `InnoDB` also retrieves the corresponding clustered index records and sets locks on them.

Differences between shared and exclusive locks are described in Section 14.6.4.1, "InnoDB Lock Modes".

If you have no indexes suitable for your statement and MySQL must scan the entire table to process the statement, every row of the table becomes locked, which in turn blocks all inserts by other users to the table. It is important to create good indexes so that your queries do not unnecessarily scan many rows.

For `SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE`, locks are acquired for scanned rows, and expected to be released for rows that do not qualify for inclusion in the result set (for example, if they do not meet the criteria given in the `WHERE` clause). However, in some cases, rows might not be unlocked immediately because the relationship between a result row and its original source is lost during query execution. For example, in a `UNION`, scanned (and locked) rows from a table might be inserted into a temporary table before evaluation whether they qualify for the result set. In this circumstance, the relationship of the rows in the temporary table to the rows in the original table is lost and the latter rows are not unlocked until the end of query execution.

InnoDB sets specific types of locks as follows.

- SELECT ... FROM is a consistent read, reading a snapshot of the database and setting no locks unless the transaction isolation level is set to SERIALIZABLE. For SERIALIZABLE level, the search sets shared next-key locks on the index records it encounters.

- SELECT ... FROM ... LOCK IN SHARE MODE sets shared next-key locks on all index records the search encounters.

- For index records the search encounters, SELECT ... FROM ... FOR UPDATE blocks other sessions from doing SELECT ... FROM ... LOCK IN SHARE MODE or from reading in certain transaction isolation levels. Consistent reads will ignore any locks set on the records that exist in the read view.

- UPDATE ... WHERE ... sets an exclusive next-key lock on every record the search encounters.

- DELETE FROM ... WHERE ... sets an exclusive next-key lock on every record the search encounters.

- INSERT sets an exclusive lock on the inserted row. This lock is an index-record lock, not a next-key lock (that is, there is no gap lock) and does not prevent other sessions from inserting into the gap before the inserted row.

  Prior to inserting the row, a type of gap lock called an insertion intention gap lock is set. This lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. Suppose that there are index records with values of 4 and 7. Separate transactions that attempt to insert values of 5 and 6 each lock the gap between 4 and 7 with insert intention locks prior to obtaining the exclusive lock on the inserted row, but do not block each other because the rows are nonconflicting.

  If a duplicate-key error occurs, a shared lock on the duplicate index record is set. This use of a shared lock can result in deadlock should there be multiple sessions trying to insert the same row if another session already has an exclusive lock. This can occur if another session deletes the row. Suppose that an InnoDB table t1 has the following structure:

```
CREATE TABLE t1 (i INT, PRIMARY KEY (i)) ENGINE = InnoDB;
```

Now suppose that three sessions perform the following operations in order:

Session 1:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 2:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 3:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 1:

```
ROLLBACK;
```

The first operation by session 1 acquires an exclusive lock for the row. The operations by sessions 2 and 3 both result in a duplicate-key error and they both request a shared lock for the row. When session 1 rolls back, it releases its exclusive lock on the row and the queued shared lock requests for sessions 2 and 3 are granted. At this point, sessions 2 and 3 deadlock: Neither can acquire an exclusive lock for the row because of the shared lock held by the other.

A similar situation occurs if the table already contains a row with key value 1 and three sessions perform the following operations in order:

Session 1:

```
START TRANSACTION;
DELETE FROM t1 WHERE i = 1;
```

Session 2:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 3:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 1:

```
COMMIT;
```

The first operation by session 1 acquires an exclusive lock for the row. The operations by sessions 2 and 3 both result in a duplicate-key error and they both request a shared lock for the row. When session 1 commits, it releases its exclusive lock on the row and the queued shared lock requests for sessions 2 and 3 are granted. At this point, sessions 2 and 3 deadlock: Neither can acquire an exclusive lock for the row because of the shared lock held by the other.

- `INSERT ... ON DUPLICATE KEY UPDATE` differs from a simple `INSERT` in that an exclusive next-key lock rather than a shared lock is placed on the row to be updated when a duplicate-key error occurs.

- `REPLACE` is done like an `INSERT` if there is no collision on a unique key. Otherwise, an exclusive next-key lock is placed on the row to be replaced.

- `INSERT INTO T SELECT ... FROM S WHERE ...` sets an exclusive index record lock (without a gap lock) on each row inserted into `T`. If the transaction isolation level is `READ COMMITTED`, or `innodb_locks_unsafe_for_binlog` is enabled and the transaction isolation level is not `SERIALIZABLE`, `InnoDB` does the search on `S` as a consistent read (no locks). Otherwise, `InnoDB` sets shared next-key locks on rows from `S`. `InnoDB` has to set locks in the latter case: In roll-forward recovery from a backup, every SQL statement must be executed in exactly the same way it was done originally.

  `CREATE TABLE ... SELECT ...` performs the `SELECT` with shared next-key locks or as a consistent read, as for `INSERT ... SELECT`.

  When a `SELECT` is used in the constructs `REPLACE INTO t SELECT ... FROM s WHERE ...` or `UPDATE t ... WHERE col IN (SELECT ... FROM s ...)`, `InnoDB` sets shared next-key locks on rows from table `s`.

- While initializing a previously specified `AUTO_INCREMENT` column on a table, `InnoDB` sets an exclusive lock on the end of the index associated with the `AUTO_INCREMENT` column. In accessing the auto-increment counter, `InnoDB` uses a specific `AUTO-INC` table lock mode where the lock lasts only to the end of the current SQL statement, not to the end of the entire transaction. Other sessions cannot insert into the table while the `AUTO-INC` table lock is held; see Section 14.6.4, "InnoDB Transaction Model and Locking".

  `InnoDB` fetches the value of a previously initialized `AUTO_INCREMENT` column without setting any locks.

- If a `FOREIGN KEY` constraint is defined on a table, any insert, update, or delete that requires the constraint condition to be checked sets shared record-level locks on the records that it looks at to check the constraint. `InnoDB` also sets these locks in the case where the constraint fails.

- `LOCK TABLES` sets table locks, but it is the higher MySQL layer above the `InnoDB` layer that sets these locks. `InnoDB` is aware of table locks if `innodb_table_locks = 1` (the default) and `autocommit = 0`, and the MySQL layer above `InnoDB` knows about row-level locks.

  Otherwise, `InnoDB`'s automatic deadlock detection cannot detect deadlocks where such table locks are involved. Also, because in this case the higher MySQL layer does not know about row-level locks, it is possible to get a table lock on a table where another session currently has row-level locks. However, this does not endanger transaction integrity, as discussed in Section 14.6.4.8, "Deadlock Detection and Rollback". See also Section 14.6.6.7, "Limits on InnoDB Tables".

14.6.4.7 Implicit Transaction Commit and Rollback

By default, MySQL starts the session for each new connection with autocommit mode enabled, so MySQL does a commit after each SQL statement if that statement did not return an error. If a statement returns an error, the commit or rollback behavior depends on the error. See Section 14.6.12.4, "InnoDB Error Handling".

If a session that has autocommit disabled ends without explicitly committing the final transaction, MySQL rolls back that transaction.

Some statements implicitly end a transaction, as if you had done a `COMMIT` before executing the statement. For details, see Section 13.3.3, "Statements That Cause an Implicit Commit".

14.6.4.8 Deadlock Detection and Rollback

`InnoDB` automatically detects transaction deadlocks and rolls back a transaction or transactions to break the deadlock. `InnoDB` tries to pick small transactions to roll back, where the size of a transaction is determined by the number of rows inserted, updated, or deleted.

`InnoDB` is aware of table locks if `innodb_table_locks = 1` (the default) and `autocommit = 0`, and the MySQL layer above it knows about row-level locks. Otherwise, `InnoDB` cannot detect deadlocks where a table lock set by a MySQL `LOCK TABLES` statement or a lock set by a storage engine other than `InnoDB` is involved. Resolve these situations by setting the value of the `innodb_lock_wait_timeout` system variable.

When `InnoDB` performs a complete rollback of a transaction, all locks set by the transaction are released. However, if just a single SQL statement is rolled back as a result of an error, some of the locks set by the statement may be preserved. This happens because `InnoDB` stores row locks in a format such that it cannot know afterward which lock was set by which statement.

As of MySQL 5.1.24, if a `SELECT` calls a stored function in a transaction, and a statement within the function fails, that statement rolls back. Furthermore, if `ROLLBACK` is executed after that, the entire transaction rolls back. Before 5.1.24, the failed statement did not roll back when it failed (even though it might ultimately get rolled back by a `ROLLBACK` later that rolls back the entire transaction).

For techniques to organize database operations to avoid deadlocks, see Section 14.6.4.9, "How to Cope with Deadlocks".

14.6.4.9 How to Cope with Deadlocks

This section builds on the conceptual information about deadlocks in Section 14.6.4.8, "Deadlock Detection and Rollback". It explains how to organize database operations to minimize deadlocks and the subsequent error handling required in applications.

Deadlocks are a classic problem in transactional databases, but they are not dangerous unless they are so frequent that you cannot run certain transactions at all. Normally, you must write your applications so that they are always prepared to re-issue a transaction if it gets rolled back because of a deadlock.

`InnoDB` uses automatic row-level locking. You can get deadlocks even in the case of transactions that just insert or delete a single row. That is because these operations are not really "atomic"; they automatically set locks on the (possibly several) index records of the row inserted or deleted.

You can cope with deadlocks and reduce the likelihood of their occurrence with the following techniques:

- Use `SHOW ENGINE INNODB STATUS` to determine the cause of the latest deadlock. That can help you to tune your application to avoid deadlocks.

- Always be prepared to re-issue a transaction if it fails due to deadlock. Deadlocks are not dangerous. Just try again.

- Keep transactions small and short in duration to make them less prone to collision.

- Commit transactions immediately after making a set of related changes to make them less prone to collision. In particular, do not leave an interactive `mysql` session open for a long time with an uncommitted transaction.

- If you are using locking reads (`SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE`), try using a lower isolation level such as `READ COMMITTED`.

- When modifying multiple tables within a transaction, or different sets of rows in the same table, do those operations in a consistent order each time. Then transactions form well-defined queues and do not deadlock. For example, organize database operations into functions within your application, or call stored routines, rather than coding multiple similar sequences of `INSERT`, `UPDATE`, and `DELETE` statements in different places.

- Add well-chosen indexes to your tables. Then your queries need to scan fewer index records and consequently set fewer locks. Use `EXPLAIN SELECT` to determine which indexes the MySQL server regards as the most appropriate for your queries.

- Use less locking. If you can afford to permit a `SELECT` to return data from an old snapshot, do not add the clause `FOR UPDATE` or `LOCK IN SHARE MODE` to it. Using the `READ COMMITTED` isolation level is good here, because each consistent read within the same transaction reads from its own fresh snapshot.

- If nothing else helps, serialize your transactions with table-level locks. The correct way to use `LOCK TABLES` with transactional tables, such as `InnoDB` tables, is to begin a transaction with `SET autocommit = 0` (not `START TRANSACTION`) followed by `LOCK TABLES`, and to not call `UNLOCK TABLES` until you commit the transaction explicitly. For example, if you need to write to table `t1` and read from table `t2`, you can do this:

```
SET autocommit=0;
LOCK TABLES t1 WRITE, t2 READ, ...;
... do something with tables t1 and t2 here ...
COMMIT;
```

```
UNLOCK TABLES;
```

Table-level locks prevent concurrent updates to the table, avoiding deadlocks at the expense of less responsiveness for a busy system.

- Another way to serialize transactions is to create an auxiliary "semaphore" table that contains just a single row. Have each transaction update that row before accessing other tables. In that way, all transactions happen in a serial fashion. Note that the `InnoDB` instant deadlock detection algorithm also works in this case, because the serializing lock is a row-level lock. With MySQL table-level locks, the timeout method must be used to resolve deadlocks.

14.6.5 InnoDB Tablespace Management

14.6.5.1 Resizing the InnoDB System Tablespace

This section describes how to increase or decrease the size of the `InnoDB` system tablespace.

Increasing the Size of the InnoDB System Tablespace

The easiest way to increase the size of the `InnoDB` system tablespace is to configure it from the beginning to be auto-extending. Specify the `autoextend` attribute for the last data file in the tablespace definition. Then `InnoDB` increases the size of that file automatically in 8MB increments when it runs out of space. The increment size can be changed by setting the value of the `innodb_autoextend_increment` system variable, which is measured in megabytes.

You can expand the system tablespace by a defined amount by adding another data file:

1. Shut down the MySQL server.

2. If the previous last data file is defined with the keyword `autoextend`, change its definition to use a fixed size, based on how large it has actually grown. Check the size of the data file, round it down to the closest multiple of 1024 × 1024 bytes (= 1MB), and specify this rounded size explicitly in `innodb_data_file_path`.

3. Add a new data file to the end of `innodb_data_file_path`, optionally making that file auto-extending. Only the last data file in the `innodb_data_file_path` can be specified as auto-extending.

4. Start the MySQL server again.

For example, this tablespace has just one auto-extending data file `ibdata1`:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:10M:autoextend
```

Suppose that this data file, over time, has grown to 988MB. Here is the configuration line after modifying the original data file to use a fixed size and adding a new auto-extending data file:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:988M;/disk2/ibdata2:50M:autoextend
```

When you add a new data file to the system tablespace configuration, make sure that the filename does not refer to an existing file. `InnoDB` creates and initializes the file when you restart the server.

Decreasing the Size of the InnoDB System Tablespace

You cannot remove a data file from the system tablespace. To decrease the size of your system tablespace, use this procedure:

1. Use `mysqldump` to dump all your `InnoDB` tables.

2. Stop the server.

3. Remove all the existing tablespace files, including the `ibdata` and `ib_log` files. If you want to keep a backup copy of the information, then copy all the `ib*` files to another location before the removing the files in your MySQL installation.

4. Remove any `.frm` files for `InnoDB` tables.

5. Configure a new tablespace.

6. Restart the server.

7. Import the dump files.

14.6.5.2 Changing the Number or Size of InnoDB Redo Log Files

To change the number or the size of your `InnoDB` redo log files, perform the following steps:

1. If `innodb_fast_shutdown` is set to 2, set `innodb_fast_shutdown` to 1:

   ```
   mysql> SET GLOBAL innodb_fast_shutdown = 1;
   ```

2. After ensuring that `innodb_fast_shutdown` is not set to 2, stop the MySQL server and make sure that it shuts down without errors (to ensure that there is no information for outstanding transactions in the log).

3. Copy the old log files into a safe place in case something went wrong during the shutdown and you need them to recover the tablespace.

4. Delete the old log files from the log file directory.

5. Edit `my.cnf` to change the log file configuration.

6. Start the MySQL server again. `mysqld` sees that no `InnoDB` log files exist at startup and creates new ones.

14.6.5.3 Using Raw Disk Partitions for the System Tablespace

You can use raw disk partitions as data files in the `InnoDB` system tablespace. This technique enables nonbuffered I/O on Windows and on some Linux and Unix systems without file system overhead. Perform tests with and without raw partitions to verify whether this change actually improves performance on your system.

When you use a raw disk partition, ensure that the user ID that runs the MySQL server has read and write privileges for that partition. For example, if you run the server as the `mysql` user, the partition must be readable and writeable by `mysql`. If you run the server with the `--memlock` option, the server must be run as `root`, so the partition must be readable and writeable by `root`.

The procedures described below involve option file modification. For additional information, see Section 4.2.6, "Using Option Files".

Allocating a Raw Disk Partition on Linux and Unix Systems

1. When you create a new data file, specify the keyword `newraw` immediately after the data file size for the `innodb_data_file_path` option. The partition must be at least as large as the size that you

specify. Note that 1MB in `InnoDB` is 1024 × 1024 bytes, whereas 1MB in disk specifications usually means 1,000,000 bytes.

```
[mysqld]
innodb_data_home_dir=
innodb_data_file_path=/dev/hdd1:3Gnewraw;/dev/hdd2:2Gnewraw
```

2. Restart the server. `InnoDB` notices the `newraw` keyword and initializes the new partition. However, do not create or change any `InnoDB` tables yet. Otherwise, when you next restart the server, `InnoDB` reinitializes the partition and your changes are lost. (As a safety measure `InnoDB` prevents users from modifying data when any partition with `newraw` is specified.)

3. After `InnoDB` has initialized the new partition, stop the server, change `newraw` in the data file specification to `raw`:

```
[mysqld]
innodb_data_home_dir=
innodb_data_file_path=/dev/hdd1:3Graw;/dev/hdd2:2Graw
```

4. Restart the server. `InnoDB` now permits changes to be made.

Allocating a Raw Disk Partition on Windows

On Windows systems, the same steps and accompanying guidelines described for Linux and Unix systems apply except that the `innodb_data_file_path` setting differs slightly on Windows.

1. When you create a new data file, specify the keyword `newraw` immediately after the data file size for the `innodb_data_file_path` option:

```
[mysqld]
innodb_data_home_dir=
innodb_data_file_path=//./D::10Gnewraw
```

The `//./` corresponds to the Windows syntax of `\\.\` for accessing physical drives. In the example above, `D:` is the drive letter of the partition.

2. Restart the server. `InnoDB` notices the `newraw` keyword and initializes the new partition.

3. After `InnoDB` has initialized the new partition, stop the server, change `newraw` in the data file specification to `raw`:

```
[mysqld]
innodb_data_home_dir=
innodb_data_file_path=//./D::10Graw
```

4. Restart the server. `InnoDB` now permits changes to be made.

14.6.5.4 InnoDB File-Per-Table Tablespaces

You can store each `InnoDB` table and its indexes in its own data file. This feature is called "file-per-table tablespaces" because in effect each table has its own tablespace.

Advantages of File-Per-Table Tablespaces

- You can reclaim disk space when truncating or dropping a table stored in a file-per-table tablepace. Truncating or dropping tables stored in the system tablespace creates free space internally in the system tablespace data files (ibdata files) which can only be used for new `InnoDB` data.

- The `TRUNCATE TABLE` operation is faster when run on tables stored in file-per-table tablepaces.

- You can store specific tables on separate storage devices, for I/O optimization, space management, or backup purposes.

- You can run `OPTIMIZE TABLE` to compact or recreate a file-per-table tablespace. When you run an `OPTIMIZE TABLE`, `InnoDB` creates a new `.ibd` file with a temporary name, using only the space required to store actual data. When the optimization is complete, `InnoDB` removes the old `.ibd` file and replaces it with the new one. If the previous `.ibd` file grew significantly but the actual data only accounted for a portion of its size, running `OPTIMIZE TABLE` can reclaim the unused space.

- You can move individual `InnoDB` tables rather than entire databases.

- You can enable compression for table and index data, using the compressed row format.

- You can enable more efficient storage for tables with large `BLOB` or `TEXT` columns using the dynamic row format.

- File-per-table tablespaces may improve chances for a successful recovery and save time when a corruption occurs, when a server cannot be restarted, or when backup and binary logs are unavailable.

- You can back up or restore a single table quickly, without interrupting the use of other `InnoDB` tables, using the MySQL Enterprise Backup product. See Partial Backup and Restore Options for details.

- You can exclude tables stored in file-per-table tablespaces from a backup. This is beneficial if you have tables that require backup less frequently or on a different schedule.

- File-per-table tablespaces are convenient for per-table status reporting when copying or backing up tables.

- You can monitor table size at a file system level, without accessing MySQL.

- Common Linux file systems do not permit concurrent writes to a single file when `innodb_flush_method` is set to `O_DIRECT`. As a result, there are possible performance improvements when using `innodb_file_per_table` in conjunction with `innodb_flush_method`.

- The system tablespace stores the data dictionary and undo logs, and has a 64TB size limit. By comparison, each file-per-table tablespace has a 64TB size limit, which provides you with room for growth. See Section C.7.3, "Limits on Table Size" for related information.

Potential Disadvantages of File-Per-Table Tablespaces

- With file-per-table tablespaces, each table may have unused space, which can only be utilized by rows of the same table. This could lead to wasted space if not properly managed.

- `fsync` operations must run on each open table rather than on a single file. Because there is a separate `fsync` operation for each file, write operations on multiple tables cannot be combined into a single I/O operation. This may require `InnoDB` to perform a higher total number of `fsync` operations.

- `mysqld` must keep one open file handle per table, which may impact performance if you have numerous tables in file-per-table tablespaces.

- More file descriptors are used.

- If backward compatibility with MySQL 5.1 is a concern, be aware that enabling `innodb_file_per_table` means that `ALTER TABLE` will move `InnoDB` tables from the system tablespace to individual `.ibd` files.

- If many tables are growing there is potential for more fragmentation which can impede `DROP TABLE` and table scan performance. However, when fragmentation is managed, having files in their own tablespace can improve performance.

- The buffer pool is scanned when dropping a file-per-table tablespace, which can take several seconds for buffer pools that are tens of gigabytes in size. The scan is performed with a broad internal lock, which may delay other operations. Tables in the system tablespace are not affected.

- The `innodb_autoextend_increment` variable, which defines increment size (in MB) for extending the size of an auto-extending shared tablespace file when it becomes full, does not apply to file-per-table tablespace files, which are auto-extending regardless of the `innodb_autoextend_increment` setting. The initial extensions are by small amounts, after which extensions occur in increments of 4MB.

Enabling and Disabling File-Per-Table Tablespaces

To enable file-per-table tablespaces, start the server with the `--innodb_file_per_table` option. For example, add a line to the `[mysqld]` section of `my.cnf`:

```
[mysqld]
innodb_file_per_table=1
```

With `innodb_file_per_table` enabled, `InnoDB` stores each newly created table into its own `tbl_name.ibd` file in the database directory where the table belongs. This is similar to what the `MyISAM` storage engine does, but `MyISAM` divides the table into a `tbl_name.MYD` data file and an `tbl_name.MYI` index file. For `InnoDB`, the data and the indexes are stored together in the `.ibd` file. The `tbl_name.frm` file is still created as usual.

You cannot freely move `.ibd` files between database directories as you can with `MyISAM` table files. This is because the table definition that is stored in the `InnoDB` shared tablespace includes the database name, and because `InnoDB` must preserve the consistency of transaction IDs and log sequence numbers.

If you remove the `innodb_file_per_table` line from `my.cnf` and restart the server, newly created `InnoDB` tables are created inside the shared tablespace files again.

The `--innodb_file_per_table` option affects only table creation, not access to existing tables. If you start the server with this option, new tables are created using `.ibd` files, but you can still access tables that exist in the shared tablespace. If you start the server without this option, new tables are created in the shared tablespace, but you can still access tables created in file-per-table tablespaces.

> **Note**
>
> `InnoDB` requires the shared tablespace to store its internal data dictionary and undo logs. The `.ibd` files alone are not sufficient for `InnoDB` to operate.

To move an `.ibd` file and the associated table from one database to another, use a `RENAME TABLE` statement:

```
RENAME TABLE db1.tbl_name TO db2.tbl_name;
```

If you have a "clean" backup of an `.ibd` file, you can restore it to the MySQL installation from which it originated as follows:

1. Issue this `ALTER TABLE` statement to delete the current `.ibd` file:

   ```
   ALTER TABLE tbl_name DISCARD TABLESPACE;
   ```

2. Copy the backup `.ibd` file to the proper database directory.

3. Issue this `ALTER TABLE` statement to tell `InnoDB` to use the new `.ibd` file for the table:

```
ALTER TABLE tbl_name IMPORT TABLESPACE;
```

In this context, a "clean" `.ibd` file backup is one for which the following requirements are satisfied:

- There are no uncommitted modifications by transactions in the `.ibd` file.

- There are no unmerged insert buffer entries in the `.ibd` file.

- Purge has removed all delete-marked index records from the `.ibd` file.

- `mysqld` has flushed all modified pages of the `.ibd` file from the buffer pool to the file.

You can make a clean backup `.ibd` file using the following method:

1. Stop all activity from the `mysqld` server and commit all transactions.

2. Wait until `SHOW ENGINE INNODB STATUS` shows that there are no active transactions in the database, and the main thread status of `InnoDB` is `Waiting for server activity`. Then you can make a copy of the `.ibd` file.

Another method for making a clean copy of an `.ibd` file is to use the commercial MySQL Enterprise Backup product:

1. Use MySQL Enterprise Backup to back up the `InnoDB` installation.

2. Start a second `mysqld` server on the backup and let it clean up the `.ibd` files in the backup.

14.6.6 InnoDB Table Management

14.6.6.1 Creating InnoDB Tables

To create an `InnoDB` table, specify an `ENGINE=InnoDB` option in the `CREATE TABLE` statement:

```
CREATE TABLE customers (a INT, b CHAR (20), INDEX (a)) ENGINE=InnoDB;
```

The statement creates a table and an index on column `a` in the `InnoDB` tablespace that consists of the data files that you specified in `my.cnf`. In addition, MySQL creates a file `customers.frm` in the `test` directory under the MySQL database directory. Internally, `InnoDB` adds an entry for the table to its own data dictionary. The entry includes the database name. For example, if `test` is the database in which the `customers` table is created, the entry is for `'test/customers'`. This means you can create a table of the same name `customers` in some other database, and the table names do not collide inside `InnoDB`.

You can query the amount of free space in the `InnoDB` tablespace by issuing a `SHOW TABLE STATUS` statement for any `InnoDB` table. The amount of free space in the tablespace appears in the `Data_free` section in the output of `SHOW TABLE STATUS` (or the `Comment` section prior to MySQL 5.1.24). For example:

```
SHOW TABLE STATUS FROM test LIKE 'customers'
```

The statistics `SHOW` displays for `InnoDB` tables are only approximate. They are used in SQL optimization. Table and index reserved sizes in bytes are accurate, though.

14.6.6.2 Using InnoDB with Different APIs

Transactions in SQL

By default, each client that connects to the MySQL server begins with autocommit mode enabled, which automatically commits every SQL statement as you execute it. To use multiple-statement transactions, you can switch autocommit off with the SQL statement `SET autocommit = 0` and end each transaction with either `COMMIT` or `ROLLBACK`. If you want to leave autocommit on, you can begin your transactions within `START TRANSACTION` and end them with `COMMIT` or `ROLLBACK`. The following example shows two transactions. The first is committed; the second is rolled back.

```
shell> mysql test

mysql> CREATE TABLE customer (a INT, b CHAR (20), INDEX (a))
    -> ENGINE=InnoDB;
Query OK, 0 rows affected (0.00 sec)
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)
mysql> INSERT INTO customer VALUES (10, 'Heikki');
Query OK, 1 row affected (0.00 sec)
mysql> COMMIT;
Query OK, 0 rows affected (0.00 sec)
mysql> SET autocommit=0;
Query OK, 0 rows affected (0.00 sec)
mysql> INSERT INTO customer VALUES (15, 'John');
Query OK, 1 row affected (0.00 sec)
mysql> ROLLBACK;
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT * FROM customer;
+------+--------+
| a    | b      |
+------+--------+
|   10 | Heikki |
+------+--------+
1 row in set (0.00 sec)
mysql>
```

Transactions in Client-Side Languages

In APIs such as PHP, Perl DBI, JDBC, ODBC, or the standard C call interface of MySQL, you can send transaction control statements such as `COMMIT` to the MySQL server as strings just like any other SQL statements such as `SELECT` or `INSERT`. Some APIs also offer separate special transaction commit and rollback functions or methods.

14.6.6.3 Moving or Copying InnoDB Tables to Another Machine

This section explains various techniques for moving or copying some or all `InnoDB` tables to a different server. For example, you might move an entire MySQL instance to a larger, faster server; you might clone an entire MySQL instance to a new replication slave server; you might copy individual tables to another server to development and test an application, or to a data warehouse server to produce reports.

On Windows, `InnoDB` always stores database and table names internally in lowercase. To move databases in a binary format from Unix to Windows or from Windows to Unix, create all databases and tables using lowercase names. A convenient way to accomplish this is to add the following line to the `[mysqld]` section of your `my.cnf` or `my.ini` file before creating any databases or tables:

```
[mysqld]
lower_case_table_names=1
```

Like `MyISAM` data files, `InnoDB` data and log files are binary-compatible on all platforms having the same floating-point number format. You can move an `InnoDB` database simply by copying all the relevant files listed in Section 14.6.10, "InnoDB Backup and Recovery". If the floating-point formats differ but you have not used `FLOAT` or `DOUBLE` data types in your tables, then the procedure is the same: simply copy the relevant files. If you use `mysqldump` to dump your tables on one machine and then import the dump files on the other machine, it does not matter whether the formats differ or your tables contain floating-point data.

One way to increase performance is to switch off autocommit mode when importing data, assuming that the tablespace has enough space for the big rollback segment that the import transactions generate. Do the commit only after importing a whole table or a segment of a table.

14.6.6.4 Converting Tables from MyISAM to InnoDB

To convert a non-`InnoDB` table to use `InnoDB` use `ALTER TABLE`:

```
ALTER TABLE table_name ENGINE=InnoDB;
```

> **Important**
>
> Do not convert MySQL system tables in the `mysql` database (such as `user` or `host`) to the `InnoDB` type. This is an unsupported operation. The system tables must always be of the `MyISAM` type.

`InnoDB` does not have a special optimization for separate index creation the way the `MyISAM` storage engine does. Therefore, it does not pay to export and import the table and create indexes afterward. The fastest way to alter a table to `InnoDB` is to do the inserts directly to an `InnoDB` table. That is, use `ALTER TABLE ... ENGINE=INNODB`, or create an empty `InnoDB` table with identical definitions and insert the rows with `INSERT INTO ... SELECT * FROM ...`.

If you have `UNIQUE` constraints on secondary keys, you can speed up a table import by turning off the uniqueness checks temporarily during the import operation:

```
SET unique_checks=0;
... import operation ...
SET unique_checks=1;
```

For big tables, this saves disk I/O because `InnoDB` can use its insert buffer to write secondary index records as a batch. Be certain that the data contains no duplicate keys. `unique_checks` permits but does not require storage engines to ignore duplicate keys.

To get better control over the insertion process, you might insert big tables in pieces:

```
INSERT INTO newtable SELECT * FROM oldtable
   WHERE yourkey > something AND yourkey <= somethingelse;
```

After all records have been inserted, you can rename the tables.

During the conversion of big tables, increase the size of the `InnoDB` buffer pool to reduce disk I/O, to a maximum of 80% of physical memory. You can also increase the sizes of the `InnoDB` log files.

Make sure that you do not fill up the tablespace: `InnoDB` tables require a lot more disk space than `MyISAM` tables. If an `ALTER TABLE` operation runs out of space, it starts a rollback, and that can take hours if it is disk-bound. For inserts, `InnoDB` uses the insert buffer to merge secondary index records to indexes in batches. That saves a lot of disk I/O. For rollback, no such mechanism is used, and the rollback can take 30 times longer than the insertion.

In the case of a runaway rollback, if you do not have valuable data in your database, it may be advisable to kill the database process rather than wait for millions of disk I/O operations to complete. For the complete procedure, see Section 14.6.12.2, "Forcing InnoDB Recovery".

If you want all new user-created tables to use the `InnoDB` storage engine, add the line `default-storage-engine=innodb` to the `[mysqld]` section of your server option file.

14.6.6.5 AUTO_INCREMENT Handling in InnoDB

Beginning with MySQL 5.1.22, `InnoDB` provides a configurable locking mechanism that can significantly improve scalability and performance of SQL statements that add rows to tables with `AUTO_INCREMENT` columns. To use the `AUTO_INCREMENT` mechanism with an `InnoDB` table, an `AUTO_INCREMENT` column must be defined as part of an index such that it is possible to perform the equivalent of an indexed `SELECT MAX(ai_col)` lookup on the table to obtain the maximum column value. Typically, this is achieved by making the column the first column of some table index.

This section describes the behavior of `AUTO_INCREMENT` lock modes, usage implications for different `AUTO_INCREMENT` lock mode settings, and how `InnoDB` initializes the `AUTO_INCREMENT` counter.

- InnoDB AUTO_INCREMENT Lock Modes
- InnoDB AUTO_INCREMENT Lock Mode Usage Implications
- InnoDB AUTO_INCREMENT Counter Initialization

InnoDB AUTO_INCREMENT Lock Modes

This section describes the behavior of `AUTO_INCREMENT` lock modes used to generate auto-increment values, and how each lock mode affects replication. Auto-increment lock modes are configured at startup using the `innodb_autoinc_lock_mode` configuration parameter, introduced in MySQL 5.1.22.

The following terms are used in describing `innodb_autoinc_lock_mode` settings:

- "`INSERT`-like" statements

  All statements that generate new rows in a table, including `INSERT`, `INSERT ... SELECT`, `REPLACE`, `REPLACE ... SELECT`, and `LOAD DATA`. Includes "simple-inserts", "bulk-inserts", and "mixed-mode" inserts.

- "Simple inserts"

  Statements for which the number of rows to be inserted can be determined in advance (when the statement is initially processed). This includes single-row and multiple-row `INSERT` and `REPLACE` statements that do not have a nested subquery, but not `INSERT ... ON DUPLICATE KEY UPDATE`.

- "Bulk inserts"

  Statements for which the number of rows to be inserted (and the number of required auto-increment values) is not known in advance. This includes `INSERT ... SELECT`, `REPLACE ... SELECT`, and `LOAD DATA` statements, but not plain `INSERT`. `InnoDB` will assign new values for the `AUTO_INCREMENT` column one at a time as each row is processed.

- "Mixed-mode inserts"

  These are "simple insert" statements that specify the auto-increment value for some (but not all) of the new rows. An example follows, where `c1` is an `AUTO_INCREMENT` column of table `t1`:

```
INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
```

Another type of "mixed-mode insert" is `INSERT ... ON DUPLICATE KEY UPDATE`, which in the worst case is in effect an `INSERT` followed by a `UPDATE`, where the allocated value for the `AUTO_INCREMENT` column may or may not be used during the update phase.

There are three possible settings for the `innodb_autoinc_lock_mode` configuration parameter. The settings are 0, 1, or 2, for "traditional", "consecutive", or "interleaved" lock mode, respectively.

- `innodb_autoinc_lock_mode = 0` ("traditional" lock mode)

  The traditional lock mode provides the same behavior that existed before the `innodb_autoinc_lock_mode` configuration parameter was introduced in MySQL 5.1. The traditional lock mode option is provided for backward compatibility, performance testing, and working around issues with "mixed-mode inserts", due to possible differences in semantics.

  In this lock mode, all "INSERT-like" statements obtain a special table-level `AUTO-INC` lock for inserts into tables with `AUTO_INCREMENT` columns. This lock is normally held to the end of the statement (not to the end of the transaction) to ensure that auto-increment values are assigned in a predictable and repeatable order for a given sequence of `INSERT` statements, and to ensure that auto-increment values assigned by any given statement are consecutive.

  In the case of statement-based replication, this means that when an SQL statement is replicated on a slave server, the same values are used for the auto-increment column as on the master server. The result of execution of multiple `INSERT` statements is deterministic, and the slave reproduces the same data as on the master. If auto-increment values generated by multiple `INSERT` statements were interleaved, the result of two concurrent `INSERT` statements would be nondeterministic, and could not reliably be propagated to a slave server using statement-based replication.

  To make this clear, consider an example that uses this table:

  ```
  CREATE TABLE t1 (
    c1 INT(11) NOT NULL AUTO_INCREMENT,
    c2 VARCHAR(10) DEFAULT NULL,
    PRIMARY KEY (c1)
  ) ENGINE=InnoDB;
  ```

  Suppose that there are two transactions running, each inserting rows into a table with an `AUTO_INCREMENT` column. One transaction is using an `INSERT ... SELECT` statement that inserts 1000 rows, and another is using a simple `INSERT` statement that inserts one row:

  ```
  Tx1: INSERT INTO t1 (c2) SELECT 1000 rows from another table ...
  Tx2: INSERT INTO t1 (c2) VALUES ('xxx');
  ```

  `InnoDB` cannot tell in advance how many rows will be retrieved from the `SELECT` in the `INSERT` statement in Tx1, and it assigns the auto-increment values one at a time as the statement proceeds. With a table-level lock, held to the end of the statement, only one `INSERT` statement referring to table `t1` can execute at a time, and the generation of auto-increment numbers by different statements is not interleaved. The auto-increment value generated by the Tx1 `INSERT ... SELECT` statement will be consecutive, and the (single) auto-increment value used by the `INSERT` statement in Tx2 will either be smaller or larger than all those used for Tx1, depending on which statement executes first.

  As long as the SQL statements execute in the same order when replayed from the binary log (when using statement-based replication, or in recovery scenarios), the results will be the same as they were when Tx1 and Tx2 first ran. Thus, table-level locks held until the end of a statement make `INSERT` statements using auto-increment safe for use with statement-based replication. However, those table-

level locks limit concurrency and scalability when multiple transactions are executing insert statements at the same time.

In the preceding example, if there were no table-level lock, the value of the auto-increment column used for the `INSERT` in Tx2 depends on precisely when the statement executes. If the `INSERT` of Tx2 executes while the `INSERT` of Tx1 is running (rather than before it starts or after it completes), the specific auto-increment values assigned by the two `INSERT` statements are nondeterministic, and may vary from run to run.

Under the consecutive lock mode, `InnoDB` can avoid using table-level `AUTO-INC` locks for "simple insert" statements where the number of rows is known in advance, and still preserve deterministic execution and safety for statement-based replication.

If you are not using the binary log to replay SQL statements as part of recovery or replication, the interleaved lock mode can be used to eliminate all use of table-level `AUTO-INC` locks for even greater concurrency and performance, at the cost of permitting gaps in auto-increment numbers assigned by a statement and potentially having the numbers assigned by concurrently executing statements interleaved.

- `innodb_autoinc_lock_mode = 1` ("consecutive" lock mode)

  This is the default lock mode. In this mode, "bulk inserts" use the special `AUTO-INC` table-level lock and hold it until the end of the statement. This applies to all `INSERT ... SELECT`, `REPLACE ... SELECT`, and `LOAD DATA` statements. Only one statement holding the `AUTO-INC` lock can execute at a time.

  "Simple inserts" (for which the number of rows to be inserted is known in advance) avoid table-level `AUTO-INC` locks by obtaining the required number of auto-increment values under the control of a mutex (a light-weight lock) that is only held for the duration of the allocation process, *not* until the statement completes. No table-level `AUTO-INC` lock is used unless an `AUTO-INC` lock is held by another transaction. If another transaction holds an `AUTO-INC` lock, a "simple insert" waits for the `AUTO-INC` lock, as if it were a "bulk insert".

  This lock mode ensures that, in the presence of `INSERT` statements where the number of rows is not known in advance (and where auto-increment numbers are assigned as the statement progresses), all auto-increment values assigned by any "`INSERT`-like" statement are consecutive, and operations are safe for statement-based replication.

  Simply put, this lock mode significantly improves scalability while being safe for use with statement-based replication. Further, as with "traditional" lock mode, auto-increment numbers assigned by any given statement are *consecutive*. There is *no change* in semantics compared to "traditional" mode for any statement that uses auto-increment, with one important exception.

  The exception is for "mixed-mode inserts", where the user provides explicit values for an `AUTO_INCREMENT` column for some, but not all, rows in a multiple-row "simple insert". For such inserts, `InnoDB` allocates more auto-increment values than the number of rows to be inserted. However, all values automatically assigned are consecutively generated (and thus higher than) the auto-increment value generated by the most recently executed previous statement. "Excess" numbers are lost.

- `innodb_autoinc_lock_mode = 2` ("interleaved" lock mode)

  In this lock mode, no "`INSERT`-like" statements use the table-level `AUTO-INC` lock, and multiple statements can execute at the same time. This is the fastest and most scalable lock mode, but it is *not safe* when using statement-based replication or recovery scenarios when SQL statements are replayed from the binary log.

In this lock mode, auto-increment values are guaranteed to be unique and monotonically increasing across all concurrently executing "`INSERT`-like" statements. However, because multiple statements can be generating numbers at the same time (that is, allocation of numbers is *interleaved* across statements), the values generated for the rows inserted by any given statement may not be consecutive.

If the only statements executing are "simple inserts" where the number of rows to be inserted is known ahead of time, there will be no gaps in the numbers generated for a single statement, except for "mixed-mode inserts". However, when "bulk inserts" are executed, there may be gaps in the auto-increment values assigned by any given statement.

InnoDB AUTO_INCREMENT Lock Mode Usage Implications

- Using auto-increment with replication

  If you are using statement-based replication, set `innodb_autoinc_lock_mode` to 0 or 1 and use the same value on the master and its slaves. Auto-increment values are not ensured to be the same on the slaves as on the master if you use `innodb_autoinc_lock_mode` = 2 ("interleaved") or configurations where the master and slaves do not use the same lock mode.

  If you are using row-based or mixed-format replication, all of the auto-increment lock modes are safe, since row-based replication is not sensitive to the order of execution of the SQL statements (and the mixed format uses row-based replication for any statements that are unsafe for statement-based replication).

- "Lost" auto-increment values and sequence gaps

  In all lock modes (0, 1, and 2), if a transaction that generated auto-increment values rolls back, those auto-increment values are "lost". Once a value is generated for an auto-increment column, it cannot be rolled back, whether or not the "`INSERT`-like" statement is completed, and whether or not the containing transaction is rolled back. Such lost values are not reused. Thus, there may be gaps in the values stored in an `AUTO_INCREMENT` column of a table.

- Specifying NULL or 0 for the `AUTO_INCREMENT` column

  In all lock modes (0, 1, and 2), if a user specifies NULL or 0 for the `AUTO_INCREMENT` column in an `INSERT`, `InnoDB` treats the row as if the value was not specified and generates a new value for it.

- Assigning a negative value to the `AUTO_INCREMENT` column

  In all lock modes (0, 1, and 2), the behavior of the auto-increment mechanism is not defined if you assign a negative value to the `AUTO_INCREMENT` column.

- If the `AUTO_INCREMENT` value becomes larger than the maximum integer for the specified integer type

  In all lock modes (0, 1, and 2), the behavior of the auto-increment mechanism is not defined if the value becomes larger than the maximum integer that can be stored in the specified integer type.

- Gaps in auto-increment values for "bulk inserts"

  With `innodb_autoinc_lock_mode` set to 0 ("traditional") or 1 ("consecutive"), the auto-increment values generated by any given statement will be consecutive, without gaps, because the table-level `AUTO-INC` lock is held until the end of the statement, and only one such statement can execute at a time.

  With `innodb_autoinc_lock_mode` set to 2 ("interleaved"), there may be gaps in the auto-increment values generated by "bulk inserts," but only if there are concurrently executing "`INSERT`-like" statements.

For lock modes 1 or 2, gaps may occur between successive statements because for bulk inserts the exact number of auto-increment values required by each statement may not be known and overestimation is possible.

- Auto-increment values assigned by "mixed-mode inserts"

  Consider a "mixed-mode insert," where a "simple insert" specifies the auto-increment value for some (but not all) resulting rows. Such a statement will behave differently in lock modes 0, 1, and 2. For example, assume `c1` is an `AUTO_INCREMENT` column of table `t1`, and that the most recent automatically generated sequence number is 100.

```
mysql> CREATE TABLE t1 (
    -> c1 INT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    -> c2 CHAR(1)
    -> ) ENGINE = INNODB;

mysql> INSERT INTO t1 VALUES(1,'a'),(101,'b'),(5,'c'),(102,'d');
```

  Now, consider the following "mixed-mode insert" statement:

```
mysql> INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
```

  With `innodb_autoinc_lock_mode` set to 0 ("traditional"), the four new rows will be:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
+-----+------+
| c1  | c2   |
+-----+------+
|   1 | a    |
| 101 | b    |
|   5 | c    |
| 102 | d    |
+-----+------+
```

  The next available auto-increment value will be 103 because the auto-increment values are allocated one at a time, not all at once at the beginning of statement execution. This result is true whether or not there are concurrently executing "`INSERT`-like" statements (of any type).

  With `innodb_autoinc_lock_mode` set to 1 ("consecutive"), the four new rows will also be:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
+-----+------+
| c1  | c2   |
+-----+------+
|   1 | a    |
| 101 | b    |
|   5 | c    |
| 102 | d    |
+-----+------+
```

  However, in this case, the next available auto-increment value will be 105, not 103 because four auto-increment values are allocated at the time the statement is processed, but only two are used. This result is true whether or not there are concurrently executing "`INSERT`-like" statements (of any type).

  With `innodb_autoinc_lock_mode` set to mode 2 ("interleaved"), the four new rows will be:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
```

```
+-----+------+
| c1  | c2   |
+-----+------+
|   1 | a    |
|   x | b    |
|   5 | c    |
|   y | d    |
+-----+------+
```

The values of x and y will be unique and larger than any previously generated rows. However, the specific values of x and y will depend on the number of auto-increment values generated by concurrently executing statements.

Finally, consider the following statement, issued when the most-recently generated sequence number was the value 4:

```
mysql> INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
```

With any innodb_autoinc_lock_mode setting, this statement will generate a duplicate-key error 23000 (Can't write; duplicate key in table) because 5 will be allocated for the row (NULL, 'b') and insertion of the row (5, 'c') will fail.

- Modifying AUTO_INCREMENT column values in the middle of a sequence of INSERT statements

  In all lock modes (0, 1, and 2), modifying an AUTO_INCREMENT column value in the middle of a sequence of INSERT statements could lead to "Duplicate entry" errors. For example, if you perform an UPDATE operation that changes an AUTO_INCREMENT column value to a value larger than the current maximum auto-increment value, subsequent INSERT operations that do not specify an unused auto-increment value could encounter "Duplicate entry" errors. This behavior is demonstrated in the following example.

```
mysql> CREATE TABLE t1 (
    -> c1 INT NOT NULL AUTO_INCREMENT,
    -> PRIMARY KEY (c1)
    ->  ) ENGINE = InnoDB;

mysql> INSERT INTO t1 VALUES(0), (0), (3);

mysql> SELECT c1 FROM t1;
+----+
| c1 |
+----+
|  1 |
|  2 |
|  3 |
+----+

mysql> UPDATE t1 SET c1 = 4 WHERE c1 = 1;

mysql> SELECT c1 FROM t1;
+----+
| c1 |
+----+
|  2 |
|  3 |
|  4 |
+----+

mysql> INSERT INTO t1 VALUES(0);
ERROR 1062 (23000): Duplicate entry '4' for key 'PRIMARY'
```

InnoDB AUTO_INCREMENT Counter Initialization

This section describes how `InnoDB` initializes `AUTO_INCREMENT` counters.

If you specify an `AUTO_INCREMENT` column for an `InnoDB` table, the table handle in the `InnoDB` data dictionary contains a special counter called the auto-increment counter that is used in assigning new values for the column. This counter is stored only in main memory, not on disk.

To initialize an auto-increment counter after a server restart, `InnoDB` executes the equivalent of the following statement on the first insert into a table containing an `AUTO_INCREMENT` column.

```
SELECT MAX(ai_col) FROM table_name FOR UPDATE;
```

`InnoDB` increments the value retrieved by the statement and assigns it to the column and to the auto-increment counter for the table. By default, the value is incremented by 1. This default can be overridden by the `auto_increment_increment` configuration setting.

If the table is empty, `InnoDB` uses the value `1`. This default can be overridden by the `auto_increment_offset` configuration setting.

If a `SHOW TABLE STATUS` statement examines the table before the auto-increment counter is initialized, `InnoDB` initializes but does not increment the value. The value is stored for use by later inserts. This initialization uses a normal exclusive-locking read on the table and the lock lasts to the end of the transaction. `InnoDB` follows the same procedure for initializing the auto-increment counter for a newly created table.

After the auto-increment counter has been initialized, if you do not explicitly specify a value for an `AUTO_INCREMENT` column, `InnoDB` increments the counter and assigns the new value to the column. If you insert a row that explicitly specifies the column value, and the value is greater than the current counter value, the counter is set to the specified column value.

`InnoDB` uses the in-memory auto-increment counter as long as the server runs. When the server is stopped and restarted, `InnoDB` reinitializes the counter for each table for the first `INSERT` to the table, as described earlier.

A server restart also cancels the effect of the `AUTO_INCREMENT = N` table option in `CREATE TABLE` and `ALTER TABLE` statements, which you can use with `InnoDB` tables to set the initial counter value or alter the current counter value.

14.6.6.6 InnoDB and FOREIGN KEY Constraints

This section describes differences in the InnoDB storage engine's handling of foreign keys as compared with that of the MySQL Server.

Foreign Key Definitions

Foreign key definitions for `InnoDB` tables are subject to the following conditions:

- `InnoDB` permits a foreign key to reference any index column or group of columns. However, in the referenced table, there must be an index where the referenced columns are listed as the *first* columns in the same order.

- `InnoDB` does not currently support foreign keys for tables with user-defined partitioning. This means that no user-partitioned `InnoDB` table may contain foreign key references or columns referenced by foreign keys.

- `InnoDB` allows a foreign key constraint to reference a non-unique key. *This is an `InnoDB` extension to standard SQL.*

Referential Actions

Referential actions for foreign keys of `InnoDB` tables are subject to the following conditions:

- While `SET DEFAULT` is allowed by the MySQL Server, it is rejected as invalid by `InnoDB`. `CREATE TABLE` and `ALTER TABLE` statements using this clause are not allowed for InnoDB tables.

- If there are several rows in the parent table that have the same referenced key value, `InnoDB` acts in foreign key checks as if the other parent rows with the same key value do not exist. For example, if you have defined a `RESTRICT` type constraint, and there is a child row with several parent rows, `InnoDB` does not permit the deletion of any of those parent rows.

- `InnoDB` performs cascading operations through a depth-first algorithm, based on records in the indexes corresponding to the foreign key constraints.

- If `ON UPDATE CASCADE` or `ON UPDATE SET NULL` recurses to update the *same table* it has previously updated during the cascade, it acts like `RESTRICT`. This means that you cannot use self-referential `ON UPDATE CASCADE` or `ON UPDATE SET NULL` operations. This is to prevent infinite loops resulting from cascaded updates. A self-referential `ON DELETE SET NULL`, on the other hand, is possible, as is a self-referential `ON DELETE CASCADE`. Cascading operations may not be nested more than 15 levels deep.

- Like MySQL in general, in an SQL statement that inserts, deletes, or updates many rows, `InnoDB` checks `UNIQUE` and `FOREIGN KEY` constraints row-by-row. When performing foreign key checks, `InnoDB` sets shared row-level locks on child or parent records it has to look at. `InnoDB` checks foreign key constraints immediately; the check is not deferred to transaction commit. According to the SQL standard, the default behavior should be deferred checking. That is, constraints are only checked after the *entire SQL statement* has been processed. Until `InnoDB` implements deferred constraint checking, some things will be impossible, such as deleting a record that refers to itself using a foreign key.

Foreign Key Usage and Error Information

You can obtain general information about foreign keys and their usage from querying the `INFORMATION_SCHEMA.KEY_COLUMN_USAGE` table. See also Section 13.1.17.3, "Using FOREIGN KEY Constraints".

In addition to `SHOW ERRORS`, in the event of a foreign key error involving `InnoDB` tables (usually Error 150 in the MySQL Server), you can obtain a detailed explanation of the most recent `InnoDB` foreign key error by checking the output of `SHOW ENGINE INNODB STATUS`.

14.6.6.7 Limits on InnoDB Tables

Warning

Do *not* convert MySQL system tables in the `mysql` database from `MyISAM` to `InnoDB` tables. This is an unsupported operation. If you do this, MySQL does not restart until you restore the old system tables from a backup or regenerate them by reinitializing the data directory (see Section 2.12.1, "Initializing the Data Directory").

Warning

It is not a good idea to configure `InnoDB` to use data files or log files on NFS volumes. Otherwise, the files might be locked by other processes and become unavailable for use by MySQL.

Maximums and Minimums

- A table can contain a maximum of 1000 columns.

- A table can contain a maximum of 64 secondary indexes.

- An index key for a single-column index can be up to 767 bytes. The same length limit applies to any index key prefix. See Section 13.1.13, "CREATE INDEX Syntax".

- The `InnoDB` internal maximum key length is 3500 bytes, but MySQL itself restricts this to 3072 bytes. This limit applies to the length of the combined index key in a multi-column index.

- The maximum row length, except for variable-length columns (`VARBINARY`, `VARCHAR`, `BLOB` and `TEXT`), is slightly less than half of a database page. That is, the maximum row length is about 8000 bytes. `LONGBLOB` and `LONGTEXT` columns must be less than 4GB, and the total row length, including `BLOB` and `TEXT` columns, must be less than 4GB.

  If a row is less than half a page long, all of it is stored locally within the page. If it exceeds half a page, variable-length columns are chosen for external off-page storage until the row fits within half a page, as described in Section 14.6.7.2, "File Space Management".

  The row size for `BLOB` columns that are chosen for external off-page storage should not exceed 10% of the combined redo log file size. If the row size exceeds 10% of the combined redo log file size, `InnoDB` could overwrite the most recent checkpoint which may result in lost data during crash recovery. (Bug#69477).

- Although `InnoDB` supports row sizes larger than 65,535 bytes internally, MySQL itself imposes a row-size limit of 65,535 for the combined size of all columns:

```
mysql> CREATE TABLE t (a VARCHAR(8000), b VARCHAR(10000),
    -> c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
    -> f VARCHAR(10000), g VARCHAR(10000)) ENGINE=InnoDB;
ERROR 1118 (42000): Row size too large. The maximum row size for the
used table type, not counting BLOBs, is 65535. You have to change some
columns to TEXT or BLOBs
```

  See Section C.7.4, "Limits on Table Column Count and Row Size".

- On some older operating systems, files must be less than 2GB. This is not a limitation of `InnoDB` itself, but if you require a large tablespace, you will need to configure it using several smaller data files rather than one large data file.

- The combined size of the `InnoDB` log files must be less than 4GB.

- The minimum tablespace size is 10MB. The maximum tablespace size is four billion database pages (64TB). This is also the maximum size for a table.

- The default database page size in `InnoDB` is 16KB.

  Note

  Changing the page size is not a supported operation and there is no guarantee that `InnoDB` will function normally with a page size other than 16KB. Problems compiling or running InnoDB may occur. In particular, `ROW_FORMAT=COMPRESSED` in the `InnoDB Plugin` assumes that the page size is at most 16KB and uses 14-bit pointers.

  A version of `InnoDB` built for one page size cannot use data files or log files from a version built for a different page size. This limitation could affect restore or downgrade operations using data from MySQL 5.6, which does support page sizes other than 16KB.

Index Types

- `InnoDB` tables do not support `FULLTEXT` indexes.

- `InnoDB` tables support spatial data types, but not indexes on them.

Restrictions on InnoDB Tables

- `ANALYZE TABLE` determines index cardinality (as displayed in the `Cardinality` column of `SHOW INDEX` output) by doing eight random dives to each of the index trees and updating index cardinality estimates accordingly. Because these are only estimates, repeated runs of `ANALYZE TABLE` may produce different numbers. This makes `ANALYZE TABLE` fast on `InnoDB` tables but not 100% accurate because it does not take all rows into account.

  For `InnoDB Plugin`, you can change the number of random dives by modifying the `innodb_stats_sample_pages` system variable.

  MySQL uses index cardinality estimates only in join optimization. If some join is not optimized in the right way, you can try using `ANALYZE TABLE`. In the few cases that `ANALYZE TABLE` does not produce values good enough for your particular tables, you can use `FORCE INDEX` with your queries to force the use of a particular index, or set the `max_seeks_for_key` system variable to ensure that MySQL prefers index lookups over table scans. See Section 5.1.4, "Server System Variables", and Section B.5.5, "Optimizer-Related Issues".

- If statements or transactions are running on a table and `ANALYZE TABLE` is run on the same table followed by a second `ANALYZE TABLE` operation, the second `ANALYZE TABLE` operation is blocked until the statements or transactions are completed. This behavior occurs because `ANALYZE TABLE` marks the currently loaded table definition as obsolete when `ANALYZE TABLE` is finished running. New statements or transactions (including a second `ANALYZE TABLE` statement) must load the new table definition into the table cache, which cannot occur until currently running statements or transactions are completed and the old table definition is purged. Loading multiple concurrent table definitions is not supported.

- `SHOW TABLE STATUS` does not give accurate statistics on `InnoDB` tables, except for the physical size reserved by the table. The row count is only a rough estimate used in SQL optimization.

- `InnoDB` does not keep an internal count of rows in a table because concurrent transactions might "see" different numbers of rows at the same time. To process a `SELECT COUNT(*) FROM t` statement, `InnoDB` scans an index of the table, which takes some time if the index is not entirely in the buffer pool. If your table does not change often, using the MySQL query cache is a good solution. To get a fast count, you have to use a counter table you create yourself and let your application update it according to the inserts and deletes it does. If an approximate row count is sufficient, `SHOW TABLE STATUS` can be used.

- On Windows, `InnoDB` always stores database and table names internally in lowercase. To move databases in a binary format from Unix to Windows or from Windows to Unix, create all databases and tables using lowercase names.

- An `AUTO_INCREMENT` column `ai_col` must be defined as part of an index such that it is possible to perform the equivalent of an indexed `SELECT MAX(ai_col)` lookup on the table to obtain the maximum column value. Typically, this is achieved by making the column the first column of some table index.

- `InnoDB` sets an exclusive lock on the end of the index associated with the `AUTO_INCREMENT` column while initializing a previously specified `AUTO_INCREMENT` column on a table.

With `innodb_autoinc_lock_mode=0`, `InnoDB` uses a special `AUTO-INC` table lock mode where the lock is obtained and held to the end of the current SQL statement while accessing the auto-increment counter. Other clients cannot insert into the table while the `AUTO-INC` table lock is held. The same behavior occurs for "bulk inserts" with `innodb_autoinc_lock_mode=1`. Table-level `AUTO-INC` locks are not used with `innodb_autoinc_lock_mode=2`. For more information, See Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB".

- When you restart the MySQL server, `InnoDB` may reuse an old value that was generated for an `AUTO_INCREMENT` column but never stored (that is, a value that was generated during an old transaction that was rolled back).

- When an `AUTO_INCREMENT` integer column runs out of values, a subsequent `INSERT` operation returns a duplicate-key error. This is general MySQL behavior, similar to how `MyISAM` works.

- `DELETE FROM tbl_name` does not regenerate the table but instead deletes all rows, one by one.

- Under some conditions, `TRUNCATE tbl_name` for an `InnoDB` table is mapped to `DELETE FROM tbl_name`. See Section 13.1.34, "TRUNCATE TABLE Syntax".

- The `LOAD TABLE FROM MASTER` statement for setting up replication slave servers does not work for `InnoDB` tables. A workaround is to alter the table to `MyISAM` on the master, then do the load, and after that alter the master table back to `InnoDB`. Do not do this if the tables use `InnoDB`-specific features such as foreign keys.

- Cascaded foreign key actions do not activate triggers.

- You cannot create a table with a column name that matches the name of an internal InnoDB column (including `DB_ROW_ID`, `DB_TRX_ID`, `DB_ROLL_PTR`, and `DB_MIX_ID`). In versions of MySQL before 5.1.10 this would cause a crash, since 5.1.10 the server will report error 1005 and refers to error −1 in the error message. This restriction applies only to use of the names in uppercase.

Locking and Transactions

- `LOCK TABLES` acquires two locks on each table if `innodb_table_locks=1` (the default). In addition to a table lock on the MySQL layer, it also acquires an `InnoDB` table lock. Versions of MySQL before 4.1.2 did not acquire `InnoDB` table locks; the old behavior can be selected by setting `innodb_table_locks=0`. If no `InnoDB` table lock is acquired, `LOCK TABLES` completes even if some records of the tables are being locked by other transactions.

- All `InnoDB` locks held by a transaction are released when the transaction is committed or aborted. Thus, it does not make much sense to invoke `LOCK TABLES` on `InnoDB` tables in `autocommit=1` mode because the acquired `InnoDB` table locks would be released immediately.

- You cannot lock additional tables in the middle of a transaction because `LOCK TABLES` performs an implicit `COMMIT` and `UNLOCK TABLES`.

- `InnoDB` has a limit of 1023 concurrent transactions that have created undo records by modifying data. Workarounds include keeping transactions as small and fast as possible, delaying changes until near the end of the transaction, and using stored routines to reduce client/server latency delays. Applications should commit transactions before doing time-consuming client-side operations.

14.6.7 InnoDB Disk I/O and File Space Management

14.6.7.1 InnoDB Disk I/O

`InnoDB` uses simulated asynchronous disk I/O: `InnoDB` creates a number of threads to take care of I/O operations, such as read-ahead.

There are two read-ahead heuristics in `InnoDB`:

- In sequential read-ahead, if `InnoDB` notices that the access pattern to a segment in the tablespace is sequential, it posts in advance a batch of reads of database pages to the I/O system.

- In random read-ahead, if `InnoDB` notices that some area in a tablespace seems to be in the process of being fully read into the buffer pool, it posts the remaining reads to the I/O system.

`InnoDB` uses a novel file flush technique involving a structure called the doublewrite buffer, which is enabled by default (`innodb_doublewrite=ON`). It adds safety to recovery following a crash or power outage, and improves performance on most varieties of Unix by reducing the need for `fsync()` operations.

Doublewrite means that before writing pages to a data file, `InnoDB` first writes them to a contiguous tablespace area called the doublewrite buffer. Only after the write and the flush to the doublewrite buffer has completed does `InnoDB` write the pages to their proper positions in the data file. If there is an operating system, storage subsystem, or `mysqld` process crash in the middle of a page write (causing a torn page condition), `InnoDB` can later find a good copy of the page from the doublewrite buffer during recovery.

14.6.7.2 File Space Management

The data files that you define in the configuration file form the `InnoDB` tablespace. The files are logically concatenated to form the tablespace. There is no striping in use. You cannot define where within the tablespace your tables are allocated. However, in a newly created tablespace, `InnoDB` allocates space starting from the first data file.

The tablespace consists of database pages with a default size of 16KB. The pages are grouped into extents of size 1MB (64 consecutive pages). The "files" inside a tablespace are called *segments* in `InnoDB`. The term "rollback segment" is somewhat confusing because it actually contains many tablespace segments.

When a segment grows inside the tablespace, `InnoDB` allocates the first 32 pages to it individually. After that, `InnoDB` starts to allocate whole extents to the segment. `InnoDB` can add up to 4 extents at a time to a large segment to ensure good sequentiality of data.

Two segments are allocated for each index in `InnoDB`. One is for nonleaf nodes of the B-tree, the other is for the leaf nodes. The idea here is to achieve better sequentiality for the leaf nodes, which contain the data.

Some pages in the tablespace contain bitmaps of other pages, and therefore a few extents in an `InnoDB` tablespace cannot be allocated to segments as a whole, but only as individual pages.

When you ask for available free space in the tablespace by issuing a `SHOW TABLE STATUS` statement, `InnoDB` reports the extents that are definitely free in the tablespace. `InnoDB` always reserves some extents for cleanup and other internal purposes; these reserved extents are not included in the free space.

When you delete data from a table, `InnoDB` contracts the corresponding B-tree indexes. Whether the freed space becomes available for other users depends on whether the pattern of deletes frees individual pages or extents to the tablespace. Dropping a table or deleting all rows from it is guaranteed to release the space to other users, but remember that deleted rows are physically removed only in an (automatic) purge operation after they are no longer needed for transaction rollbacks or consistent reads. (See Section 14.6.3.1, "InnoDB Multi-Versioning".)

To see information about the tablespace, use the Tablespace Monitor. See Section 14.6.9, "InnoDB Monitors".

The maximum row length, except for variable-length columns (`VARBINARY`, `VARCHAR`, `BLOB` and `TEXT`), is slightly less than half of a database page. That is, the maximum row length is about 8000 bytes. `LONGBLOB` and `LONGTEXT` columns must be less than 4GB, and the total row length, including `BLOB` and `TEXT` columns, must be less than 4GB.

If a row is less than half a page long, all of it is stored locally within the page. If it exceeds half a page, variable-length columns are chosen for external off-page storage until the row fits within half a page. For a column chosen for off-page storage, `InnoDB` stores the first 768 bytes locally in the row, and the rest externally into overflow pages. Each such column has its own list of overflow pages. The 768-byte prefix is accompanied by a 20-byte value that stores the true length of the column and points into the overflow list where the rest of the value is stored.

14.6.7.3 Defragmenting a Table

If there are random insertions into or deletions from the indexes of a table, the indexes may become fragmented. Fragmentation means that the physical ordering of the index pages on the disk is not close to the index ordering of the records on the pages, or that there are many unused pages in the 64-page blocks that were allocated to the index.

One symptom of fragmentation is that a table takes more space than it "should" take. How much that is exactly, is difficult to determine. All `InnoDB` data and indexes are stored in B-trees, and their fill factor may vary from 50% to 100%. Another symptom of fragmentation is that a table scan such as this takes more time than it "should" take:

```
SELECT COUNT(*) FROM t WHERE a_non_indexed_column <> 12345;
```

The preceding query requires MySQL to perform a full table scan, the slowest type of query for a large table.

It can speed up index scans if you periodically perform a "null" `ALTER TABLE` operation, which causes MySQL to rebuild the table:

```
ALTER TABLE tbl_name ENGINE=INNODB
```

Another way to perform a defragmentation operation is to use `mysqldump` to dump the table to a text file, drop the table, and reload it from the dump file.

If the insertions into an index are always ascending and records are deleted only from the end, the `InnoDB` filespace management algorithm guarantees that fragmentation in the index does not occur.

14.6.8 InnoDB Startup Options and System Variables

This section describes the `InnoDB`-related command options and system variables.

- System variables that are true or false can be enabled at server startup by naming them, or disabled by using a `--skip-` prefix. For example, to enable or disable `InnoDB` checksums, you can use `--innodb_checksums` or `--skip-innodb_checksums` on the command line, or `innodb_checksums` or `skip-innodb_checksums` in an option file.

- System variables that take a numeric value can be specified as `--var_name=value` on the command line or as `var_name=value` in option files.

- Many system variables can be changed at runtime (see Section 5.1.5.2, "Dynamic System Variables").

- For information about `GLOBAL` and `SESSION` variable scope modifiers, refer to the `SET` statement documentation.

- For more information on specifying options and system variables, see Section 4.2.3, "Specifying Program Options".

Table 14.5 `InnoDB` Option/Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
foreign_key_checks			Yes		Session	Yes
have_innodb			Yes		Global	No
ignore-builtin-innodb	Yes	Yes			Global	No
- *Variable*: ignore_builtin_innodb			Yes		Global	No
innodb	Yes	Yes				
innodb_adaptive_flushing	Yes	Yes	Yes		Global	Yes
innodb_adaptive_hash_index	Yes	Yes	Yes		Global	No
innodb_additional_mem_pool_size	Yes	Yes	Yes		Global	No
innodb_autoextend_increment	Yes	Yes	Yes		Global	Yes
innodb_autoinc_lock_mode	Yes	Yes	Yes		Global	No
innodb_buffer_pool_awe_mem_mb	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_pages_data				Yes	Global	No
Innodb_buffer_pool_pages_dirty				Yes	Global	No
Innodb_buffer_pool_pages_flushed				Yes	Global	No
Innodb_buffer_pool_pages_free				Yes	Global	No
Innodb_buffer_pool_pages_latched				Yes	Global	No
Innodb_buffer_pool_pages_misc				Yes	Global	No
Innodb_buffer_pool_pages_total				Yes	Global	No
Innodb_buffer_pool_read_ahead				Yes	Global	No
Innodb_buffer_pool_read_ahead_evicted				Yes	Global	No
Innodb_buffer_pool_read_ahead_rnd				Yes	Global	No
Innodb_buffer_pool_read_ahead_seq				Yes	Global	No
Innodb_buffer_pool_read_requests				Yes	Global	No
Innodb_buffer_pool_reads				Yes	Global	No
innodb_buffer_pool_size	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_wait_free				Yes	Global	No
Innodb_buffer_pool_write_requests				Yes	Global	No
innodb_change_buffering	Yes	Yes	Yes		Global	Yes
innodb_change_buffering_debug	Yes	Yes	Yes		Global	Yes
innodb_checksums	Yes	Yes	Yes		Global	No
innodb_commit_concurrency	Yes	Yes	Yes		Global	Yes
innodb_concurrency_tickets	Yes	Yes	Yes		Global	Yes
innodb_data_file_path	Yes	Yes	Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Innodb_data_fsyncs				Yes	Global	No
innodb_data_home_dir	Yes	Yes	Yes		Global	No
Innodb_data_pending_fsyncs				Yes	Global	No
Innodb_data_pending_reads				Yes	Global	No
Innodb_data_pending_writes				Yes	Global	No
Innodb_data_read				Yes	Global	No
Innodb_data_reads				Yes	Global	No
Innodb_data_writes				Yes	Global	No
Innodb_data_written				Yes	Global	No
Innodb_dblwr_pages_written				Yes	Global	No
Innodb_dblwr_writes				Yes	Global	No
innodb_doublewrite	Yes	Yes	Yes		Global	No
innodb_fast_shutdown	Yes	Yes	Yes		Global	Yes
innodb_file_format	Yes	Yes	Yes		Global	Yes
innodb_file_format_check	Yes	Yes	Yes		Global	Yes
innodb_file_io_threads	Yes	Yes	Yes		Global	No
innodb_file_per_table	Yes	Yes	Yes		Global	No
innodb_flush_log_at_trx_commit	Yes	Yes	Yes		Global	Yes
innodb_flush_method	Yes	Yes	Yes		Global	No
innodb_force_recovery	Yes	Yes	Yes		Global	No
Innodb_have_atomic_builtins				Yes	Global	No
innodb_io_capacity	Yes	Yes	Yes		Global	No
innodb_limit_optimistic_insert_debug	Yes	Yes	Yes		Global	Yes
innodb_lock_wait_timeout	Yes	Yes	Yes		Varies	No
innodb_locks_unsafe_for_binlog	Yes	Yes	Yes		Global	No
innodb_log_arch_dir	Yes	Yes	Yes		Global	No
innodb_log_archive	Yes	Yes	Yes		Global	No
innodb_log_buffer_size	Yes	Yes	Yes		Global	No
innodb_log_file_size	Yes	Yes	Yes		Global	No
innodb_log_files_in_group	Yes	Yes	Yes		Global	No
innodb_log_group_home_dir	Yes	Yes	Yes		Global	No
Innodb_log_waits				Yes	Global	No
Innodb_log_write_requests				Yes	Global	No
Innodb_log_writes				Yes	Global	No
innodb_max_dirty_pages_pct	Yes	Yes	Yes		Global	Yes
innodb_max_purge_lag	Yes	Yes	Yes		Global	Yes
innodb_mirrored_log_groups	Yes	Yes	Yes		Global	No
innodb_old_blocks_pct	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_old_blocks_time	Yes	Yes	Yes		Global	Yes
innodb_open_files	Yes	Yes	Yes		Global	No
Innodb_os_log_fsyncs				Yes	Global	No
Innodb_os_log_pending_fsyncs				Yes	Global	No
Innodb_os_log_pending_writes				Yes	Global	No
Innodb_os_log_written				Yes	Global	No
Innodb_page_size				Yes	Global	No
Innodb_pages_created				Yes	Global	No
Innodb_pages_read				Yes	Global	No
Innodb_pages_written				Yes	Global	No
innodb_random_read_ahead	Yes	Yes	Yes		Global	Yes
innodb_read_ahead_threshold	Yes	Yes	Yes		Global	Yes
innodb_read_io_threads	Yes	Yes	Yes		Global	No
innodb_replication_delay	Yes	Yes	Yes		Global	Yes
innodb_rollback_on_timeout	Yes	Yes	Yes		Global	No
Innodb_row_lock_current_waits				Yes	Global	No
Innodb_row_lock_time				Yes	Global	No
Innodb_row_lock_time_avg				Yes	Global	No
Innodb_row_lock_time_max				Yes	Global	No
Innodb_row_lock_waits				Yes	Global	No
Innodb_rows_deleted				Yes	Global	No
Innodb_rows_inserted				Yes	Global	No
Innodb_rows_read				Yes	Global	No
Innodb_rows_updated				Yes	Global	No
innodb_spin_wait_delay	Yes	Yes	Yes		Global	Yes
innodb_stats_method	Yes	Yes	Yes		Global	Yes
innodb_stats_on_metadata	Yes	Yes	Yes		Global	Varies
innodb_stats_sample_pages	Yes	Yes	Yes		Global	Yes
innodb-status-file	Yes	Yes				
innodb_strict_mode	Yes	Yes	Yes		Both	Yes
innodb_support_xa	Yes	Yes	Yes		Both	Yes
innodb_sync_spin_loops	Yes	Yes	Yes		Global	Yes
innodb_table_locks	Yes	Yes	Yes		Both	Yes
innodb_thread_concurrency	Yes	Yes	Yes		Global	Yes
innodb_thread_sleep_delay	Yes	Yes	Yes		Global	Yes
innodb_trx_purge_view_update_only_debug	Yes	Yes	Yes		Global	Yes
innodb_trx_rseg_n_slots_debug	Yes	Yes	Yes		Global	Yes
innodb_use_legacy_cardinality_algorithm	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_use_sys_malloc	Yes	Yes	Yes		Global	No
innodb_version			Yes		Global	No
innodb_write_io_threads	Yes	Yes	Yes		Global	No
timed_mutexes	Yes	Yes	Yes		Global	Yes
unique_checks			Yes		Session	Yes

InnoDB Command Options

- `--ignore-builtin-innodb`

Introduced	5.1.33	
Command-Line Format	`--ignore-builtin-innodb`	
System Variable	Name	`ignore_builtin_innodb`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`boolean`

This option causes the server to behave as if the built-in `InnoDB` is not present, which enables `InnoDB Plugin` to be used instead. See Section 14.6.2.1, "Using InnoDB Plugin Instead of the Built-In InnoDB".

If this option is given but `InnoDB Plugin` is not used in place of the built-in `InnoDB`, it has the following effects:

- Other `InnoDB` options (including `--innodb` and `--skip-innodb`) will not be recognized and should not be used.

- The server will not start if the default storage engine is set to `InnoDB`. Use `--default-storage-engine` to set the default to some other engine if necessary.

- `InnoDB` will not appear in the output of `SHOW ENGINES`.

This option was added in MySQL 5.1.33.

- `--innodb[=value]`

Controls loading of the `InnoDB` storage engine, if the server was compiled with `InnoDB` support. As of MySQL 5.1.36, this option has a tristate format, with possible values of `OFF`, `ON`, or `FORCE`. Before MySQL 5.1.36, this is a boolean option. See Section 5.1.8.1, "Installing and Uninstalling Plugins".

To disable `InnoDB`, use `--innodb=OFF` or `--skip-innodb`. In this case, the server will not start if the default storage engine is set to `InnoDB`. Use `--default-storage-engine` to set the default to some other engine if necessary.

- `--innodb-status-file`

Command-Line Format	`--innodb-status-file`	
Permitted Values	Type	`boolean`
	Default	`OFF`

Controls whether `InnoDB` creates a file named `innodb_status.<pid>` in the MySQL data directory. If enabled, `InnoDB` periodically writes the output of `SHOW ENGINE INNODB STATUS` to this file.

By default, the file is not created. To create it, start `mysqld` with the `--innodb-status-file=1` option. The file is deleted during normal shutdown.

- `--skip-innodb`

Disable the `InnoDB` storage engine. See the description of `--innodb`.

InnoDB System Variables

- `ignore_builtin_innodb`

Introduced	5.1.33	
Command-Line Format	`--ignore-builtin-innodb`	
System Variable	Name	`ignore_builtin_innodb`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`boolean`

Whether the server was started with the `--ignore-builtin-innodb` option, which causes the server to behave as if the built-in `InnoDB` is not present. For more information, see the description of `--ignore-builtin-innodb` under "`InnoDB` Command Options" earlier in this section. This variable was added in MySQL 5.1.33.

- `innodb_adaptive_flushing`

Introduced	5.1.38	
Command-Line Format	`--innodb_adaptive_flushing=#`	
System Variable	Name	`innodb_adaptive_flushing`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`ON`

(`InnoDB Plugin` only) `InnoDB Plugin` 1.0.4 and up uses a heuristic to determine when to flush dirty pages in the buffer pool. This heuristic is designed to avoid bursts of I/O activity and is used when `innodb_adaptive_flushing` is enabled (which is the default).

- `innodb_adaptive_hash_index`

Introduced	5.1.24
Command-Line Format	`--innodb_adaptive_hash_index=#`

System Variable	Name	`innodb_adaptive_hash_index`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`boolean`
	Default	`ON`

Whether the `InnoDB` adaptive hash index is enabled or disabled. The adaptive hash index feature is useful for some workloads, and not for others; conduct benchmarks with it both enabled and disabled, using realistic workloads. See Adaptive Hash Indexes for details. This variable is enabled by default. Use `--skip-innodb_adaptive_hash_index` at server startup to disable it. This variable was added in MySQL 5.1.24.

- `innodb_additional_mem_pool_size`

Command-Line Format	`--innodb_additional_mem_pool_size=#`	
System Variable	Name	`innodb_additional_mem_pool_size`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	`1048576`
	Min Value	`524288`
	Max Value	`4294967295`

The size in bytes of a memory pool `InnoDB` uses to store data dictionary information and other internal data structures. The more tables you have in your application, the more memory you need to allocate here. If `InnoDB` runs out of memory in this pool, it starts to allocate memory from the operating system and writes warning messages to the MySQL error log. The default value is 1MB for the built-in `InnoDB`, 8MB for `InnoDB Plugin`.

This variable relates to the `InnoDB` internal memory allocator, which is unused if `innodb_use_sys_malloc` is enabled.

- `innodb_autoextend_increment`

Command-Line Format	`--innodb_autoextend_increment=#`	
System Variable	Name	`innodb_autoextend_increment`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`8`

	Min Value	1
	Max Value	1000

The increment size (in MB) for extending the size of an auto-extending shared tablespace file when it becomes full. The default value is 8. This variable does not affect the per-table tablespace files that are created if you use `innodb_file_per_table=1`. Those files are auto-extending regardless of the value of `innodb_autoextend_increment`. The initial extensions are by small amounts, after which extensions occur in increments of 4MB.

- `innodb_buffer_pool_awe_mem_mb`

Removed	5.1.13	
Command-Line Format	`--innodb_buffer_pool_awe_mem_mb=#`	
System Variable	**Name**	`innodb_buffer_pool_awe_mem_mb`
	Variable Scope	Global
	Dynamic Variable	No
Platform Specific	Windows	
Permitted Values (Windows)	**Type**	`integer`
	Default	0
	Min Value	0
	Max Value	63000

The size of the buffer pool (in MB), if it is placed in the AWE memory. If it is greater than 0, `innodb_buffer_pool_size` is the window in the 32-bit address space of `mysqld` where `InnoDB` maps that AWE memory. A good value for `innodb_buffer_pool_size` is 500MB. The maximum possible value is 63000.

To take advantage of AWE memory, you will need to recompile MySQL yourself. The current project settings needed for doing this can be found in the `storage/innobase/os/os0proc.c` source file.

This variable was removed in MySQL 5.1.13. Before that, it is relevant only in 32-bit Windows. If your 32-bit Windows operating system supports more than 4GB memory, using so-called "Address Windowing Extensions," you can allocate the `InnoDB` buffer pool into the AWE physical memory using this variable.

- `innodb_autoinc_lock_mode`

Introduced	5.1.22	
Command-Line Format	`--innodb_autoinc_lock_mode=#`	
System Variable	**Name**	`innodb_autoinc_lock_mode`
	Variable Scope	Global
	Dynamic Variable	No

Permitted Values	Type	integer
	Default	1
	Valid Values	0
		1
		2

The locking mode to use for generating auto-increment values. The permissible values are 0, 1, or 2, for "traditional", "consecutive", or "interleaved" lock mode, respectively. Section 14.6.6.5, "AUTO_INCREMENT Handling in InnoDB", describes the characteristics of these modes.

This variable was added in MySQL 5.1.22 with a default of 1 ("consecutive" lock mode). Before 5.1.22, `InnoDB` uses "traditional" lock mode.

- `innodb_buffer_pool_size`

Command-Line Format	`--innodb_buffer_pool_size=#`	
System Variable	Name	`innodb_buffer_pool_size`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (<= 5.1.27)	Type	integer
	Default	8388608
	Min Value	1048576
Permitted Values (32-bit platforms, >= 5.1.28)	Type	integer
	Default	134217728
	Min Value	1048576
	Max Value	2**32-1
Permitted Values (64-bit platforms, >= 5.1.28)	Type	integer
	Default	134217728
	Min Value	1048576
	Max Value	2**64-1

The size in bytes of the memory buffer `InnoDB` uses to cache data and indexes of its tables. The default value is 128MB, increased from a historical default of 8MB. In MySQL 5.1.28 and later, the maximum value depends on the CPU architecture; the maximum is 4294967295 (2^{32}-1) on 32-bit systems and 18446744073709551615 (2^{64}-1) on 64-bit systems. On 32-bit systems, the CPU architecture and operating system may impose a lower practical maximum size than the stated maximum.

A larger buffer pool requires less disk I/O to access the same table data more than once. On a dedicated database server, you might set the buffer pool size to 80% of the machine's physical memory size. Be

aware of the following potential issues when configuring buffer pool size, and be prepared to scale back the size of the buffer pool if necessary.

- Competition for physical memory can cause paging in the operating system.

- `InnoDB` reserves additional memory for buffers and control structures, so that the total allocated space is approximately 10% greater than the specified buffer pool size.

- Address space for the buffer pool must be contiguous, which can be an issue on Windows systems with DLLs that load at specific addresses.

- The time to initialize the buffer pool is roughly proportional to its size. On large installations, initialization time might be significant. For example, on a modern Linux x86_64 server, initialization of a 10GB buffer pool takes approximately 6 seconds. See Section 8.10.2, "The InnoDB Buffer Pool".

- `innodb_change_buffering`

Introduced	5.1.38	
Command-Line Format	`--innodb_change_buffering=#`	
System Variable	**Name**	`innodb_change_buffering`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`inserts`
	Valid Values	`inserts`
		`none`

(`InnoDB Plugin` only) Whether `InnoDB` performs insert buffering. The permitted values `none` (do not buffer any operations) and `inserts` (buffer insert operations). The default is `inserts`. For details, see Insert Buffering.

- `innodb_change_buffering_debug`

Introduced	5.1.53	
Command-Line Format	`--innodb_change_buffering_debug=#`	
System Variable	**Name**	`innodb_change_buffering_debug`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Max Value	`2`

Sets a debug flag for `InnoDB` change buffering. A value of 1 forces all changes to the change buffer. A value of 2 causes a crash at merge. A default value of 0 indicates that the change buffering debug flag

is not set. This option is only available when debugging support is compiled in using the `WITH_DEBUG` `CMake` option.

- `innodb_checksums`

Command-Line Format	`--innodb_checksums`	
System Variable	**Name**	`innodb_checksums`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`ON`

`InnoDB` can use checksum validation on all pages read from the disk to ensure extra fault tolerance against broken hardware or data files. This validation is enabled by default. However, under some rare circumstances (such as when running benchmarks) this extra safety feature is unneeded and can be disabled with `--skip-innodb-checksums`.

- `innodb_commit_concurrency`

Command-Line Format	`--innodb_commit_concurrency=#`	
System Variable	**Name**	`innodb_commit_concurrency`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`1000`

The number of threads that can commit at the same time. A value of 0 (the default) permits any number of transactions to commit simultaneously.

As of MySQL 5.1.36, the value of `innodb_commit_concurrency` cannot be changed at runtime from zero to nonzero or vice versa. The value can still be changed from one nonzero value to another.

- `innodb_concurrency_tickets`

Command-Line Format	`--innodb_concurrency_tickets=#`	
System Variable	**Name**	`innodb_concurrency_tickets`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values	Type	integer
	Default	500
	Min Value	1
	Max Value	4294967295

The number of threads that can enter `InnoDB` concurrently is determined by the `innodb_thread_concurrency` variable. A thread is placed in a queue when it tries to enter `InnoDB` if the number of threads has already reached the concurrency limit. When a thread is permitted to enter `InnoDB`, it is given a number of "free tickets" equal to the value of `innodb_concurrency_tickets`, and the thread can enter and leave `InnoDB` freely until it has used up its tickets. After that point, the thread again becomes subject to the concurrency check (and possible queuing) the next time it tries to enter `InnoDB`. The default value is 500.

With a small `innodb_concurrency_tickets` value, small transactions that only need to process a few rows compete fairly with larger transactions that process many rows. The disadvantage of a small `innodb_concurrency_tickets` value is that large transactions must loop through the queue many times before they can complete, which extends the length of time required to complete their task.

With a large `innodb_concurrency_tickets` value, large transactions spend less time waiting for a position at the end of the queue (controlled by `innodb_thread_concurrency`) and more time retrieving rows. Large transactions also require fewer trips through the queue to complete their task. The disadvantage of a large `innodb_concurrency_tickets` value is that too many large transactions running at the same time can starve smaller transactions by making them wait a longer time before executing.

With a non-zero `innodb_thread_concurrency` value, you may need to adjust the `innodb_concurrency_tickets` value up or down to find the optimal balance between larger and smaller transactions. The `SHOW ENGINE INNODB STATUS` report shows the number of tickets remaining for an executing transaction in its current pass through the queue.

- `innodb_data_file_path`

Command-Line Format	--innodb_data_file_path=name	
System Variable	Name	innodb_data_file_path
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	string
	Default	ibdata1:10M:autoextend

The paths to individual data files and their sizes. The full directory path to each data file is formed by concatenating `innodb_data_home_dir` to each path specified here. The file sizes are specified MB or GB (1024MB) by appending `M` or `G` to the size value. The sum of the sizes of the files must be at least slightly larger than 10MB. If you do not specify `innodb_data_file_path`, the default behavior is to create a single auto-extending data file, slightly larger than 10MB, named `ibdata1`. The size limit of individual files is determined by your operating system. You can set the file size to more than 4GB on those operating systems that support big files. You can also use raw disk partitions as data files. For detailed information on configuring `InnoDB` tablespace files, see Section 14.6.2, "InnoDB Configuration".

- `innodb_data_home_dir`

Command-Line Format	`--innodb_data_home_dir=dir_name`	
System Variable	**Name**	`innodb_data_home_dir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`

The common part of the directory path for all `InnoDB` data files in the shared tablespace. This setting does not affect the location of per-file tablespaces when `innodb_file_per_table` is enabled. The default value is the MySQL `data` directory. If you specify the value as an empty string, you can use absolute file paths in `innodb_data_file_path`.

- `innodb_doublewrite`

Command-Line Format	`--innodb-doublewrite`	
System Variable	**Name**	`innodb_doublewrite`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`ON`

If this variable is enabled (the default), `InnoDB` stores all data twice, first to the doublewrite buffer, and then to the actual data files. This variable can be turned off with `--skip-innodb_doublewrite` for benchmarks or cases when top performance is needed rather than concern for data integrity or possible failures.

- `innodb_fast_shutdown`

Command-Line Format	`--innodb_fast_shutdown[=#]`	
System Variable	**Name**	`innodb_fast_shutdown`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1`
	Valid Values	`0`
		`1`
		`2`

The `InnoDB` shutdown mode. By default, the value is 1, which causes a "fast" shutdown (the normal type of shutdown). If the value is 0, `InnoDB` does a full purge and an insert buffer merge before a shutdown. These operations can take minutes, or even hours in extreme cases. If the value is 1, `InnoDB` skips

these operations at shutdown. If the value is 2, `InnoDB` will just flush its logs and then shut down cold, as if MySQL had crashed; no committed transaction will be lost, but crash recovery will be done at the next startup. A value of 2 cannot be used on NetWare.

- `innodb_file_format`

Introduced	5.1.38	
Command-Line Format	`--innodb_file_format=#`	
System Variable	**Name**	`innodb_file_format`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (>= 5.1.38)	**Type**	`string`
	Default	`Antelope`
	Valid Values	`Antelope`
		`Barracuda`

(`InnoDB Plugin` only) The file format to use for new `InnoDB` tables. Currently `Antelope` and `Barracuda` are supported. This applies only for tables that have their own tablespace, so for it to have an effect `innodb_file_per_table` must be enabled. The Barracuda file format is required for certain `InnoDB` features such as table compression.

- `innodb_file_format_check`

Introduced	5.1.38	
Command-Line Format	`--innodb_file_format_check=#`	
System Variable	**Name**	`innodb_file_format_check`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.1.41)	**Type**	`string`
	Default	`Antelope`
Permitted Values (>= 5.1.42)	**Type**	`string`
	Default	`Barracuda`

(`InnoDB Plugin` only) This variable can be set to 1 or 0 at server startup to enable or disable whether `InnoDB` checks the file format tag in the shared tablespace (for example, `Antelope` or `Barracuda`). If the tag is checked and is higher than that supported by the current version of `InnoDB`, an error occurs and `InnoDB` does not start. If the tag is not higher, `InnoDB` sets the value of `innodb_file_format_check` to the file format tag, which is the value seen at runtime.

- `innodb_file_io_threads`

Command-Line Format	`--innodb_file_io_threads=#`	
System Variable	**Name**	`innodb_file_io_threads`

		Variable Scope	Global
		Dynamic Variable	No
Permitted Values		Type	`integer`
		Default	`4`
		Min Value	`4`
		Max Value	`64`

The number of file I/O threads in `InnoDB`. Normally, this should be left at the default value of 4, but disk I/O on Windows may benefit from a larger number. On Unix, increasing the number has no effect; `InnoDB` always uses the default value.

With `InnoDB Plugin`, this variable is unused. Use `innodb_read_io_threads` and `innodb_write_io_threads` instead.

- `innodb_file_per_table`

Command-Line Format		`--innodb_file_per_table`	
System Variable	Name	`innodb_file_per_table`	
	Variable Scope	Global	
	Dynamic Variable	No	
Permitted Values	Type	`boolean`	
	Default	`OFF`	

If `innodb_file_per_table` is disabled (the default), `InnoDB` creates tables in the system tablespace. If `innodb_file_per_table` is enabled, `InnoDB` creates each new table using its own `.ibd` file for storing data and indexes, rather than in the system tablespace. See Section 14.6.5.4, "InnoDB File-Per-Table Tablespaces" for information about advantages, disadvantages, and features, such as `InnoDB` table compression, that only work for tables stored in separate tablespaces.

- `innodb_flush_log_at_trx_commit`

Command-Line Format		`--innodb_flush_log_at_trx_commit[=#]`	
System Variable	Name	`innodb_flush_log_at_trx_commit`	
	Variable Scope	Global	
	Dynamic Variable	Yes	
Permitted Values	Type	`enumeration`	
	Default	`1`	
	Valid Values	`0`	
		`1`	

		2

If the value of `innodb_flush_log_at_trx_commit` is 0, the log buffer is written out to the log file once per second and the flush to disk operation is performed on the log file, but nothing is done at a transaction commit. When the value is 1 (the default), the log buffer is written out to the log file at each transaction commit and the flush to disk operation is performed on the log file. When the value is 2, the log buffer is written out to the file at each commit, but the flush to disk operation is not performed on it. However, the flushing on the log file takes place once per second also when the value is 2. Note that the once-per-second flushing is not 100% guaranteed to happen every second, due to process scheduling issues.

The default value of 1 is required for full ACID compliance. You can achieve better performance by setting the value different from 1, but then you can lose up to one second worth of transactions in a crash. With a value of 0, any `mysqld` process crash can erase the last second of transactions. With a value of 2, only an operating system crash or a power outage can erase the last second of transactions. `InnoDB`'s crash recovery works regardless of the value.

For the greatest possible durability and consistency in a replication setup using `InnoDB` with transactions, use `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in your master server `my.cnf` file.

> **Caution**
>
> Many operating systems and some disk hardware fool the flush-to-disk operation. They may tell `mysqld` that the flush has taken place, even though it has not. Then the durability of transactions is not guaranteed even with the setting 1, and in the worst case a power outage can even corrupt the `InnoDB` database. Using a battery-backed disk cache in the SCSI disk controller or in the disk itself speeds up file flushes, and makes the operation safer. You can also try using the Unix command `hdparm` to disable the caching of disk writes in hardware caches, or use some other command specific to the hardware vendor.

- `innodb_flush_method`

Command-Line Format	`--innodb_flush_method=name`	
System Variable	**Name**	`innodb_flush_method`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (Unix, <= 5.1.23)	**Type**	`string`
	Default	`NULL`
	Valid Values	`fdatasync`
		`O_DSYNC`
		`littlesync`
		`nosync`
		`O_DIRECT`
Permitted Values (Unix, >= 5.1.24)	**Type**	`string`
	Default	`NULL`

		fsync
	Valid Values	littlesync
		nosync
		O_DSYNC
		O_DIRECT
Permitted Values (Windows)	**Type**	string
	Default	NULL
	Valid Values	async_unbuffered
		normal
		unbuffered

Defines the method used to flush data to the InnoDB data files and log files, which can affect I/O throughput.

If innodb_flush_method=NULL on a Unix-like system, the fsync option is used by default. If innodb_flush_method=NULL on Windows, the async_unbuffered option is used by default.

The innodb_flush_method options for Unix-like systems include:

- fsync: InnoDB uses the fsync() system call to flush both the data and log files. fsync is the default setting.

- O_DSYNC: InnoDB uses O_SYNC to open and flush the log files, and fsync() to flush the data files. InnoDB does not use O_DSYNC directly because there have been problems with it on many varieties of Unix.

- littlesync: This option is used for internal performance testing and is currently unsupported. Use at your own risk.

- nosync: This option is used for internal performance testing and is currently unsupported. Use at your own risk.

- O_DIRECT: InnoDB uses O_DIRECT (or directio() on Solaris) to open the data files, and uses fsync() to flush both the data and log files. This option is available on some GNU/Linux versions, FreeBSD, and Solaris.

The innodb_flush_method options for Windows systems include:

- async_unbuffered: InnoDB uses Windows asynchronous I/O and non-buffered I/O. async_unbuffered is the default setting on Windows systems.

- normal: InnoDB uses a simulated asynchronous I/O and buffered I/O. This option is used for internal performance testing and is currently unsupported. Use at your own risk.

- unbuffered: InnoDB uses a simulated asynchronous I/O and non-buffered I/O. This option is used for internal performance testing and is currently unsupported. Use at your own risk.

How each settings affects performance depends on hardware configuration and workload. Benchmark your particular configuration to decide which setting to use, or whether to keep the default setting. Examine the Innodb_data_fsyncs status variable to see the overall number of fsync() calls for each setting. The mix of read and write operations in your workload can affect how a setting performs. For example, on a system with a hardware RAID controller and battery-backed write cache, O_DIRECT

can help to avoid double buffering between the `InnoDB` buffer pool and the operating system's file system cache. On some systems where `InnoDB` data and log files are located on a SAN, the default value or `O_DSYNC` might be faster for a read-heavy workload with mostly `SELECT` statements. Always test this parameter with hardware and workload that reflect your production environment.

Prior to MySQL 5.1.24, the default `innodb_flush_method` option was named `fdatasync`. When `fdatasync` was specified, `InnoDB` used the `fsync()` system call to flush both the data and log files. To avoid confusing the `fdatasync` option name with the `fdatasync()` system call, the option name was changed to `fsync` in MySQL 5.1.24.

- `innodb_force_recovery`

Command-Line Format	`--innodb_force_recovery=#`	
System Variable	Name	`innodb_force_recovery`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`6`

The crash recovery mode. Possible values are from 0 to 6. For the meanings of these values and important information about `innodb_force_recovery`, see Section 14.6.12.2, "Forcing InnoDB Recovery".

> **Warning**
>
> Only set this variable to a value greater than 0 in an emergency situation, so that you can start `InnoDB` and dump your tables. As a safety measure, `InnoDB` prevents `INSERT`, `UPDATE`, or `DELETE` operations when `innodb_force_recovery` is greater than 0.

- `innodb_io_capacity`

Introduced	5.1.38	
Command-Line Format	`--innodb_io_capacity=#`	
System Variable	Name	`innodb_io_capacity`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`200`
	Min Value	`100`

	Max Value	2**32-1
Permitted Values (64-bit platforms)	**Type**	integer
	Default	200
	Min Value	100
	Max Value	2**64-1

(`InnoDB Plugin` only) An upper limit on the I/O activity performed by the `InnoDB` background tasks, such as flushing pages from the buffer pool and merging data from the insert buffer. The default value is 200. For busy systems capable of higher I/O rates, you can set a higher value at server startup, to help the server handle the background maintenance work associated with a high rate of row changes. For systems with individual 5400 RPM or 7200 RPM drives, you might lower the value to the former default of `100`.

This parameter should be set to approximately the number of I/O operations that the system can perform per second. Ideally, keep this setting as low as practical, but not so low that these background activities fall behind. If the value is too high, data is removed from the buffer pool and insert buffer too quickly to provide significant benefit from the caching.

The value represents an estimated proportion of the I/O operations per second (IOPS) available to older-generation disk drives that could perform about 100 IOPS. The current default of 200 reflects that modern storage devices are capable of much higher I/O rates.

In general, you can increase the value as a function of the number of drives used for `InnoDB` I/O, particularly fast drives capable of high numbers of IOPS. For example, systems that use multiple disks or solid-state disks for `InnoDB` are likely to benefit from the ability to control this parameter.

Although you can specify a very high number, in practice such large values have little if any benefit; for example, a value of one million would be considered very high.

You can set the `innodb_io_capacity` value to any number 100 or greater, and the default value is `200`. You can set the value of this parameter in the MySQL option file (`my.cnf` or `my.ini`) or change it dynamically with the `SET GLOBAL` command, which requires the `SUPER` privilege.

See Configuring the InnoDB Master Thread I/O Rate for more guidelines about this option. For general information about InnoDB I/O performance, see Section 8.6.7, "Optimizing InnoDB Disk I/O".

This variable was added in MySQL 5.1.38.

- `innodb_limit_optimistic_insert_debug`

Introduced	5.1.68	
Command-Line Format	`--innodb_limit_optimistic_insert_debug=#`	
System Variable	**Name**	innodb_limit_optimistic_insert_debug
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer

	Default	0
	Min Value	0
	Max Value	`2**32-1`

Limits the number of records per [B-tree](#) page. A default value of 0 means that no limit is imposed. This option is only available if debugging support is compiled in using the `WITH_DEBUG CMake` option.

- `innodb_lock_wait_timeout`

Command-Line Format	`--innodb_lock_wait_timeout=#`	
System Variable (<= 5.1.37)	**Name**	`innodb_lock_wait_timeout`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.1.38)	**Name**	`innodb_lock_wait_timeout`
	Variable Scope	Global, Session
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`50`
	Min Value	`1`
	Max Value	`1073741824`

The timeout in seconds an `InnoDB` transaction waits for a row lock before giving up. The default value is 50 seconds. A transaction that tries to access a row that is locked by another `InnoDB` transaction waits at most this many seconds for write access to the row before issuing the following error:

```
ERROR 1205 (HY000): Lock wait timeout exceeded; try restarting transaction
```

When a lock wait timeout occurs, the current statement is rolled back (not the entire transaction). To have the entire transaction roll back, start the server with the `--innodb_rollback_on_timeout` option. See also [Section 14.6.12.4, "InnoDB Error Handling"](#).

You might decrease this value for highly interactive applications or [OLTP](#) systems, to display user feedback quickly or put the update into a queue for processing later. You might increase this value for long-running back-end operations, such as a transform step in a data warehouse that waits for other large insert or update operations to finish.

`innodb_lock_wait_timeout` applies to `InnoDB` row locks only. A MySQL table lock does not happen inside `InnoDB` and this timeout does not apply to waits for table locks.

`InnoDB` does detect transaction deadlocks in its own lock table immediately and rolls back one transaction. The lock wait timeout value does not apply to such a wait.

For the built-in `InnoDB`, this variable can be set only at server startup. For `InnoDB Plugin`, it can be set at startup or changed at runtime, and has both global and session values.

- `innodb_locks_unsafe_for_binlog`

Command-Line Format	`--innodb_locks_unsafe_for_binlog`	
System Variable	**Name**	`innodb_locks_unsafe_for_binlog`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`OFF`

This variable affects how `InnoDB` uses gap locking for searches and index scans. Normally, `InnoDB` uses an algorithm called *next-key locking* that combines index-row locking with gap locking. `InnoDB` performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are actually index-record locks. In addition, a next-key lock on an index record also affects the "gap" before that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record `R` in an index, another session cannot insert a new index record in the gap immediately before `R` in the index order. See Section 14.6.4.2, "InnoDB Record, Gap, and Next-Key Locks".

By default, the value of `innodb_locks_unsafe_for_binlog` is 0 (disabled), which means that gap locking is enabled: `InnoDB` uses next-key locks for searches and index scans. To enable the variable, set it to 1. This causes gap locking to be disabled: `InnoDB` uses only index-record locks for searches and index scans.

Enabling `innodb_locks_unsafe_for_binlog` does not disable the use of gap locking for foreign-key constraint checking or duplicate-key checking.

The effect of enabling `innodb_locks_unsafe_for_binlog` is similar to but not identical to setting the transaction isolation level to `READ COMMITTED`:

- Enabling `innodb_locks_unsafe_for_binlog` is a global setting and affects all sessions, whereas the isolation level can be set globally for all sessions, or individually per session.

- `innodb_locks_unsafe_for_binlog` can be set only at server startup, whereas the isolation level can be set at startup or changed at runtime.

`READ COMMITTED` therefore offers finer and more flexible control than `innodb_locks_unsafe_for_binlog`. For additional details about the effect of isolation level on gap locking, see Section 13.3.6, "SET TRANSACTION Syntax".

Enabling `innodb_locks_unsafe_for_binlog` may cause phantom problems because other sessions can insert new rows into the gaps when gap locking is disabled. Suppose that there is an index on the `id` column of the `child` table and that you want to read and lock all rows from the table having an identifier value larger than 100, with the intention of updating some column in the selected rows later:

```
SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

The query scans the index starting from the first record where `id` is greater than 100. If the locks set on the index records in that range do not lock out inserts made in the gaps, another session can insert a new row into the table. Consequently, if you were to execute the same `SELECT` again within the same transaction, you would see a new row in the result set returned by the query. This also means that if new items are added to the database, `InnoDB` does not guarantee serializability. Therefore, if `innodb_locks_unsafe_for_binlog` is enabled, `InnoDB` guarantees at most an isolation level of `READ COMMITTED`. (Conflict serializability is still guaranteed.) For additional information about phantoms, see Section 14.6.4.3, "Avoiding the Phantom Problem Using Next-Key Locking".

Enabling `innodb_locks_unsafe_for_binlog` has additional effects:

- For `UPDATE` or `DELETE` statements, `InnoDB` holds locks only for rows that it updates or deletes. Record locks for nonmatching rows are released after MySQL has evaluated the `WHERE` condition. This greatly reduces the probability of deadlocks, but they can still happen.

- For `UPDATE` statements, if a row is already locked, `InnoDB` performs a "semi-consistent" read, returning the latest committed version to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`. If the row matches (must be updated), MySQL reads the row again and this time `InnoDB` either locks it or waits for a lock on it.

Consider the following example, beginning with this table:

```
CREATE TABLE t (a INT NOT NULL, b INT) ENGINE = InnoDB;
INSERT INTO t VALUES (1,2),(2,3),(3,2),(4,3),(5,2);
COMMIT;
```

In this case, table has no indexes, so searches and index scans use the hidden clustered index for record locking (see Clustered and Secondary Indexes).

Suppose that one client performs an `UPDATE` using these statements:

```
SET autocommit = 0;
UPDATE t SET b = 5 WHERE b = 3;
```

Suppose also that a second client performs an `UPDATE` by executing these statements following those of the first client:

```
SET autocommit = 0;
UPDATE t SET b = 4 WHERE b = 2;
```

As `InnoDB` executes each `UPDATE`, it first acquires an exclusive lock for each row, and then determines whether to modify it. If `InnoDB` does not modify the row and `innodb_locks_unsafe_for_binlog` is enabled, it releases the lock. Otherwise, `InnoDB` retains the lock until the end of the transaction. This affects transaction processing as follows.

If `innodb_locks_unsafe_for_binlog` is disabled, the first `UPDATE` acquires x-locks and does not release any of them:

```
x-lock(1,2); retain x-lock
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); retain x-lock
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); retain x-lock
```

The second `UPDATE` blocks as soon as it tries to acquire any locks (because first update has retained locks on all rows), and does not proceed until the first `UPDATE` commits or rolls back:

```
x-lock(1,2); block and wait for first UPDATE to commit or roll back
```

If `innodb_locks_unsafe_for_binlog` is enabled, the first `UPDATE` acquires x-locks and releases those for rows that it does not modify:

```
x-lock(1,2); unlock(1,2)
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); unlock(3,2)
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); unlock(5,2)
```

For the second `UPDATE`, `InnoDB` does a "semi-consistent" read, returning the latest committed version of each row to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`:

```
x-lock(1,2); update(1,2) to (1,4); retain x-lock
x-lock(2,3); unlock(2,3)
x-lock(3,2); update(3,2) to (3,4); retain x-lock
x-lock(4,3); unlock(4,3)
x-lock(5,2); update(5,2) to (5,4); retain x-lock
```

Semi-consistent read is available as of MySQL 5.1.5. Before 5.1.5, the second `UPDATE` proceeds part way before it blocks. It begins acquiring x-locks, and blocks when it tries to acquire one for a row still locked by first `UPDATE`. The second `UPDATE` does not proceed until the first `UPDATE` commits or rolls back:

```
x-lock(1,2); update(1,2) to (1,4); retain x-lock
x-lock(2,3); block and wait for first UPDATE to commit or roll back
```

In this case, the second `UPDATE` must wait for a commit or rollback of the first `UPDATE`, even though it affects different rows. The first `UPDATE` has an exclusive lock on row (2,3) that it has not released. As the second `UPDATE` scans rows, it tries to acquire an exclusive lock for that same row, which it cannot have. Thus, before MySQL 5.1.5, enabling `innodb_locks_unsafe_for_binlog` still does not permit operations such as `UPDATE` to overtake other similar operations (such as another `UPDATE`) even when they affect different rows.

- `innodb_log_arch_dir`

  This variable is deprecated, and was removed in MySQL 5.1.21.

- `innodb_log_archive`

  This variable is deprecated, and was removed in MySQL 5.1.18.

- `innodb_log_buffer_size`

Command-Line Format	`--innodb_log_buffer_size=#`	
System Variable	**Name**	`innodb_log_buffer_size`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`1048576`
	Min Value	`1048576`
	Max Value	`4294967295`

The size in bytes of the buffer that `InnoDB` uses to write to the log files on disk. The default value is 1MB for the built-in `InnoDB`, 8MB for `InnoDB Plugin`. Sensible values range from 1MB to 8MB. A large log buffer enables large transactions to run without a need to write the log to disk before the transactions commit. Thus, if you have big transactions, making the log buffer larger saves disk I/O.

- `innodb_log_file_size`

Command-Line Format	`--innodb_log_file_size=#`	
System Variable	**Name**	`innodb_log_file_size`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`5242880`
	Min Value	`1048576`
	Max Value	`4GB / innodb_log_files_in_group`

The size in bytes of each log file in a log group. The combined size of log files (`innodb_log_file_size` * `innodb_log_files_in_group`) cannot exceed a maximum value that is slightly less than 4GB. A pair of 2047 MB log files, for example, would allow you to approach the range limit but not exceed it. The default value is 5MB. Sensible values range from 1MB to 1/N-th of the size of the buffer pool, where N is the number of log files in the group. The larger the value, the less checkpoint flush activity is needed in the buffer pool, saving disk I/O. But larger log files also mean that recovery is slower in case of a crash.

- `innodb_log_files_in_group`

Command-Line Format	`--innodb_log_files_in_group=#`	
System Variable	**Name**	`innodb_log_files_in_group`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`2`

	Min Value	2
	Max Value	100

The number of log files in the log group. `InnoDB` writes to the files in a circular fashion. The default (and recommended) value is 2.

- `innodb_log_group_home_dir`

Command-Line Format	`--innodb_log_group_home_dir=dir_name`	
System Variable	**Name**	`innodb_log_group_home_dir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`

The directory path to the `InnoDB` log files. If you do not specify any `InnoDB` log variables, the default is to create two files named `ib_logfile0` and `ib_logfile1` in the MySQL data directory. Their size is given by the size of the `innodb_log_file_size` system variable.

- `innodb_max_dirty_pages_pct`

Command-Line Format	`--innodb_max_dirty_pages_pct=#`	
System Variable	**Name**	`innodb_max_dirty_pages_pct`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`numeric`
	Default	`90`
	Min Value	`0`
	Max Value	`100`

This is an integer in the range from 0 to 100. The default value is 90 for the built-in `InnoDB`, 75 for `InnoDB Plugin`. The main thread in `InnoDB` tries to write pages from the buffer pool so that the percentage of dirty (not yet written) pages will not exceed this value.

- `innodb_max_purge_lag`

Command-Line Format	`--innodb_max_purge_lag=#`	
System Variable	**Name**	`innodb_max_purge_lag`
	Variable Scope	Global

	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	0
	Min Value	0
	Max Value	`4294967295`

This variable controls how to delay `INSERT`, `UPDATE`, and `DELETE` operations when purge operations are lagging (see Section 14.6.3.1, "InnoDB Multi-Versioning"). The default value 0 (no delays).

The `InnoDB` transaction system maintains a list of transactions that have index records delete-marked by `UPDATE` or `DELETE` operations. Let the length of this list be *purge_lag*. When *purge_lag* exceeds `innodb_max_purge_lag`, each `INSERT`, `UPDATE`, and `DELETE` operation is delayed by ((*purge_lag*/`innodb_max_purge_lag`)×10)−5 milliseconds. The delay is computed in the beginning of a purge batch, every ten seconds. The operations are not delayed if purge cannot run because of an old consistent read view that could see the rows to be purged.

A typical setting for a problematic workload might be 1 million, assuming that transactions are small, only 100 bytes in size, and it is permissible to have 100MB of unpurged `InnoDB` table rows.

The lag value is displayed as the history list length in the `TRANSACTIONS` section of InnoDB Monitor output. For example, if the output includes the following lines, the lag value is 20:

```
------------
TRANSACTIONS
------------
Trx id counter 0 290328385
Purge done for trx's n:o < 0 290315608 undo n:o < 0 17
History list length 20
```

- `innodb_mirrored_log_groups`

  Has no effect.

- `innodb_old_blocks_pct`

Introduced	5.1.41
Command-Line Format	`--innodb_old_blocks_pct=#`
System Variable	**Name**	`innodb_old_blocks_pct`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	37
	Min Value	5

Max Value	95	

(`InnoDB Plugin` only) Specifies the approximate percentage of the `InnoDB` buffer pool used for the old block sublist. The range of values is 5 to 95. The default value is 37 (that is, 3/8 of the pool). See Section 8.10.2, "The InnoDB Buffer Pool" for information about buffer pool management, such as the LRU algorithm and eviction policies.

This variable was added in MySQL 5.1.41.

- `innodb_old_blocks_time`

Introduced	5.1.41	
Command-Line Format	`--innodb_old_blocks_time=#`	
System Variable	**Name**	`innodb_old_blocks_time`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	0
	Min Value	0
	Max Value	`2**32-1`

(`InnoDB Plugin` only) Specifies how long in milliseconds (ms) a block inserted into the old sublist must stay there after its first access before it can be moved to the new sublist. The default value is 0: A block inserted into the old sublist moves immediately to the new sublist the first time it is accessed, no matter how soon after insertion the access occurs. If the value is greater than 0, blocks remain in the old sublist until an access occurs at least that many ms after the first access. For example, a value of 1000 causes blocks to stay in the old sublist for 1 second after the first access before they become eligible to move to the new sublist.

This variable is often used in combination with `innodb_old_blocks_pct`. See Section 8.10.2, "The InnoDB Buffer Pool" for information about buffer pool management, such as the LRU algorithm and eviction policies.

This variable was added in MySQL 5.1.41.

- `innodb_open_files`

Command-Line Format	`--innodb_open_files=#`	
System Variable	**Name**	`innodb_open_files`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`

Default	300
Min Value	10
Max Value	4294967295

This variable is relevant only if you use multiple `InnoDB` tablespaces. It specifies the maximum number of `.ibd` files that MySQL can keep open at one time. The minimum value is 10. The default value is 300.

The file descriptors used for `.ibd` files are for `InnoDB` tables only. They are independent of those specified by the `--open-files-limit` server option, and do not affect the operation of the table cache.

* `innodb_random_read_ahead`

Introduced	5.1.59	
Command-Line Format	`--innodb_random_read_ahead=#`	
System Variable	Name	`innodb_random_read_ahead`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

Enables the random read-ahead technique for optimizing `InnoDB` I/O. Random read-ahead functionality was removed from the `InnoDB Plugin` (version 1.0.4) and was therefore not included in MySQL 5.5.0 when `InnoDB Plugin` became the "built-in" version of `InnoDB`. Random read-ahead was reintroduced in MySQL 5.1.59 and 5.5.16 and higher along with the `innodb_random_read_ahead` configuration option, which is disabled by default.

See Configuring InnoDB Buffer Pool Prefetching (Read-Ahead) for details about the performance considerations for the different types of read-ahead requests. For general I/O tuning advice, see Section 8.6.7, "Optimizing InnoDB Disk I/O".

* `innodb_read_ahead_threshold`

Introduced	5.1.38	
Command-Line Format	`--innodb_read_ahead_threshold=#`	
System Variable	Name	`innodb_read_ahead_threshold`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	56
	Min Value	0

	Max Value	64

(`InnoDB Plugin` only) Controls the sensitivity of linear read-ahead that `InnoDB` uses to prefetch pages into the buffer pool. If `InnoDB` reads at least `innodb_read_ahead_threshold` pages sequentially from an extent (64 pages), it initiates an asynchronous read for the entire following extent. The permissible range of values is 0 to 64. The default is 56: `InnoDB` must read at least 56 pages sequentially from an extent to initiate an asynchronous read for the following extent.

This variable was added in MySQL 5.1.38.

- `innodb_read_io_threads`

Introduced	5.1.38	
Command-Line Format	`--innodb_read_io_threads=#`	
System Variable	Name	`innodb_read_io_threads`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`integer`
	Default	4
	Min Value	1
	Max Value	64

(`InnoDB Plugin` only) The number of I/O threads for read operations in `InnoDB`. The default value is 4.

> **Note**
>
> On Linux systems, running multiple MySQL servers (typically more than 12) with default settings for `innodb_read_io_threads`, `innodb_write_io_threads`, and the Linux `aio-max-nr` setting can exceed system limits. Ideally, increase the `aio-max-nr` setting; as a workaround, you might reduce the settings for one or both of the MySQL configuration options.

This variable was added in MySQL 5.1.38.

- `innodb_replication_delay`

Introduced	5.1.38	
Command-Line Format	`--innodb_replication_delay=#`	
System Variable	Name	`innodb_replication_delay`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`

	Default	0
	Min Value	0
	Max Value	4294967295

(`InnoDB Plugin` only) The replication thread delay (in ms) on a slave server if `innodb_thread_concurrency` is reached.

This variable was added in MySQL 5.1.38.

- `innodb_rollback_on_timeout`

Introduced	5.1.15	
Command-Line Format	`--innodb_rollback_on_timeout`	
System Variable	Name	`innodb_rollback_on_timeout`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`boolean`
	Default	`OFF`

In MySQL 5.1, `InnoDB` rolls back only the last statement on a transaction timeout by default. If `--innodb_rollback_on_timeout` is specified, a transaction timeout causes `InnoDB` to abort and roll back the entire transaction (the same behavior as in MySQL 4.1). This variable was added in MySQL 5.1.15.

- `innodb_spin_wait_delay`

Introduced	5.1.38	
Command-Line Format	`--innodb_spin_wait_delay=#`	
System Variable	Name	`innodb_spin_wait_delay`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	`integer`
	Default	6
	Min Value	0
	Max Value	`2**32-1`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	6
	Min Value	0

	Max Value	2**64-1

(`InnoDB Plugin` only) The maximum delay between polls for a spin lock. The low-level implementation of this mechanism varies depending on the combination of hardware and operating system, so the delay does not correspond to a fixed time interval. The default value is 6.

This variable was added in MySQL 5.1.38.

- `innodb_stats_method`

Introduced	5.1.56	
Command-Line Format	`--innodb_stats_method=name`	
System Variable	**Name**	`innodb_stats_method`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`nulls_equal`
	Valid Values	`nulls_equal`
		`nulls_unequal`
		`nulls_ignored`

How the server treats `NULL` values when collecting statistics about the distribution of index values for `InnoDB` tables. This variable has three possible values, `nulls_equal`, `nulls_unequal`, and `nulls_ignored`. For `nulls_equal`, all `NULL` index values are considered equal and form a single value group that has a size equal to the number of `NULL` values. For `nulls_unequal`, `NULL` values are considered unequal, and each `NULL` forms a distinct value group of size 1. For `nulls_ignored`, `NULL` values are ignored.

The method that is used for generating table statistics influences how the optimizer chooses indexes for query execution, as described in Section 8.3.7, "InnoDB and MyISAM Index Statistics Collection".

- `innodb_stats_on_metadata`

Introduced	5.1.17	
Command-Line Format	`--innodb_stats_on_metadata`	
System Variable (<= 5.1.31)	**Name**	`innodb_stats_on_metadata`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.1.32)	**Name**	`innodb_stats_on_metadata`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values	Type	`boolean`
	Default	`ON`

When this variable is enabled (which is the default, as before the variable was created), `InnoDB` updates statistics during metadata statements such as `SHOW TABLE STATUS` or `SHOW INDEX`, or when accessing the `INFORMATION_SCHEMA` tables `TABLES` or `STATISTICS`. (These updates are similar to what happens for `ANALYZE TABLE`.) When disabled, `InnoDB` does not update statistics during these operations. Disabling this variable can improve access speed for schemas that have a large number of tables or indexes. It can also improve the stability of execution plans for queries that involve `InnoDB` tables.

This variable was added in MySQL 5.1.17.

- `innodb_stats_sample_pages`

Introduced	5.1.38	
Command-Line Format	`--innodb_stats_sample_pages=#`	
System Variable	Name	`innodb_stats_sample_pages`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`8`
	Min Value	`1`
	Max Value	`2**64-1`

(`InnoDB Plugin` only) The number of index pages to sample for index distribution statistics such as are calculated by `ANALYZE TABLE`. The default value is 8.

This variable was added in MySQL 5.1.38.

- `innodb_strict_mode`

Introduced	5.1.38	
Command-Line Format	`--innodb_strict_mode=#`	
System Variable	Name	`innodb_strict_mode`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`OFF`

When `innodb_strict_mode` is `ON`, `InnoDB` returns errors rather than warnings for certain conditions. The default value is `OFF`.

Strict mode helps guard against ignored typos and syntax errors in SQL, or other unintended consequences of various combinations of operational modes and SQL statements. When `innodb_strict_mode` is `ON`, InnoDB raises error conditions in certain cases, rather than issuing a warning and processing the specified statement (perhaps with unintended behavior). This is analogous to `sql_mode` in MySQL, which controls what SQL syntax MySQL accepts, and determines whether it silently ignores errors, or validates input syntax and data values.

The `innodb_strict_mode` setting affects the handling of syntax errors for `CREATE TABLE`, `ALTER TABLE` and `CREATE INDEX` statements. `innodb_strict_mode` also enables a record size check, so that an `INSERT` or `UPDATE` never fails due to the record being too large for the selected page size.

Oracle recommends enabling `innodb_strict_mode` when using `ROW_FORMAT` and `KEY_BLOCK_SIZE` clauses on `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements. When `innodb_strict_mode` is `OFF`, InnoDB ignores conflicting clauses and creates the table or index, with only a warning in the message log. The resulting table might have different behavior than you intended, such as having no compression when you tried to create a compressed table. When `innodb_strict_mode` is `ON`, such problems generate an immediate error and the table or index is not created, avoiding a troubleshooting session later.

You can turn `innodb_strict_mode` `ON` or `OFF` on the command line when you start `mysqld`, or in the configuration file `my.cnf` or `my.ini`. You can also enable or disable `innodb_strict_mode` at runtime with the statement `SET [GLOBAL|SESSION] innodb_strict_mode=mode`, where *mode* is either `ON` or `OFF`. Changing the `GLOBAL` setting requires the `SUPER` privilege and affects the operation of all clients that subsequently connect. Any client can change the `SESSION` setting for `innodb_strict_mode`, and the setting affects only that client.

- `innodb_support_xa`

Command-Line Format	`--innodb_support_xa`	
System Variable	Name	`innodb_support_xa`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`TRUE`

Enables `InnoDB` support for two-phase commit in XA transactions, causing an extra disk flush for transaction preparation. This setting is the default. The XA mechanism is used internally and is essential for any server that has its binary log turned on and is accepting changes to its data from more than one thread. If you turn it off, transactions can be written to the binary log in a different order from the one in which the live database is committing them. This can produce different data when the binary log is replayed in disaster recovery or on a replication slave. Do not turn it off on a replication master server unless you have an unusual setup where only one thread is able to change data.

For a server that is accepting data changes from only one thread, it is safe and recommended to turn off this option to improve performance for `InnoDB` tables. For example, you can turn it off on replication slaves where only the replication SQL thread is changing data.

You can also turn off this option if you do not need it for safe binary logging or replication, and you also do not use an external XA transaction manager.

- innodb_sync_spin_loops

Command-Line Format	--innodb_sync_spin_loops=#	
System Variable	**Name**	innodb_sync_spin_loops
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	20
	Min Value	0
	Max Value	4294967295

The number of times a thread waits for an `InnoDB` mutex to be freed before the thread is suspended. The default value is 20 for the built-in `InnoDB`, 30 for `InnoDB Plugin`.

- innodb_table_locks

Command-Line Format	--innodb_table_locks	
System Variable	**Name**	innodb_table_locks
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	boolean
	Default	TRUE

If `autocommit = 0`, `InnoDB` honors `LOCK TABLES`; MySQL does not return from `LOCK TABLES ... WRITE` until all other threads have released all their locks to the table. The default value of `innodb_table_locks` is 1, which means that `LOCK TABLES` causes InnoDB to lock a table internally if `autocommit = 0`.

- innodb_thread_concurrency

Command-Line Format	--innodb_thread_concurrency=#	
System Variable	**Name**	innodb_thread_concurrency
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	8
	Min Value	0

	Max Value	1000

`InnoDB` tries to keep the number of operating system threads concurrently inside `InnoDB` less than or equal to the limit given by this variable (`InnoDB` uses operating system threads to process user transactions). Once the number of threads reaches this limit, additional threads are placed into a wait state within a "First In, First Out" (FIFO) queue for execution. Threads waiting for locks are not counted in the number of concurrently executing threads.

The range of this variable is 0 to 1000. A value of 20 or higher is interpreted as infinite concurrency before MySQL 5.1.12. From 5.1.12 on, you can disable thread concurrency checking by setting the value to 0. Disabling thread concurrency checking enables `InnoDB` to create as many threads as it needs. A value of 0 also disables the `queries inside InnoDB` and `queries in queue counters` in the `ROW OPERATIONS` section of `SHOW ENGINE INNODB STATUS` output.

The default value for the built-in `InnoDB` is 20 before MySQL 5.1.11 and 8 from 5.1.11 on. The default for the `InnoDB Plugin` is 0.

Consider setting this variable if your MySQL instance shares CPU resources with other applications, or if your workload or number of concurrent users is growing. The correct setting depends on workload, computing environment, and the version of MySQL that you are running. You will need to test a range of values to determine the setting that provides the best performance. `innodb_thread_concurrency` is a dynamic variable, which allows you to experiment with different settings on a live test system. If a particular setting performs poorly, you can quickly set `innodb_thread_concurrency` back to 0.

Use the following guidelines to help find and maintain an appropriate setting:

- If the number of concurrent user threads for a workload is less than 64, set `innodb_thread_concurrency=0`.

- If your workload is consistently heavy or occasionally spikes, start by setting `innodb_thread_concurrency=128`, and lowering the value to 96, 80, 64, and so on, until you find the number of threads that provides the best performance. For example, suppose your system typically has 40 to 50 users, but periodically the number increases to 60, 70, or even 200. You find that performance is stable at 80 concurrent users but starts to show a regression above this number. In this case, you would set `innodb_thread_concurrency=80` to avoid impacting performance.

- If you do not want `InnoDB` to use more than a certain number of vCPUs for user threads (20 vCPUs for example), set `innodb_thread_concurrency` to this number (or possibly lower, depending on performance results). If your goal is to isolate MySQL from other applications, you may consider binding the `mysqld` process exclusively to the vCPUs. Be aware, however, that exclusive binding could result in non-optimal hardware usage if the `mysqld` process is not consistently busy. In this case, you might bind the `mysqld` process to the vCPUs but also allow other applications to use some or all of the vCPUs.

> **Note**
>
> From an operating system perspective, using a resource management solution (if available) to manage how CPU time is shared among applications may be preferable to binding the `mysqld` process. For example, you could assign 90% of vCPU time to a given application while other critical process *are not* running, and scale that value back to 40% when other critical processes *are* running.

- `innodb_thread_concurrency` values that are too high can cause performance regression due to increased contention on system internals and resources.

- In some cases, the optimal `innodb_thread_concurrency` setting can be smaller than the number of vCPUs.

- Monitor and analyze your system regularly. Changes to workload, number of users, or computing environment may require that you adjust the `innodb_thread_concurrency` setting.

- `innodb_thread_sleep_delay`

Command-Line Format	`--innodb_thread_sleep_delay=#`	
System Variable	**Name**	`innodb_thread_sleep_delay`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`18446744073709551615`

How long `InnoDB` threads sleep before joining the `InnoDB` queue, in microseconds. The default value is 10,000. A value of 0 disables sleep.

- `innodb_trx_purge_view_update_only_debug`

Introduced	5.1.68	
Command-Line Format	`--innodb_trx_purge_view_update_only_debug=#`	
System Variable	**Name**	`innodb_trx_purge_view_update_only_debug`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Pauses purging of delete-marked records while allowing the purge view to be updated. This option artificially creates a situation in which the purge view is updated but purges have not yet been performed. This option is only available if debugging support is compiled in using the `WITH_DEBUG` `CMake` option.

- `innodb_trx_rseg_n_slots_debug`

Introduced	5.1.62	
Command-Line Format	`--innodb_trx_rseg_n_slots_debug=#`	
System Variable	Name	`innodb_trx_rseg_n_slots_debug`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`0`
	Max Value	`1024`

Sets a debug flag that limits `TRX_RSEG_N_SLOTS` to a given value for the `trx_rsegf_undo_find_free` function which looks for a free slot for an undo log segment. This option is only available if debugging support is compiled in using the `WITH_DEBUG CMake` option.

- `innodb_use_legacy_cardinality_algorithm`

Introduced	5.1.35	
Command-Line Format	`--innodb_use_legacy_cardinality_algorithm=#`	
System Variable	Name	`innodb_use_legacy_cardinality_algorithm`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`ON`

`InnoDB` uses random numbers to generate dives into indexes for calculating index cardinality. However, under certain conditions, the algorithm does not generate random numbers, so `ANALYZE TABLE` sometimes does not update cardinality estimates properly. An alternative algorithm was introduced in MySQL 5.1.35 with better randomization properties, and the `innodb_use_legacy_cardinality_algorithm`, system variable which algorithm to use. The default value of the variable is 1 (`ON`), to use the original algorithm for compatibility with existing applications. The variable can be set to 0 (`OFF`) to use the new algorithm with improved randomness.

This variable is not used in `InnoDB Plugin` because the improved algorithm is used by default. Also, the number of random dives can be changed by modifying the `innodb_stats_sample_pages` system variable.

- `innodb_use_sys_malloc`

Introduced	5.1.38	
Command-Line Format	`--innodb_use_sys_malloc=#`	
System Variable	Name	`innodb_use_sys_malloc`

	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`ON`

(`InnoDB Plugin` only) Whether `InnoDB` uses the operating system memory allocator (`ON`) or its own (`OFF`). The default value is `ON`.

This variable was added in MySQL 5.1.38.

- `innodb_version`

(`InnoDB Plugin` only) The `InnoDB` version number. Starting in 5.1.68, the separate numbering for `InnoDB` is discontinued and this value is the same as for the `version` variable.

This variable was added in MySQL 5.1.38.

- `innodb_write_io_threads`

Introduced	5.1.38	
Command-Line Format	`--innodb_write_io_threads=#`	
System Variable	**Name**	`innodb_write_io_threads`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`4`
	Min Value	`1`
	Max Value	`64`

(`InnoDB Plugin` only) The number of I/O threads for write operations in `InnoDB`. The default value is 4.

> **Note**
>
> On Linux systems, running multiple MySQL servers (typically more than 12) with default settings for `innodb_read_io_threads`, `innodb_write_io_threads`, and the Linux `aio-max-nr` setting can exceed system limits. Ideally, increase the `aio-max-nr` setting; as a workaround, you might reduce the settings for one or both of the MySQL configuration options.

This variable was added in MySQL 5.1.38.

You should also take into consideration the value of `sync_binlog`, which controls synchronization of the binary log to disk.

14.6.9 InnoDB Monitors

`InnoDB` Monitors provide information about the `InnoDB` internal state. This information is useful for performance tuning. Each Monitor can be enabled by creating a table with a special name, which causes `InnoDB` to write Monitor output periodically. Output for the standard `InnoDB` Monitor is also available on demand through the `SHOW ENGINE INNODB STATUS` SQL statement. Additionally, to assist with troubleshooting, `InnoDB` temporarily enables standard `InnoDB` Monitor output under certain conditions. For more information, see Section 14.6.12, "InnoDB Troubleshooting".

There are several types of `InnoDB` Monitors:

- The standard `InnoDB` Monitor displays the following types of information:

  - Table and record locks held by each active transaction.

  - Lock waits of a transaction.

  - Semaphore waits of threads.

  - Pending file I/O requests.

  - Buffer pool statistics.

  - Purge and insert buffer merge activity of the main `InnoDB` thread.

  For a discussion of `InnoDB` lock modes, see Section 14.6.4.1, "InnoDB Lock Modes".

  To enable the standard `InnoDB` Monitor for periodic output, create a table named `innodb_monitor`. To obtain Monitor output on demand, use the `SHOW ENGINE INNODB STATUS` SQL statement to fetch the output to your client program. If you are using the `mysql` interactive client, the output is more readable if you replace the usual semicolon statement terminator with `\G`:

  ```
  mysql> SHOW ENGINE INNODB STATUS\G
  ```

- The `InnoDB` Lock Monitor prints additional lock information as part of the standard `InnoDB` Monitor output. To enable the `InnoDB` Lock Monitor, create a table named `innodb_lock_monitor`.

- The `InnoDB` Tablespace Monitor prints a list of file segments in the shared tablespace and validates the tablespace allocation data structures. To enable this Monitor for periodic output, create a table named `innodb_tablespace_monitor`.

- The `InnoDB` Table Monitor prints the contents of the `InnoDB` internal data dictionary. To enable this Monitor for periodic output, create a table named `innodb_table_monitor`.

To enable an `InnoDB` Monitor for periodic output, use a `CREATE TABLE` statement to create the table associated with the Monitor. For example, to enable the standard `InnoDB` Monitor, create the `innodb_monitor` table:

```
CREATE TABLE innodb_monitor (a INT) ENGINE=INNODB;
```

To stop the Monitor, drop the table:

```
DROP TABLE innodb_monitor;
```

The `CREATE TABLE` syntax is just a way to pass a command to the `InnoDB` engine through MySQL's SQL parser: The only things that matter are the table name `innodb_monitor` and that it be an `InnoDB` table.

The structure of the table is not relevant at all for the `InnoDB` Monitor. If you shut down the server, the Monitor does not restart automatically when you restart the server. Drop the Monitor table and issue a new `CREATE TABLE` statement to start the Monitor. (This syntax may change in a future release.)

As of MySQL 5.1.24, the `PROCESS` privilege is required to start or stop the `InnoDB` Monitor tables.

When you enable `InnoDB` Monitors for periodic output, `InnoDB` writes their output to the `mysqld` server standard error output (`stderr`). In this case, no output is sent to clients. When switched on, `InnoDB` Monitors print data about every 15 seconds. Server output usually is directed to the error log (see Section 5.4.2, "The Error Log"). This data is useful in performance tuning. On Windows, start the server from a command prompt in a console window with the `--console` option if you want to direct the output to the window rather than to the error log.

`InnoDB` sends diagnostic output to `stderr` or to files rather than to `stdout` or fixed-size memory buffers, to avoid potential buffer overflows. As a side effect, the output of `SHOW ENGINE INNODB STATUS` is written to a status file in the MySQL data directory every fifteen seconds. The name of the file is `innodb_status.pid`, where `pid` is the server process ID. `InnoDB` removes the file for a normal shutdown. If abnormal shutdowns have occurred, instances of these status files may be present and must be removed manually. Before removing them, you might want to examine them to see whether they contain useful information about the cause of abnormal shutdowns. The `innodb_status.pid` file is created only if the configuration option `innodb-status-file=1` is set.

`InnoDB` Monitors should be enabled only when you actually want to see Monitor information because output generation does result in some performance decrement. Also, if you enable monitor output by creating the associated table, your error log may become quite large if you forget to remove the table later.

For additional information about `InnoDB` monitors, see:

• Mark Leith: InnoDB Table and Tablespace Monitors

Each monitor begins with a header containing a timestamp and the monitor name. For example:

```
=====================================
141017  9:57:58 INNODB MONITOR OUTPUT
=====================================
```

The header for the standard Monitor (`INNODB MONITOR OUTPUT`) is also used for the Lock Monitor because the latter produces the same output with the addition of extra lock information.

The following sections describe the output for each Monitor.

14.6.9.1 InnoDB Standard Monitor and Lock Monitor Output

The Lock Monitor is the same as the standard Monitor except that it includes additional lock information. Enabling either monitor for periodic output by creating the associated `InnoDB` table turns on the same output stream, but the stream includes the extra information if the Lock Monitor is enabled. For example, if you create the `innodb_monitor` and `innodb_lock_monitor` tables, that turns on a single output stream. The stream includes extra lock information until you disable the Lock Monitor by removing the `innodb_lock_monitor` table.

Example InnoDB Monitor output (as of MySQL 5.1.72):

```
mysql> SHOW ENGINE INNODB STATUS\G
*************************** 1. row ***************************
  Type: InnoDB
  Name:
Status:
=====================================
```

```
141017  9:57:58 INNODB MONITOR OUTPUT
=====================================
Per second averages calculated from the last 9 seconds
----------
SEMAPHORES
----------
OS WAIT ARRAY INFO: reservation count 416, signal count 413
Mutex spin waits 0, rounds 4630, OS waits 153
RW-shared spins 516, OS waits 258; RW-excl spins 9, OS waits 5
------------------------
LATEST FOREIGN KEY ERROR
------------------------
141017  9:50:15 Transaction:
TRANSACTION 0 2309, ACTIVE 0 sec, process no 4615, OS thread id 140008823879424
inserting, thread declared inside InnoDB 498
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1216, 3 row lock(s), undo log entries 3
MySQL thread id 1, query id 90 localhost msandbox update
INSERT INTO child VALUES (NULL, 1), (NULL, 2), (NULL, 3), (NULL, 4), (NULL, 5),
(NULL, 6)
Foreign key constraint fails for table `mysql`.`child`:
,
  CONSTRAINT `child_ibfk_1` FOREIGN KEY (`parent_id`) REFERENCES `parent` (`id`)
 ON DELETE CASCADE ON UPDATE CASCADE
Trying to add in child table, in index `par_ind` tuple:
DATA TUPLE: 2 fields;
 0: len 4; hex 80000003; asc     ;; 1: len 4; hex 80000003; asc     ;;

But in parent table `mysql`.`parent`, in index `PRIMARY`,
the closest match we can find is record:
PHYSICAL RECORD: n_fields 3; compact format; info bits 0
 0: len 4; hex 80000004; asc     ;; 1: len 6; hex 000000000902; asc       ;; 2:
len 7; hex 800000002d0134; asc    - 4;;

------------------------
LATEST DETECTED DEADLOCK
------------------------
141017  9:52:52
*** (1) TRANSACTION:
TRANSACTION 0 2313, ACTIVE 9 sec, process no 4615, OS thread id 140008823346944
starting index read
mysql tables in use 1, locked 1
LOCK WAIT 2 lock struct(s), heap size 368, 1 row lock(s)
MySQL thread id 3, query id 103 localhost msandbox updating
DELETE FROM t WHERE i = 1
*** (1) WAITING FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 0 page no 56 n bits 72 index `GEN_CLUST_INDEX` of table `m
ysql`.`t` trx id 0 2313 lock_mode X waiting
Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
 0: len 6; hex 000000000300; asc        ;; 1: len 6; hex 000000000907; asc
;; 2: len 7; hex 800000002d0110; asc     -  ;; 3: len 4; hex 80000001; asc     ;
;

*** (2) TRANSACTION:
TRANSACTION 0 2312, ACTIVE 27 sec, process no 4615, OS thread id 140008823879424
 starting index read, thread declared inside InnoDB 500
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1216, 3 row lock(s)
MySQL thread id 1, query id 104 localhost msandbox updating
DELETE FROM t WHERE i = 1
*** (2) HOLDS THE LOCK(S):
RECORD LOCKS space id 0 page no 56 n bits 72 index `GEN_CLUST_INDEX` of table `m
ysql`.`t` trx id 0 2312 lock mode S
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
 0: len 8; hex 73757072656d756d; asc supremum;;

Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
```

```
 0: len 6; hex 000000000300; asc         ;; 1: len 6; hex 000000000907; asc
;; 2: len 7; hex 800000002d0110; asc    -  ;; 3: len 4; hex 80000001; asc     ;
;

*** (2) WAITING FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 0 page no 56 n bits 72 index `GEN_CLUST_INDEX` of table `m
ysql`.`t` trx id 0 2312 lock_mode X waiting
Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
 0: len 6; hex 000000000300; asc         ;; 1: len 6; hex 000000000907; asc
;; 2: len 7; hex 800000002d0110; asc    -  ;; 3: len 4; hex 80000001; asc     ;
;

*** WE ROLL BACK TRANSACTION (1)
------------
TRANSACTIONS
------------
Trx id counter 0 3160
Purge done for trx's n:o < 0 2935 undo n:o < 0 0
History list length 18
LIST OF TRANSACTIONS FOR EACH SESSION:
---TRANSACTION 0 3159, not started, process no 4615, OS thread id 14000882361318
4
MySQL thread id 2, query id 957 localhost msandbox
INSERT INTO `dept_emp` VALUES (77697,'d007','1993-08-23','1993-09-10'),(77698,'d
004','1990-07-24','2002-02-16'),(77698,'d009','2002-02-16','9999-01-01'),(77699,
'd008','1998-01-12','9999-01-01'),(77700,'d005','1995-07-05','9999-01-01'),(7770
1,'d007','1986-10-10','1992-05-07'),(77702,'d007','1988-11-22','9999-01-01'),(77
703,'d004','1992-11-16','9999-01-01'),(77704,'d007','1999-06-23','9999-01-01'),(
77705,'d004','1998-09-29','9999-01-01'),(77706,'d007','1991-03-17','2001-02-20')
,(77707,'d001','1997-06-16','2002-03-03'),(77707,'d007','2002-03-03','9999-01-01
'),(77708,'d008','1987-04-08','9999-01-0
---TRANSACTION 0 2313, not started, process no 4615, OS thread id 14000882334694
4
MySQL thread id 3, query id 105 localhost msandbox
---TRANSACTION 0 2312, ACTIVE 333 sec, process no 4615, OS thread id 14000882387
9424
4 lock struct(s), heap size 1216, 4 row lock(s), undo log entries 1
MySQL thread id 1, query id 958 localhost msandbox
SHOW ENGINE INNODB STATUS
TABLE LOCK table `mysql`.`t` trx id 0 2312 lock mode IS
RECORD LOCKS space id 0 page no 56 n bits 72 index `GEN_CLUST_INDEX` of table `m
ysql`.`t` trx id 0 2312 lock mode S
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
 0: len 8; hex 73757072656d756d; asc supremum;;

Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 32
 0: len 6; hex 000000000300; asc         ;; 1: len 6; hex 000000000908; asc
;; 2: len 7; hex 00000000320a51; asc     2 Q;; 3: len 4; hex 80000001; asc     ;
;

TABLE LOCK table `mysql`.`t` trx id 0 2312 lock mode IX
RECORD LOCKS space id 0 page no 56 n bits 72 index `GEN_CLUST_INDEX` of table `m
ysql`.`t` trx id 0 2312 lock_mode X
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
 0: len 8; hex 73757072656d756d; asc supremum;;

Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 32
 0: len 6; hex 000000000300; asc         ;; 1: len 6; hex 000000000908; asc
;; 2: len 7; hex 00000000320a51; asc     2 Q;; 3: len 4; hex 80000001; asc     ;
;

--------
FILE I/O
--------
I/O thread 0 state: waiting for i/o request (insert buffer thread)
I/O thread 1 state: waiting for i/o request (log thread)
I/O thread 2 state: waiting for i/o request (read thread)
```

```
I/O thread 3 state: waiting for i/o request (write thread)
Pending normal aio reads: 0, aio writes: 0,
 ibuf aio reads: 0, log i/o's: 0, sync i/o's: 0
Pending flushes (fsync) log: 0; buffer pool: 0
5934 OS file reads, 14161 OS file writes, 4182 OS fsyncs
12.22 reads/s, 39023 avg bytes/read, 38.00 writes/s, 11.33 fsyncs/s
-----------------------------------
INSERT BUFFER AND ADAPTIVE HASH INDEX
-----------------------------------
Ibuf: size 1, free list len 0, seg size 2,
0 inserts, 0 merged recs, 0 merges
Hash table size 17393, node heap has 79 buffer(s)
73846.91 hash searches/s, 1343.52 non-hash searches/s
---
LOG
---
Log sequence number 0 1509321681
Log flushed up to   0 1509321681
Last checkpoint at  0 1506336310
0 pending log writes, 0 pending chkp writes
5287 log i/o's done, 14.55 log i/o's/second
----------------------
BUFFER POOL AND MEMORY
----------------------
Total memory allocated 20644802; in additional pool allocated 852992
Dictionary memory allocated 88200
Buffer pool size    512
Free buffers        2
Database pages      431
Modified db pages   110
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages read 15891, created 51023, written 61061
29.11 reads/s, 137.21 creates/s, 145.76 writes/s
Buffer pool hit rate 1000 / 1000
--------------
ROW OPERATIONS
--------------
0 queries inside InnoDB, 0 queries in queue
1 read views open inside InnoDB
Main thread process no. 4615, id 140008618981120, state: sleeping
Number of rows inserted 16050922, updated 0, deleted 3, read 4
41645.71 inserts/s, 0.00 updates/s, 0.00 deletes/s, 0.00 reads/s
----------------------------
END OF INNODB MONITOR OUTPUT
============================
```

InnoDB Monitor output is limited to 64,000 bytes when produced using the SHOW ENGINE INNODB STATUS statement. This limit does not apply to output written to the server's error output.

Some notes on the output sections:

Status

This section shows the timestamp, the monitor name, and the number of seconds that per-second averages are based on. The number of seconds is the elapsed time between the current time and the last time InnoDB Monitor output was printed.

BACKGROUND THREAD

The srv_master_thread lines shows work done by the main background thread. This section is displayed only by InnoDB Plugin.

SEMAPHORES

This section reports threads waiting for a semaphore and statistics on how many times threads have needed a spin or a wait on a mutex or a rw-lock semaphore. A large number of threads waiting for semaphores may be a result of disk I/O, or contention problems inside `InnoDB`. Contention can be due to heavy parallelism of queries or problems in operating system thread scheduling. Setting the `innodb_thread_concurrency` system variable smaller than the default value might help in such situations. The `Spin rounds per wait` line (`InnoDB Plugin` only) shows the number of spinlock rounds per OS wait for a mutex.

LATEST FOREIGN KEY ERROR

This section provides information about the most recent foreign key constraint error. It is not present if no such error has occurred. The contents include the statement that failed as well as information about the constraint that failed and the referenced and referencing tables.

LATEST DETECTED DEADLOCK

This section provides information about the most recent deadlock. It is not present if no deadlock has occurred. The contents show which transactions are involved, the statement each was attempting to execute, the locks they have and need, and which transaction `InnoDB` decided to roll back to break the deadlock. The lock modes reported in this section are explained in Section 14.6.4.1, "InnoDB Lock Modes".

TRANSACTIONS

If this section reports lock waits, your applications might have lock contention. The output can also help to trace the reasons for transaction deadlocks.

FILE I/O

This section provides information about threads that `InnoDB` uses to perform various types of I/O. The first few of these are dedicated to general `InnoDB` processing. The contents also display information for pending I/O operations and statistics for I/O performance.

On Unix, the number of threads is always 4. On Windows, the number depends on the setting of the `innodb_file_io_threads` system variable.

INSERT BUFFER AND ADAPTIVE HASH INDEX

This section shows the status of the `InnoDB` insert buffer and adaptive hash index. (See Insert Buffering, and Adaptive Hash Indexes.) The contents include the number of operations performed for each, plus statistics for hash index performance.

LOG

This section displays information about the `InnoDB` log. The contents include the current log sequence number, how far the log has been flushed to disk, and the position at which `InnoDB` last took a checkpoint. (See Section 14.6.10.2, "InnoDB Checkpoints".) The section also displays information about pending writes and write performance statistics.

BUFFER POOL AND MEMORY

This section gives you statistics on pages read and written. You can calculate from these numbers how many data file I/O operations your queries currently are doing.

For additional information about the operation of the buffer pool, see Section 8.10.2, "The InnoDB Buffer Pool".

ROW OPERATIONS

This section shows what the main thread is doing, including the number and performance rate for each type of row operation.

14.6.9.2 InnoDB Tablespace Monitor Output

The `InnoDB` Tablespace Monitor prints information about the file segments in the shared tablespace and validates the tablespace allocation data structures. If you use individual tablespaces by enabling `innodb_file_per_table`, the Tablespace Monitor does not describe those tablespaces.

Example `InnoDB` Tablespace Monitor output:

```
================================================
090408 21:28:09 INNODB TABLESPACE MONITOR OUTPUT
================================================
FILE SPACE INFO: id 0
size 13440, free limit 3136, free extents 28
not full frag extents 2: used pages 78, full frag extents 3
first seg id not used 0 23845
SEGMENT id 0 1 space 0; page 2; res 96 used 46; full ext 0
fragm pages 32; free extents 0; not full extents 1: pages 14
SEGMENT id 0 2 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
SEGMENT id 0 3 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
...
SEGMENT id 0 15 space 0; page 2; res 160 used 160; full ext 2
fragm pages 32; free extents 0; not full extents 0: pages 0
SEGMENT id 0 488 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
SEGMENT id 0 17 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
...
SEGMENT id 0 171 space 0; page 2; res 592 used 481; full ext 7
fragm pages 16; free extents 0; not full extents 2: pages 17
SEGMENT id 0 172 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
SEGMENT id 0 173 space 0; page 2; res 96 used 44; full ext 0
fragm pages 32; free extents 0; not full extents 1: pages 12
...
SEGMENT id 0 601 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
NUMBER of file segments: 73
Validating tablespace
Validation ok
-------------------------------------
END OF INNODB TABLESPACE MONITOR OUTPUT
=====================================
```

The Tablespace Monitor output includes information about the shared tablespace as a whole, followed by a list containing a breakdown for each segment within the tablespace.

The tablespace consists of database pages with a default size of 16KB. The pages are grouped into extents of size 1MB (64 consecutive pages).

The initial part of the output that displays overall tablespace information has this format:

```
FILE SPACE INFO: id 0
size 13440, free limit 3136, free extents 28
not full frag extents 2: used pages 78, full frag extents 3
first seg id not used 0 23845
```

Overall tablespace information includes these values:

- `id`: The tablespace ID. A value of 0 refers to the shared tablespace.

- `size`: The current tablespace size in pages.

- `free limit`: The minimum page number for which the free list has not been initialized. Pages at or above this limit are free.

- `free extents`: The number of free extents.

- `not full frag extents`, `used pages`: The number of fragment extents that are not completely filled, and the number of pages in those extents that have been allocated.

- `full frag extents`: The number of completely full fragment extents.

- `first seg id not used`: The first unused segment ID.

Individual segment information has this format:

```
SEGMENT id 0 15 space 0; page 2; res 160 used 160; full ext 2
fragm pages 32; free extents 0; not full extents 0: pages 0
```

Segment information includes these values:

`id`: The segment ID.

`space`, `page`: The tablespace number and page within the tablespace where the segment "inode" is located. A tablespace number of 0 indicates the shared tablespace. `InnoDB` uses inodes to keep track of segments in the tablespace. The other fields displayed for a segment (`id`, `res`, and so forth) are derived from information in the inode.

`res`: The number of pages allocated (reserved) for the segment.

`used`: The number of allocated pages in use by the segment.

`full ext`: The number of extents allocated for the segment that are completely used.

`fragm pages`: The number of initial pages that have been allocated to the segment.

`free extents`: The number of extents allocated for the segment that are completely unused.

`not full extents`: The number of extents allocated for the segment that are partially used.

`pages`: The number of pages used within the not-full extents.

When a segment grows, it starts as a single page, and `InnoDB` allocates the first pages for it individually, up to 32 pages (this is the `fragm pages` value). After that, `InnoDB` allocates complete 64-page extents. `InnoDB` can add up to 4 extents at a time to a large segment to ensure good sequentiality of data.

For the example segment shown earlier, it has 32 fragment pages, plus 2 full extents (64 pages each), for a total of 160 pages used out of 160 pages allocated. The following segment has 32 fragment pages and one partially full extent using 14 pages for a total of 46 pages used out of 96 pages allocated:

```
SEGMENT id 0 1 space 0; page 2; res 96 used 46; full ext 0
fragm pages 32; free extents 0; not full extents 1: pages 14
```

It is possible for a segment that has extents allocated to it to have a `fragm pages` value less than 32 if some of the individual pages have been deallocated subsequent to extent allocation.

14.6.9.3 InnoDB Table Monitor Output

The `InnoDB` Table Monitor prints the contents of the `InnoDB` internal data dictionary.

The output contains one section per table. The `SYS_FOREIGN` and `SYS_FOREIGN_COLS` sections are for internal data dictionary tables that maintain information about foreign keys. There are also sections for the Table Monitor table and each user-created `InnoDB` table. Suppose that the following two tables have been created in the `test` database:

```
CREATE TABLE parent
(
  par_id     INT NOT NULL,
  fname      CHAR(20),
  lname      CHAR(20),
  PRIMARY KEY (par_id),
  UNIQUE INDEX (lname, fname)
) ENGINE = INNODB;

CREATE TABLE child
(
  par_id      INT NOT NULL,
  child_id    INT NOT NULL,
  name        VARCHAR(40),
  birth       DATE,
  weight      DECIMAL(10,2),
  misc_info   VARCHAR(255),
  last_update TIMESTAMP,
  PRIMARY KEY (par_id, child_id),
  INDEX (name),
  FOREIGN KEY (par_id) REFERENCES parent (par_id)
    ON DELETE CASCADE
    ON UPDATE CASCADE
) ENGINE = INNODB;
```

Then the Table Monitor output will look something like this (reformatted slightly):

```
==========================================
090420 12:09:32 INNODB TABLE MONITOR OUTPUT
==========================================
--------------------------------------
TABLE: name SYS_FOREIGN, id 0 11, columns 7, indexes 3, appr.rows 1
  COLUMNS: ID: DATA_VARCHAR DATA_ENGLISH len 0;
           FOR_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           REF_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           N_COLS: DATA_INT len 4;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name ID_IND, id 0 11, fields 1/6, uniq 1, type 3
   root page 46, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:   ID DB_TRX_ID DB_ROLL_PTR FOR_NAME REF_NAME N_COLS
  INDEX: name FOR_IND, id 0 12, fields 1/2, uniq 2, type 0
   root page 47, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:   FOR_NAME ID
  INDEX: name REF_IND, id 0 13, fields 1/2, uniq 2, type 0
   root page 48, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:   REF_NAME ID
--------------------------------------
TABLE: name SYS_FOREIGN_COLS, id 0 12, columns 7, indexes 1, appr.rows 1
  COLUMNS: ID: DATA_VARCHAR DATA_ENGLISH len 0;
           POS: DATA_INT len 4;
           FOR_COL_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           REF_COL_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
```

```
   INDEX: name ID_IND, id 0 14, fields 2/6, uniq 2, type 3
    root page 49, appr.key vals 1, leaf pages 1, size pages 1
    FIELDS:  ID POS DB_TRX_ID DB_ROLL_PTR FOR_COL_NAME REF_COL_NAME
--------------------------------------
TABLE: name test/child, id 0 14, columns 10, indexes 2, appr.rows 201
  COLUMNS: par_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           child_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           name: DATA_VARCHAR prtype 524303 len 40;
           birth: DATA_INT DATA_BINARY_TYPE len 3;
           weight: DATA_FIXBINARY DATA_BINARY_TYPE len 5;
           misc_info: DATA_VARCHAR prtype 524303 len 255;
           last_update: DATA_INT DATA_UNSIGNED DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name PRIMARY, id 0 17, fields 2/9, uniq 2, type 3
   root page 52, appr.key vals 201, leaf pages 5, size pages 6
   FIELDS:  par_id child_id DB_TRX_ID DB_ROLL_PTR name birth weight misc_info last_update
  INDEX: name name, id 0 18, fields 1/3, uniq 3, type 0
   root page 53, appr.key vals 210, leaf pages 1, size pages 1
   FIELDS:  name par_id child_id
  FOREIGN KEY CONSTRAINT test/child_ibfk_1: test/child ( par_id )
            REFERENCES test/parent ( par_id )
--------------------------------------
TABLE: name test/innodb_table_monitor, id 0 15, columns 4, indexes 1, appr.rows 0
  COLUMNS: i: DATA_INT DATA_BINARY_TYPE len 4;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name GEN_CLUST_INDEX, id 0 19, fields 0/4, uniq 1, type 1
   root page 193, appr.key vals 0, leaf pages 1, size pages 1
   FIELDS:  DB_ROW_ID DB_TRX_ID DB_ROLL_PTR i
--------------------------------------
TABLE: name test/parent, id 0 13, columns 6, indexes 2, appr.rows 299
  COLUMNS: par_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           fname: DATA_CHAR prtype 524542 len 20;
           lname: DATA_CHAR prtype 524542 len 20;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name PRIMARY, id 0 15, fields 1/5, uniq 1, type 3
   root page 50, appr.key vals 299, leaf pages 2, size pages 3
   FIELDS:  par_id DB_TRX_ID DB_ROLL_PTR fname lname
  INDEX: name lname, id 0 16, fields 2/3, uniq 2, type 2
   root page 51, appr.key vals 300, leaf pages 1, size pages 1
   FIELDS:  lname fname par_id
  FOREIGN KEY CONSTRAINT test/child_ibfk_1: test/child ( par_id )
            REFERENCES test/parent ( par_id )
--------------------------------
END OF INNODB TABLE MONITOR OUTPUT
==================================
```

For each table, Table Monitor output contains a section that displays general information about the table and specific information about its columns, indexes, and foreign keys.

The general information for each table includes the table name (in `db_name`/`tbl_name` format except for internal tables), its ID, the number of columns and indexes, and an approximate row count.

The `COLUMNS` part of a table section lists each column in the table. Information for each column indicates its name and data type characteristics. Some internal columns are added by `InnoDB`, such as `DB_ROW_ID` (row ID), `DB_TRX_ID` (transaction ID), and `DB_ROLL_PTR` (a pointer to the rollback/undo data).

- `DATA_xxx`: These symbols indicate the data type. There may be multiple `DATA_xxx` symbols for a given column.

- `prtype`: The column's "precise" type. This field includes information such as the column data type, character set code, nullability, signedness, and whether it is a binary string. This field is described in the `innobase/include/data0type.h` source file.

- `len`: The column length in bytes.

Each `INDEX` part of the table section provides the name and characteristics of one table index:

- `name`: The index name. If the name is `PRIMARY`, the index is a primary key. If the name is `GEN_CLUST_INDEX`, the index is the clustered index that is created automatically if the table definition doesn't include a primary key or non-`NULL` unique index. See Clustered and Secondary Indexes.

- `id`: The index ID.

- `fields`: The number of fields in the index, as a value in m/n format:

  - m is the number of user-defined columns; that is, the number of columns you would see in the index definition in a `CREATE TABLE` statement.

  - n is the total number of index columns, including those added internally. For the clustered index, the total includes the other columns in the table definition, plus any columns added internally. For a secondary index, the total includes the columns from the primary key that are not part of the secondary index.

- `uniq`: The number of leading fields that are enough to determine index values uniquely.

- `type`: The index type. This is a bit field. For example, 1 indicates a clustered index and 2 indicates a unique index, so a clustered index (which always contains unique values), will have a `type` value of 3. An index with a `type` value of 0 is neither clustered nor unique. The flag values are defined in the `innobase/include/dict0mem.h` source file.

- `root page`: The index root page number.

- `appr. key vals`: The approximate index cardinality.

- `leaf pages`: The approximate number of leaf pages in the index.

- `size pages`: The approximate total number of pages in the index.

- `FIELDS`: The names of the fields in the index. For a clustered index that was generated automatically, the field list begins with the internal `DB_ROW_ID` (row ID) field. `DB_TRX_ID` and `DB_ROLL_PTR` are always added internally to the clustered index, following the fields that comprise the primary key. For a secondary index, the final fields are those from the primary key that are not part of the secondary index.

The end of the table section lists the `FOREIGN KEY` definitions that apply to the table. This information appears whether the table is a referencing or referenced table.

14.6.10 InnoDB Backup and Recovery

The key to safe database management is making regular backups. Depending on your data volume, number of MySQL servers, and database workload, you can use these techniques, alone or in combination: hot backup with MySQL Enterprise Backup; cold backup by copying files while the MySQL server is shut down; physical backup for fast operation (especially for restore); logical backup with `mysqldump` for smaller data volumes or to record the structure of schema objects.

Hot Backups

The `mysqlbackup` command, part of the MySQL Enterprise Backup component, lets you back up a running MySQL instance, including `InnoDB` and `MyISAM` tables, with minimal disruption to operations while producing a consistent snapshot of the database. When `mysqlbackup` is copying `InnoDB` tables, reads and writes to both `InnoDB` and `MyISAM` tables can continue. During the copying of `MyISAM` tables, reads

(but not writes) to those tables are permitted. MySQL Enterprise Backup can also create compressed backup files, and back up subsets of tables and databases. In conjunction with MySQL's binary log, users can perform point-in-time recovery. MySQL Enterprise Backup is part of the MySQL Enterprise subscription. For more details, see Section 23.2, "MySQL Enterprise Backup Overview".

Cold Backups

If you can shut down your MySQL server, you can make a binary backup that consists of all files used by `InnoDB` to manage its tables. Use the following procedure:

1. Do a slow shutdown of the MySQL server and make sure that it stops without errors.

2. Copy all `InnoDB` data files (`ibdata` files and `.ibd` files) into a safe place.

3. Copy all the `.frm` files for `InnoDB` tables to a safe place.

4. Copy all `InnoDB` log files (`ib_logfile` files) to a safe place.

5. Copy your `my.cnf` configuration file or files to a safe place.

Alternative Backup Types

In addition to making binary backups as just described, regularly make dumps of your tables with `mysqldump`. A binary file might be corrupted without you noticing it. Dumped tables are stored into text files that are human-readable, so spotting table corruption becomes easier. Also, because the format is simpler, the chance for serious data corruption is smaller. `mysqldump` also has a `--single-transaction` option for making a consistent snapshot without locking out other clients. See Section 7.3.1, "Establishing a Backup Policy".

Replication works with `InnoDB` tables, so you can use MySQL replication capabilities to keep a copy of your database at database sites requiring high availability.

Performing Recovery

To recover your `InnoDB` database to the present from the time at which the binary backup was made, you must run your MySQL server with binary logging turned on, even before taking the backup. To achieve point-in-time recovery after restoring a backup, you can apply changes from the binary log that occurred after the backup was made. See Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log".

To recover from a crash of your MySQL server, the only requirement is to restart it. `InnoDB` automatically checks the logs and performs a roll-forward of the database to the present. `InnoDB` automatically rolls back uncommitted transactions that were present at the time of the crash. During recovery, `mysqld` displays output something like this:

```
InnoDB: Database was not shut down normally.
InnoDB: Starting recovery from log files...
InnoDB: Starting log scan based on checkpoint at
InnoDB: log sequence number 0 13674004
InnoDB: Doing recovery: scanned up to log sequence number 0 13739520
InnoDB: Doing recovery: scanned up to log sequence number 0 13805056
InnoDB: Doing recovery: scanned up to log sequence number 0 13870592
InnoDB: Doing recovery: scanned up to log sequence number 0 13936128
...
InnoDB: Doing recovery: scanned up to log sequence number 0 20555264
InnoDB: Doing recovery: scanned up to log sequence number 0 20620800
InnoDB: Doing recovery: scanned up to log sequence number 0 20664692
InnoDB: 1 uncommitted transaction(s) which must be rolled back
InnoDB: Starting rollback of uncommitted transactions
```

```
InnoDB: Rolling back trx no 16745
InnoDB: Rolling back of trx no 16745 completed
InnoDB: Rollback of uncommitted transactions completed
InnoDB: Starting an apply batch of log records to the database...
InnoDB: Apply batch completed
InnoDB: Started
mysqld: ready for connections
```

If your database becomes corrupted or disk failure occurs, you must perform the recovery using a backup. In the case of corruption, first find a backup that is not corrupted. After restoring the base backup, do a point-in-time recovery from the binary log files using `mysqlbinlog` and `mysql` to restore the changes that occurred after the backup was made.

In some cases of database corruption, it is enough just to dump, drop, and re-create one or a few corrupt tables. You can use the `CHECK TABLE` SQL statement to check whether a table is corrupt, although `CHECK TABLE` naturally cannot detect every possible kind of corruption. You can use the Tablespace Monitor to check the integrity of the file space management inside the tablespace files.

In some cases, apparent database page corruption is actually due to the operating system corrupting its own file cache, and the data on disk may be okay. It is best first to try restarting your computer. Doing so may eliminate errors that appeared to be database page corruption. If MySQL still has trouble starting because of `InnoDB` consistency problems, see Section 14.6.12.2, "Forcing InnoDB Recovery" for steps to start the instance in a diagnostic mode where you can dump the data.

14.6.10.1 The InnoDB Recovery Process

`InnoDB` crash recovery consists of several steps:

- Applying the redo log: Redo log application is the first step and is performed during initialization, before accepting any connections. If all changes were flushed from the buffer pool to the tablespaces (`ibdata*` and `*.ibd` files) at the time of the shutdown or crash, the redo log application can be skipped. If the redo log files are missing at startup, `InnoDB` skips the redo log application.

  Removing redo logs to speed up the recovery process is not recommended, even if some data loss is acceptable. Removing redo logs should only be considered an option after a clean shutdown is performed, with `innodb_fast_shutdown` set to `0` or `1`.

- Rolling back incomplete transactions: Any transactions that were active at the time of crash or fast shutdown. The time it takes to roll back an incomplete transaction can be three or four times the amount of time a transaction is active before it is interrupted, depending on server load.

  You cannot cancel transactions that are in the process of being rolled back. In extreme cases, when rolling back transactions is expected to take an exceptionally long time, it may be faster to start `InnoDB` with an `innodb_force_recovery` setting of `3` or greater. See Section 14.6.12.2, "Forcing InnoDB Recovery" for more information.

- Insert buffer merge: Applying changes from the insert buffer (part of the system tablespace) to leaf pages of secondary indexes, as the index pages are read to the buffer pool.

- Purge: Deleting delete-marked records that are no longer visible for any active transaction.

The steps that follow redo log application do not depend on the redo log (other than for logging the writes) and are performed in parallel with normal processing. Of these, only rollback of incomplete transactions is special to crash recovery. The insert buffer merge and the purge are performed during normal processing.

After redo log application, `InnoDB` attempts to accept connections as early as possible, to reduce downtime. As part of crash recovery, `InnoDB` rolls back any transactions that were not committed or in `XA PREPARE` state when the server crashed. The rollback is performed by a background thread, executed in

parallel with transactions from new connections. Until the rollback operation is completed, new connections may encounter locking conflicts with recovered transactions.

In most situations, even if the MySQL server was killed unexpectedly in the middle of heavy activity, the recovery process happens automatically and no action is needed from the DBA. If a hardware failure or severe system error corrupted `InnoDB` data, MySQL might refuse to start. In that case, see Section 14.6.12.2, "Forcing InnoDB Recovery" for the steps to troubleshoot such an issue.

For information about the binary log and `InnoDB` crash recovery, see Section 5.4.4, "The Binary Log".

14.6.10.2 InnoDB Checkpoints

`InnoDB` implements a checkpoint mechanism known as "fuzzy" checkpointing. `InnoDB` flushes modified database pages from the buffer pool in small batches. There is no need to flush the buffer pool in one single batch, which would in practice stop processing of user SQL statements during the checkpointing process.

During crash recovery, `InnoDB` looks for a checkpoint label written to the log files. It knows that all modifications to the database before the label are present in the disk image of the database. Then `InnoDB` scans the log files forward from the checkpoint, applying the logged modifications to the database.

`InnoDB` writes to its log files on a rotating basis. It also writes checkpoint information to the first log file at each checkpoint. All committed modifications that make the database pages in the buffer pool different from the images on disk must be available in the log files in case `InnoDB` has to do a recovery. This means that when `InnoDB` starts to reuse a log file, it has to make sure that the database page images on disk contain the modifications logged in the log file that `InnoDB` is going to reuse. In other words, `InnoDB` must create a checkpoint and this often involves flushing of modified database pages to disk.

The preceding description explains why making your log files very large may reduce disk I/O in checkpointing. It often makes sense to set the total size of the log files as large as the buffer pool or even larger. The disadvantage of using large log files is that crash recovery can take longer because there is more logged information to apply to the database.

14.6.11 InnoDB and MySQL Replication

MySQL replication works for `InnoDB` tables as it does for `MyISAM` tables. It is also possible to use replication in a way where the storage engine on the slave is not the same as the original storage engine on the master. For example, you can replicate modifications to an `InnoDB` table on the master to a `MyISAM` table on the slave.

To set up a new slave for a master, make a copy of the `InnoDB` tablespace and the log files, as well as the `.frm` files of the `InnoDB` tables, and move the copies to the slave. If the `innodb_file_per_table` option is enabled, copy the `.ibd` files as well. For the proper procedure to do this, see Section 14.6.10, "InnoDB Backup and Recovery".

To make a new slave without taking down the master or an existing slave, use the MySQL Enterprise Backup product. If you can shut down the master or an existing slave, take a cold backup of the `InnoDB` tablespaces and log files and use that to set up a slave.

You cannot set up replication for `InnoDB` using the `LOAD TABLE FROM MASTER` statement, which works only for `MyISAM` tables. There are two possible workarounds:

- Dump the table on the master and import the dump file into the slave.

- Use `ALTER TABLE tbl_name ENGINE=MyISAM` on the master before setting up replication with `LOAD TABLE tbl_name FROM MASTER`, and then use `ALTER TABLE` to convert the master table back to

InnoDB afterward. However, this should not be done for tables that have foreign key definitions because the definitions will be lost.

Transactions that fail on the master do not affect replication at all. MySQL replication is based on the binary log where MySQL writes SQL statements that modify data. A transaction that fails (for example, because of a foreign key violation, or because it is rolled back) is not written to the binary log, so it is not sent to slaves. See Section 13.3.1, "START TRANSACTION, COMMIT, and ROLLBACK Syntax".

Replication and CASCADE. Cascading actions for InnoDB tables on the master are replicated on the slave *only* if the tables sharing the foreign key relation use InnoDB on both the master and slave. This is true whether you are using statement-based or row-based replication. Suppose that you have started replication, and then create two tables on the master using the following CREATE TABLE statements:

```
CREATE TABLE fc1 (
    i INT PRIMARY KEY,
    j INT
) ENGINE = InnoDB;

CREATE TABLE fc2 (
    m INT PRIMARY KEY,
    n INT,
    FOREIGN KEY ni (n) REFERENCES fc1 (i)
        ON DELETE CASCADE
) ENGINE = InnoDB;
```

Suppose that the slave does not have InnoDB support enabled. If this is the case, then the tables on the slave are created, but they use the MyISAM storage engine, and the FOREIGN KEY option is ignored. Now we insert some rows into the tables on the master:

```
master> INSERT INTO fc1 VALUES (1, 1), (2, 2);
Query OK, 2 rows affected (0.09 sec)
Records: 2  Duplicates: 0  Warnings: 0

master> INSERT INTO fc2 VALUES (1, 1), (2, 2), (3, 1);
Query OK, 3 rows affected (0.19 sec)
Records: 3  Duplicates: 0  Warnings: 0
```

At this point, on both the master and the slave, table fc1 contains 2 rows, and table fc2 contains 3 rows, as shown here:

```
master> SELECT * FROM fc1;
+---+------+
| i | j    |
+---+------+
| 1 |    1 |
| 2 |    2 |
+---+------+
2 rows in set (0.00 sec)

master> SELECT * FROM fc2;
+---+------+
| m | n    |
+---+------+
| 1 |    1 |
| 2 |    2 |
| 3 |    1 |
+---+------+
3 rows in set (0.00 sec)

slave> SELECT * FROM fc1;
```

```
+---+------+
| i | j    |
+---+------+
| 1 |    1 |
| 2 |    2 |
+---+------+
2 rows in set (0.00 sec)

slave> SELECT * FROM fc2;
+---+------+
| m | n    |
+---+------+
| 1 |    1 |
| 2 |    2 |
| 3 |    1 |
+---+------+
3 rows in set (0.00 sec)
```

Now suppose that you perform the following DELETE statement on the master:

```
master> DELETE FROM fc1 WHERE i=1;
Query OK, 1 row affected (0.09 sec)
```

Due to the cascade, table `fc2` on the master now contains only 1 row:

```
master> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 2 | 2 |
+---+---+
1 row in set (0.00 sec)
```

However, the cascade does not propagate on the slave because on the slave the DELETE for `fc1` deletes no rows from `fc2`. The slave's copy of `fc2` still contains all of the rows that were originally inserted:

```
slave> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 1 | 1 |
| 3 | 1 |
| 2 | 2 |
+---+---+
3 rows in set (0.00 sec)
```

This difference is due to the fact that the cascading deletes are handled internally by the InnoDB storage engine, which means that none of the changes are logged.

14.6.12 InnoDB Troubleshooting

The following general guidelines apply to troubleshooting InnoDB problems:

- When an operation fails or you suspect a bug, look at the MySQL server error log (see Section 5.4.2, "The Error Log"). Section B.3, "Server Error Codes and Messages" provides troubleshooting information for some of the common InnoDB-specific errors that you may encounter.

- Issues relating to the InnoDB data dictionary include failed CREATE TABLE statements (orphan table files), inability to open .InnoDB files, and system cannot find the path specified errors. For

information about these sorts of problems and errors, see Section 14.6.12.3, "Troubleshooting InnoDB Data Dictionary Operations".

- When troubleshooting, it is usually best to run the MySQL server from the command prompt, rather than through `mysqld_safe` or as a Windows service. You can then see what `mysqld` prints to the console, and so have a better grasp of what is going on. On Windows, start `mysqld` with the `--console` option to direct the output to the console window.

- Enable the `InnoDB` Monitors to obtain information about a problem (see Section 14.6.9, "InnoDB Monitors"). If the problem is performance-related, or your server appears to be hung, you should enable the standard Monitor to print information about the internal state of `InnoDB`. If the problem is with locks, enable the Lock Monitor. If the problem is in creation of tables or other data dictionary operations, enable the Table Monitor to print the contents of the `InnoDB` internal data dictionary. To see tablespace information enable the Tablespace Monitor.

  `InnoDB` temporarily enables standard `InnoDB` Monitor output under the following conditions:

  - A long semaphore wait

  - `InnoDB` cannot find free blocks in the buffer pool

  - Over 67% of the buffer pool is occupied by lock heaps or the adaptive hash index

- If you suspect that a table is corrupt, run `CHECK TABLE` on that table.

14.6.12.1 Dealing with InnoDB Initialization Problems

If `InnoDB` prints an operating system error during a file operation, usually the problem has one of the following causes:

- You did not create the `InnoDB` data file directory or the `InnoDB` log directory.

- `mysqld` does not have access rights to create files in those directories.

- `mysqld` cannot read the proper `my.cnf` or `my.ini` option file, and consequently does not see the options that you specified.

- The disk is full or a disk quota is exceeded.

- You have created a subdirectory whose name is equal to a data file that you specified, so the name cannot be used as a file name.

- There is a syntax error in the `innodb_data_home_dir` or `innodb_data_file_path` value.

If something goes wrong when `InnoDB` attempts to initialize its tablespace or its log files, delete all files created by `InnoDB`. This means all `ibdata` files and all `ib_logfile` files. In case you have already created some `InnoDB` tables, delete the corresponding `.frm` files for these tables (and any `.ibd` files if you are using multiple tablespaces) from the MySQL database directories as well. Then you can try the `InnoDB` database creation again. It is best to start the MySQL server from a command prompt so that you see what is happening.

14.6.12.2 Forcing InnoDB Recovery

If there is database page corruption, you may want to dump your tables from the database with `SELECT ... INTO OUTFILE`. Usually, most of the data obtained in this way is intact. However, it is possible that the corruption might cause `SELECT * FROM` *tbl_name* statements or `InnoDB` background operations to crash or assert, or even cause `InnoDB` roll-forward recovery to crash. In such cases, you can use the `innodb_force_recovery` option to force the `InnoDB` storage engine to start up while

preventing background operations from running, so that you can dump your tables. For example, you can add the following line to the `[mysqld]` section of your option file before restarting the server:

```
[mysqld]
innodb_force_recovery = 1
```

> **Warning**
>
> Only set `innodb_force_recovery` to a value greater than 0 in an emergency situation, so that you can start `InnoDB` and dump your tables. Before doing so, ensure that you have a backup copy of your database in case you need to recreate it. Values of 4 or greater can permanently corrupt data files. Only use an `innodb_force_recovery` setting of 4 or greater on a production server instance after you have successfully tested the setting on separate physical copy of your database. When forcing `InnoDB` recovery, you should always start with `innodb_force_recovery=1` and only increase the value incrementally, as necessary.

`innodb_force_recovery` is 0 by default (normal startup without forced recovery). The permissible nonzero values for `innodb_force_recovery` are 1 to 6. A larger value includes the functionality of lesser values. For example, a value of 3 includes all of the functionality of values 1 and 2.

If you are able to dump your tables with an `innodb_force_recovery` value of 3 or less, then you are relatively safe that only some data on corrupt individual pages is lost. A value of 4 or greater is considered dangerous because data files can be permanently corrupted. A value of 6 is considered drastic because database pages are left in an obsolete state, which in turn may introduce more corruption into B-trees and other database structures.

As a safety measure, `InnoDB` prevents users from performing `INSERT`, `UPDATE`, or `DELETE` operations when `innodb_force_recovery` is greater than 0.

- 1 (`SRV_FORCE_IGNORE_CORRUPT`)

  Let the server run even if it detects a corrupt page. Try to make `SELECT * FROM` *tbl_name* jump over corrupt index records and pages, which helps in dumping tables.

- 2 (`SRV_FORCE_NO_BACKGROUND`)

  Prevent the master thread from running. If a crash would occur during the purge operation, this recovery value prevents it.

- 3 (`SRV_FORCE_NO_TRX_UNDO`)

  Do not run transaction rollbacks after crash recovery.

- 4 (`SRV_FORCE_NO_IBUF_MERGE`)

  Prevent insert buffer merge operations. If they would cause a crash, do not do them. Do not calculate table statistics. This value can permanently corrupt data files. After using this value, be prepared to drop and recreate all secondary indexes.

- 5 (`SRV_FORCE_NO_UNDO_LOG_SCAN`)

  Do not look at undo logs when starting the database: `InnoDB` treats even incomplete transactions as committed. This value can permanently corrupt data files.

- 6 (`SRV_FORCE_NO_LOG_REDO`)

Do not do the redo log roll-forward in connection with recovery. This value can permanently corrupt data files. Leaves database pages in an obsolete state, which in turn may introduce more corruption into B-trees and other database structures.

You can `SELECT` from tables to dump them, or `DROP` or `CREATE` tables even if forced recovery is used. If you know that a given table is causing a crash on rollback, you can drop it. You can also use this to stop a runaway rollback caused by a failing mass import or `ALTER TABLE`. You can kill the `mysqld` process and set `innodb_force_recovery` to `3` to bring the database up without the rollback, then `DROP` the table that is causing the runaway rollback.

If corruption within the table data prevents you from dumping the entire table contents, a query with an `ORDER BY` `primary_key` `DESC` clause might be able to dump the portion of the table after the corrupted part.

If a high `innodb_force_recovery` value is required to start `InnoDB`, there may be corrupted data structures that could cause complex queries (queries containing `WHERE`, `ORDER BY`, or other clauses) to fail. In this case, you may only be able to run basic `SELECT * FROM t` queries.

14.6.12.3 Troubleshooting InnoDB Data Dictionary Operations

A specific issue with tables is that the MySQL server keeps data dictionary information in `.frm` files it stores in the database directories, whereas `InnoDB` also stores the information into its own data dictionary inside the tablespace files. If you move `.frm` files around, or if the server crashes in the middle of a data dictionary operation, the locations of the `.frm` files may end up out of synchrony with the locations recorded in the `InnoDB` internal data dictionary.

If a data dictionary corruption or consistency issue prevents you from starting `InnoDB`, see Section 14.6.12.2, "Forcing InnoDB Recovery" for information about manual recovery.

CREATE TABLE Failure Due to Orphan Table

A symptom of an out-of-sync data dictionary is that a `CREATE TABLE` statement fails. If this occurs, look in the server's error log. If the log says that the table already exists inside the `InnoDB` internal data dictionary, you have an orphan table inside the `InnoDB` tablespace files that has no corresponding `.frm` file. The error message looks like this:

```
InnoDB: Error: table test/parent already exists in InnoDB internal
InnoDB: data dictionary. Have you deleted the .frm file
InnoDB: and not used DROP TABLE? Have you used DROP DATABASE
InnoDB: for InnoDB tables in MySQL version <= 3.23.43?
InnoDB: See the Restrictions section of the InnoDB manual.
InnoDB: You can drop the orphaned table inside InnoDB by
InnoDB: creating an InnoDB table with the same name in another
InnoDB: database and moving the .frm file to the current database.
InnoDB: Then MySQL thinks the table exists, and DROP TABLE will
InnoDB: succeed.
```

You can drop the orphan table by following the instructions given in the error message. If you are still unable to use `DROP TABLE` successfully, the problem may be due to name completion in the `mysql` client. To work around this problem, start the `mysql` client with the `--skip-auto-rehash` option and try `DROP TABLE` again. (With name completion on, `mysql` tries to construct a list of table names, which fails when a problem such as just described exists.)

Cannot Open File Error

Another symptom of an out-of-sync data dictionary is that MySQL prints an error that it cannot open an `InnoDB` file:

```
ERROR 1016: Can't open file: 'child2.ibd'. (errno: 1)
```

In the error log you can find a message like this:

```
InnoDB: Cannot find table test/child2 from the internal data dictionary
InnoDB: of InnoDB though the .frm file for the table exists. Maybe you
InnoDB: have deleted and recreated InnoDB data files but have forgotten
InnoDB: to delete the corresponding .frm files of InnoDB tables?
```

This means that there is an orphan `.frm` file without a corresponding table inside `InnoDB`. You can drop the orphan `.frm` file by deleting it manually.

Orphan Temporary Tables

If MySQL exits in the middle of an `ALTER TABLE` operation, you may be left with an orphan temporary table that takes up space on your system. This section describes how to identify and remove orphan temporary tables.

Orphan temporary table names begin with an `#sql-` prefix (e.g., `#sql-540_3`). The accompanying `.frm` file has the same base name as the orphan temporary table.

> **Note**
>
> If there is no `.frm` file, you can recreate it. The `.frm` file must have the same table schema as the orphan temporary table (it must have the same columns and indexes) and must be placed in the database directory of the orphan temporary table.

To identify orphan temporary tables on your system, you can view Table Monitor output. Look for table names that begin with `#sql`. If the original table resides in a file-per-table tablespace, the tablespace file (the `#sql-*.ibd` file) for the orphan temporary table should be visible in the database directory.

To remove an orphan temporary table, drop the table by issuing a `DROP TABLE` statement, prefixing the name of the table with `#mysql50#` and enclosing the table name in backticks. For example:

```
mysql> DROP TABLE `#mysql50##sql-540_3`;
```

The `#mysql50#` prefix tells MySQL to ignore `file name safe encoding` introduced in MySQL 5.1. Enclosing the table name in backticks is required to perform SQL statements on table names with special characters such as "#".

Tablespace Does Not Exist

With `innodb_file_per_table` enabled, the following message might occur if the `.frm` or `.ibd` files (or both) are missing:

```
InnoDB: in InnoDB data dictionary has tablespace id N,
InnoDB: but tablespace with that id or name does not exist. Have
InnoDB: you deleted or moved .ibd files?
InnoDB: This may also be a table created with CREATE TEMPORARY TABLE
InnoDB: whose .ibd and .frm files MySQL automatically removed, but the
InnoDB: table still exists in the InnoDB internal data dictionary.
```

If this occurs, try the following procedure to resolve the problem:

1. Create a matching `.frm` file in some other database directory and copy it to the database directory where the orphan table is located.

2. Issue `DROP TABLE` for the original table. That should successfully drop the table and `InnoDB` should print a warning to the error log that the `.ibd` file was missing.

14.6.12.4 InnoDB Error Handling

The following items describe how `InnoDB` performs error handling. `InnoDB` sometimes rolls back only the statement that failed, other times it rolls back the entire transaction.

- If you run out of file space in the tablespace, a MySQL `Table is full` error occurs and `InnoDB` rolls back the SQL statement.

- A transaction deadlock causes `InnoDB` to roll back the entire transaction. Retry the whole transaction when this happens.

  A lock wait timeout causes `InnoDB` to roll back only the single statement that was waiting for the lock and encountered the timeout. (To have the entire transaction roll back, start the server with the `--innodb_rollback_on_timeout` option, available as of MySQL 5.1.15.) Retry the statement if using the current behavior, or the entire transaction if using `--innodb_rollback_on_timeout`.

  Both deadlocks and lock wait timeouts are normal on busy servers and it is necessary for applications to be aware that they may happen and handle them by retrying. You can make them less likely by doing as little work as possible between the first change to data during a transaction and the commit, so the locks are held for the shortest possible time and for the smallest possible number of rows. Sometimes splitting work between different transactions may be practical and helpful.

  When a transaction rollback occurs due to a deadlock or lock wait timeout, it cancels the effect of the statements within the transaction. But if the start-transaction statement was `START TRANSACTION` or `BEGIN` statement, rollback does not cancel that statement. Further SQL statements become part of the transaction until the occurrence of `COMMIT`, `ROLLBACK`, or some SQL statement that causes an implicit commit.

- A duplicate-key error rolls back the SQL statement, if you have not specified the `IGNORE` option in your statement.

- A `row too long error` rolls back the SQL statement.

- Other errors are mostly detected by the MySQL layer of code (above the `InnoDB` storage engine level), and they roll back the corresponding SQL statement. Locks are not released in a rollback of a single SQL statement.

During implicit rollbacks, as well as during the execution of an explicit `ROLLBACK` SQL statement, `SHOW PROCESSLIST` displays `Rolling back` in the `State` column for the relevant connection.

14.7 The IBMDB2I Storage Engine

The `IBMDB2I` storage engine is designed as a fully featured transaction-capable storage engine that enables MySQL to store its data in DB2 tables running on IBM i. With the `IBMDB2I` storage engine, data can be shared between MySQL applications and applications coded for native DB2 for i interfaces.

`IBMDB2I` provides ACID-compliant transactions, support for foreign key constraints, full crash recovery, radix-tree-based indexes, and the unique ability to enable DB2 for i applications to see and update table data in real time.

More information about the storage engine and its interaction with DB2 for i can be found in IBM's *Using DB2 for i as a Storage Engine for MySQL* Redbook publication, at IBM DB2 for i a Storage Engine for MySQL Redbook.

> **Note**
>
> The `IBMDB2I` storage engine was introduced in MySQL 5.1.33 and considered GA in MySQL 5.1.35. It was removed in MySQL 5.1.54.

14.7.1 Installation

Because it relies on features specific to the IBM i operating system running on IBM Power systems, the `IBMDB2I` storage engine is only available on builds of MySQL specifically created for the IBM i operating system.

IBM i 5.4 or later is required to run `IBMDB2I`. Some features may require IBM i 6.1 or later versions. As well, a set of program temporary fixes (PTFs) must be installed. Information about the specific PTF numbers can be obtained from http://www-912.ibm.com/n_dir/nas4apar.nsf/c79815e083182fec862564c00079d117/67d12878076e4827862574e2003c6d4a?OpenDocument.

The engine is built as a dynamic plugin and so must be installed by using the following command:

```
mysql> INSTALL PLUGIN ibmdb2i SONAME ha_ibmdb2i.so;
```

14.7.2 Configuration Options

Table 14.6 `IBMDB2I` Storage Engine Features

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
ibmdb2i_assume_exclusive_use	Yes	Yes	Yes		Global	Yes
ibmdb2i_async_enabled	Yes	Yes	Yes		Both	Yes
ibmdb2i_compat_opt_allow_zero_date_vals	Yes	Yes	Yes		Both	Yes
ibmdb2i_compat_opt_blob_cols	Yes	Yes	Yes		Both	Yes
ibmdb2i_compat_opt_time_as_duration	Yes	Yes	Yes		Both	Yes
ibmdb2i_compat_opt_year_as_int	Yes	Yes	Yes		Both	Yes
ibmdb2i_create_index_option	Yes	Yes	Yes		Both	Yes
ibmdb2i_lob_alloc_size	Yes	Yes	Yes		Both	Yes
ibmdb2i_max_read_buffer_size	Yes	Yes	Yes		Both	Yes
ibmdb2i_max_write_buffer_size	Yes	Yes	Yes		Both	Yes
ibmdb2i_propogate_default_col_vals	Yes	Yes	Yes		Both	Yes
ibmdb2i_rdb_name	Yes	Yes	Yes		Global	No
ibmdb2i_system_trace_level	Yes	Yes	Yes		Global	Yes
ibmdb2i_transaction_unsafe	Yes	Yes	Yes		Both	Yes

- `ibmdb2i_assume_exclusive_use`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_assume_exclusive_use`	
System Variable	**Name**	`ibmdb2i_assume_exclusive_use`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values (IBM System i)	Type	`boolean`
	Default	`off`

Specifies whether an external interface (such as DB2 for i) may be altering the data accessible by the `IBMDB2I` engine. This is an advisory value that may improve performance when correctly set to ON. When the value is ON, `IBMDB2I` may perform some internal caching of table statistics. When the value is set to OFF, `IBMDB2I` must assume that the table rows could be inserted and deleted without its direct knowledge and must call DB2 to obtain accurate statistics before each operation.

Default Value: OFF

- `ibmdb2i_async_enabled`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_async_enabled`	
System Variable	Name	`ibmdb2i_async_enabled`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	Type	`boolean`
	Default	`on`

Specifies whether buffering between `IBMDB2I` and the QSQSRVR jobs responsible for fetching row data should be done in an asynchronous manner. Asynchronous reads are enabled by default and provide optimal performance.Under normal circumstances, this value will never need to be modified.

Default Value: ON

- `ibmdb2i_create_index_option`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_create_index_option`	
System Variable	Name	`ibmdb2i_create_index_option`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	Type	`numeric`
	Default	`0`

Controls whether additional indexes are created for use by traditional DB2 for i interfaces. When the value is 0, no additional indexes will be created. When the value is 1 and the index created on behalf of MySQL is ASCII-based, an additional index is created based on EBCDIC hexadecimal sorting. The additional index may be useful for traditional DB2 for i interfaces which expect indexes to use EBCDIC-based sort sequences.

Default Value: 0

- `ibmdb2i_compat_opt_time_as_duration`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_compat_opt_time_as_duration`	
System Variable	**Name**	`ibmdb2i_compat_opt_time_as_duration`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`boolean`
	Default	`off`

Controls how MySQL TIME columns are mapped to DB2 data types when creating or altering an `IBMDB2I` table. When the value is `ON`, the column is mapped to an `INTEGER` type in DB2 and supports the full range of values defined by MySQL for `TIME` types. When the value is `OFF`, the column is mapped to a DB2 `TIME` type and supports values in the range of '00:00:00' to '23:59:59'. This option is provided to provide enhanced interoperability with DB2 for i interfaces.

Default Value: OFF

- `ibmdb2i_system_trace_level`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_system_trace_level`	
System Variable	**Name**	`ibmdb2i_system_trace_level`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`boolean`
	Default	0

Specifies what kind of debugging information is to be gathered for `QSQSRVR` jobs servicing MySQL connections. Multiple sources of information may be specified by summing the respective values. Changes to this option only affect new connections. Valid values include

- `0`: No information (Default)

- `2`: `STRDBMON`

- `4`: `STRDBG`

- `8`: `DSPJOBLOG`

- `16`: `STRTRC`

- `32`: `PRTSQLINF`

The most useful sources of information are `DSPJOBLOG`, which will capture the job log for each `QSQSRVR` job in a spoolfile, and `STRDBG`, which will increase the diagnostic information in each job log.

Default Value: 0

- `ibmdb2i_compat_opt_allow_zero_date_vals`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_compat_opt_allow_zero_date_vals`	
System Variable	**Name**	`ibmdb2i_compat_opt_allow_zero_date_vals`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`boolean`
	Default	`0`

Specifies whether the storage engine should permit the `0000-00-00` date in `DATETIME`, `TIMESTAMP` and `DATE` columns. When the option is 0, attempts to insert a row containing this zero date into an `IBMDB2I` table will fail. As well, a warning will be generated when creating a column with this zero value as the default value. When this option is 1, the zero value will be substituted with `0001-01-01` when stored in DB2, and a `0001-01-01` value will be translated to `0000-00-00` when read from DB2. Similarly, when a column with a default zero value is created, the DB2 default value will be '0001-01-01'. Users must be aware that, when this option is 1, all values of `0001-01-01` in DB2 will be interpreted as `0000-00-00`. This option is primarily added for compatibility with applications which rely on the zero date.

Default Value: 0

- `ibmdb2i_propagate_default_col_vals`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_propogate_default_col_vals`	
System Variable	**Name**	`ibmdb2i_propogate_default_col_vals`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`boolean`
	Default	`on`

Specifies whether `DEFAULT` value associated with each column should be propagated to the DB2 definition of the table when a table is created or altered. The default value is ON. This ensures that rows inserted from a standard DB2 interface will use the same default values as when inserted from MySQL.

Default Value: ON

- `ibmdb2i_compat_opt_year_as_int`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_compat_opt_year_as_int`	
System Variable	**Name**	`ibmdb2i_compat_opt_year_as_int`
	Variable Scope	Global, Session

	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`boolean`
	Default	`0`

Controls how YEAR columns are stored in DB2. The default is 0 and causes `YEAR` columns to be created as `CHAR(4) CCSID 1208` columns in DB2. Setting this option to 1 causes the YEAR columns to be created as `SMALLINT` columns. This provides a slight performance increase and enables indexes that combine a `YEAR` column with a character column.

Default Value: 0

- `ibmdb2i_lob_alloc_size`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_lob_alloc_size`	
System Variable	**Name**	`ibmdb2i_lob_alloc_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`numeric`
	Default	`2MB`

Controls how much space is allocated by default for reading data from a `BLOB` or `TEXT` field. If an application consistently uses `BLOB` or `TEXT` fields that contain more than 2 MB of data, read performance may be improved if this value is increased. Conversely, an application which uses smaller `BLOB` or `TEXT` fields may find that the MySQL memory footprint is reduced if a smaller value is specified for this option.

Default Value: 2 MB

- `ibmdb2i_compat_opt_blob_cols`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_compat_opt_blob_cols`	
System Variable	**Name**	`ibmdb2i_compat_opt_blob_cols`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`numeric`
	Default	`0`

Specifies how MySQL `TEXT` and `BLOB` columns larger than 255 characters are mapped when creating `IBMDB2I` tables. When the value is 0, `TEXT` columns are mapped to `CLOB` or `DBCLOB` columns for DB2 for i. This enables the column to contain the maximum size documented for `TEXT` columns (64K characters), but the column can not be included in an index. When the value is 1, `TEXT` columns are mapped to `LONG VARCHAR`/`VARGRAPHIC` columns, and `BLOB` columns are mapped to `LONG`

`VARBINARY`. This permits indexes to be created over the column, but it reduces the amount of storage available to the column below the documented maximum for `TEXT` columns. This option was provided to enable applications which relied on the ability to create prefix indexes over `TEXT` columns.

Default Value: 0

- `ibmdb2i_max_read_buffer_size`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_max_read_buffer_size`	
System Variable	**Name**	`ibmdb2i_max_read_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`numeric`
	Default	`1MB`

Controls the maximum amount of memory allocated for buffering row data when doing reads from an `IBMDB2I` table. This buffering is done independently of any row buffering done within MySQL proper. Setting this value too low may reduce read performance, while setting it too high may increase memory usage and may also reduce read performance.

Default Value: 1 MB

- `ibmdb2i_max_write_buffer_size`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_max_write_buffer_size`	
System Variable	**Name**	`ibmdb2i_max_write_buffer_size`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	**Type**	`numeric`
	Default	`8MB`

Controls the maximum amount of memory allocated for buffering row data when inserting multiple rows into an `IBMDB2I` table. This buffering is done independently of any row buffering done within MySQL proper. Setting this value too low may reduce write performance, while setting it too high may increase memory usage.

Default Value: 8 MB

- `ibmdb2i_rdb_name`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_rdb_name`	
System Variable	**Name**	`ibmdb2i_rdb_name`

	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (IBM System i)	Type	`string`
	Default	

The name of a local DB2 for i relational database that will act as a container for all `IBMDB2I` tables. This enables an independent auxiliary storage pool (IASP) to be selected for usage. If no value is specified, the system database (*SYSBAS) is used.

Default Value: <blank>

- `ibmdb2i_transaction_unsafe`

Introduced	5.1.33	
Command-Line Format	`ibmdb2i_transaction_unsafe`	
System Variable	Name	`ibmdb2i_transaction_unsafe`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (IBM System i)	Type	`boolean`
	Default	`off`

Controls whether `IBMDB2I` honors the transactional commands and isolation levels specified for MySQL. If the value is OFF, transactions are fully supported. If the value is ON, transactional behavior is not implemented. This may provide a moderate performance increase for applications that do not rely on transactional guarantees.

Default Value: OFF

The values specified for `ibmdb2i_create_index_option`, `ibmdb2i_create_time_columns_as_tod`, `ibmdb2i_map_blob_to_varchar`, `ibmdb2i_compat_opt_allow_zero_date_vals`, `ibmdb2i_propagate_default_col_vals`, and `ibmdb2i_propagate_default_col_val` will be applied whenever an `IBMDB2I` table is created. Tables are implicitly destroyed and re-created when an `offline ALTER TABLE` is performed on an `IBMDB2I` table. Therefore it is highly recommended that the values of these variables be consistent across the lifetime of a table to prevent an `ALTER TABLE` from running under a different set of options than were used to originally create the table. If this recommendation is not followed, the `ALTER TABLE` may fail upon encountering incompatible data when re-creating the table.

14.7.3 Creating schemas and tables

`IBMDB2I` tables are created by specifying the `ENGINE=IBMDB2I` option on a `CREATE TABLE` or `ALTER TABLE` statement. These tables are stored as DB2 for i objects in the QSYS.LIB file system. Therefore, in contrast to the behavior of other storage engines, `IBMDB2I` table and index data does not reside beneath the datadir directory with other MySQL table data.

When the first `IBMDB2I` table is created in a MySQL schema, the corresponding DB2 schema will be created (if it does not already exist).

Note that if the user profile running MySQL has sufficient authority dropping a MySQL schema will drop a DB2 schema of the same name even if the schema never contained any `IBMDB2I` tables and contains objects not related to MySQL. Therefore, it is recommended that extreme caution be used when dropping MySQL schemas when the `IBMDB2I` plugin is installed.

14.7.3.1 Identifier names

DB2 for i file objects have both a short (10-character) system name and an SQL name. The DB2 for i SQL name is always the same as the MySQL name. However, because MySQL's sensitivity to the lettercase of schema and table names depends on the file system containing the datadir, mapping the MySQL name to the system name of the corresponding DB2 for i object must account for several factors, described below.

When MySQL is operating in a case-sensitive mode (that is, datadir is in a case-sensitive file-system like (/QOpenSys), the case of the system name of the `IBMDB2I` object reflects the case of the name specified to MySQL. If the object has all uppercase characters and is equal to or less than 10 characters in length, the system name will be undelimited and in uppercase.If the object name has mixed or lower-case letters, the IBM i system name will contain up to 8 characters of the name in the specified case and will be delimited by surrounding quotation marks. If the MySQL name has more characters than can fit in the delimited system name, the system name will be generated as a mangled name delimited by surrounding quotation marks.

Examples of this naming behavior are given below:

Table 14.7 Naming Behavior in DB2 Storage Engine

MySQL name	DB2 for i SQL name	IBM i System name
mytable	mytable	"mytable"
mylongertable	mylongertable	"mylo0001"
UPPERTABLE	UPPERTABLE	UPPERTABLE
UPPERLONGTABLE	UPPERLONGTABLE	UPPER00001
MixedTab	MixedTab	"MixedTab"
MixedlongerTab	MixedlongerTab	"Mixe0001"

If MySQL is operating in a case-insensitive mode, the IBM i system name will contain up to 8 characters of the name in lower case and will be delimited by surrounding quotation marks. If the MySQL name has more characters than can fit in the delimited system name, the system name will be generated as a mangled name delimited by surrounding quotation marks.

Note that IBM i system names are not changed when a RENAME TABLE command is executed. Only the DB2 for i SQL name changes.

14.7.3.2 Index names

Unlike MySQL, DB2 for i requires that index names be unique to an entire schema. To support MySQL indexes, `IBMDB2I` creates the DB2 for i indexes with modified file names. The generated name is a concatenation of the index name, three underscores (_), and the table name. For example, `CREATE INDEX idx1 ON tab1 (a, b)` would create a DB2 index named `idx___tab1`. If the ibmdb2i_create_index_option value is set to 1, an additional index may be created which is named with an additional `H_` marker between the index and table names (for example, idx___H_tab1). These generated names are then mangled to create the an IBM i system name, as described above.

If a table is renamed, the indexes will also be renamed.

This index name generation scheme also has implications for the length of index and table names; to permit the generated name and allow for delimiting quotation marks, the combined length of the index and table names must be less than or equal to 121 characters.

Data type mapping

When creating a table, `IBMDB2I` may map the MySQL types specified on a `CREATE TABLE` statement into a corresponding or compatible DB2 for i type. Examples include the `BIT` type, which is stored as a `BINARY` field, or the `MEDIUMINT` type, which is stored as an `INTEGER` field. For most data types, this mapping is transparent. Data types which have restrictions unique to `IBMDB2I` are documented in Section 14.7.7, "Notes and Limitations".

14.7.4 Database/metadata management

When an `IBMDB2I` table is created, a File Level ID (FID) file is created in the database directory. This file has an extension .FID and contains the last known FID of the associated DB2 for i physical file. The `IBMDB2I` engine uses this FID value to determine whether incompatible changes have been made to the table by an external (non-MySQL) interface. If the physical file is altered, DB2 for i automatically generates a new FID. The next time `IBMDB2I` attempts to access the file, it will detect that the new FID does not match the known FID, and it will prevent MySQL from using the table.

In some cases, the changes to the physical file that cause the FID to be updated may not adversely affect access through MySQL and `IBMDB2I`. In this case, a user may wish to override the FID check that `IBMDB2I` performs. A user with appropriate permissions may do so simply by deleting the `.FID` file associated with the table and performing a `FLUSH TABLE` statement against the table. `IBMDB2I` will then regenerate the file with the new FID the next time the table is accessed from MySQL.

If triggers or constraints are applied to the table from a native DB2 interface, they will be respected when accessing the table from MySQL, but MySQL will have no knowledge of the triggers or constraints. Likewise, views and indexes can be created over the tables from a DB2 interface, but the indexes will not be accessible from MySQL.

14.7.5 Transaction behavior

The `IBMDB2I` storage engine supports row-level transaction management. All MySQL isolation levels are supported by the engine, and where highest performance is required, transaction support can be disabled globally or per session by modifying the ibmdb2i_transaction_unsafe configuration option.

`IBMDB2I` uses the underlying DB2 for i transaction support to implement MySQL isolation levels. DB2 for i uses table and row locks to implement the various isolation levels, as described below:

Table 14.8 IBMDB2I Isolation Levels

Isolation level	Read-only (SELECT)		Read-write (UPDATE, DELETE)	
	Lock enforcement	Visibility of uncommitted work on behalf of other connections	Lock enforcement	Visibility of uncommitted work on behalf of other connections
SERIALIZABLE	Table is locked until end of transaction.Other connections may read rows while locked.	N/A	Table is locked until end of transaction.Other connections may	N/A

Isolation level	Read-only (SELECT)		Read-write (UPDATE, DELETE)	
	Lock enforcement	Visibility of uncommitted work on behalf of other connections	Lock enforcement	Visibility of uncommitted work on behalf of other connections
			read rows while locked.	
REPEATABLE READ	Rows that have been read are locked until end of transaction.Other connections may read and insert rows while locked.	Rows cannot be read until work is committed.	Rows that have been read are locked until end of transaction.Other connections may read and insert rows while locked.	Rows cannot be read until work is committed.
READ COMMITTED	Row is locked while cursor is positioned on that row.Other connections may read and insert rows while locked.	Rows cannot be read until work is committed.	Row is locked while cursor is positioned on that row.Other connections may read and insert rows while locked.	Rows cannot be read until work is committed.
READ UNCOMMITTED	Row is locked while cursor is positioned on that row.Other connections may read and insert rows while locked.	Rows can be read before work is committed.	Row is locked while cursor is positioned on that row.Other connections may read and insert rows while locked.	Rows can be read before work is committed.
transaction_unsafe	No locks	Full access	Table is locked until end of transaction.Other connections may read rows while locked.	Unrestricted access

Attempts to access locked rows time out according to the timeout value associated with the underlying DB2 physical file. This timeout wait is 30 seconds by default. Refer to http://publib.boulder.ibm.com/infocenter/ iseries/v5r4/index.jsp?topic=/dbp/rbafoconcrec.htm for more information.

Because `IBMDB2I` does not multi-version rows under commitment control, row lock contention may occur under certain scenarios. In particular, when multiple connections attempt to read overlapping ranges of rows while performing a statement that does updates, the connections may contend for the same row locks. This may lead to delays until the row lock timeout expires. Creating appropriate indexes and increasing query selectivity to reduce range overlap may help to alleviate this contention.

14.7.6 Principles and Terminology

`AUTO_INCREMENT`

The MySQL auto_increment column attribute can be used to generate a unique identity for new rows.The `IBMDB2I` storage engine maps the MySQL auto_increment attribute to the DB2 for i identity attribute

For most MySQL storage engines, the auto_increment value is determined by adding one to the maximum value stored in the table for the column.For the `IBMDB2I` storage engine, DB2 for i generates the identity

value by adding one to the last generated value. Following are some example MySQL statements to illustrate the point.

```
create table t1 (a int auto increment, primary key(a)) engine = ibmdb2i;
insert into t1 values(3);
insert into t1 values(null),(null);
```

For the first INSERT statement, an explicit value of 3 is specified for the auto_increment column, so the value 3 is stored in the inserted row.For the second INSERT statement null is specified, so generated values 1 and 2 will be stored in the rows.

Duplicate key failures can occur in DB2 for i if a MySQL application mixes explicit auto_increment values with generated values within a table. For the example above, if one more record is inserted into the table for which an auto_increment value is generated, a duplicate key error will occur because the value 3 (that is, the last generated value plus one) already exists in the table.To effect the MySQL behavior for auto_increment columns, the `IBMDB2I` storage engine will detect a duplicate key error, alter the restart value for the DB2 identity column to the maximum value plus one, and retry the failed insert, but only if the following conditions are true:

- The duplicate key error occurred on an index for which the auto_increment column is a key field

- An exclusive (LENR) lock can be acquired on the table

- The error occurred on the first or only row of the `INSERT` statement.

The `IBMDB2I` storage engine does not support the following usage of auto_increment columns:

1. Any MySQL global or session variable that affects the start, increment, or offset for generated auto_increment values.

2. Any MySQL feature that returns the *next value to be used* for an auto_increment column.

3. An auto_increment column on a MySQL partitioned table.

14.7.7 Notes and Limitations

- When using multiples instances of MySQL on a single i5 host you should be aware that the two independent instances will access the same database within the DB2 environment. This can lead to namespace collisions and issues. To get round this limitation, you should configure different IBM i independent auxiliary storage pools (ISAPs) for each MySQL server, and then use the `ibmdb2i_rdb_name` option to MySQL to configure which IASP should be used for each MySQL instance.

- Indexes over `VARBINARY` columns may not provide accurate estimates the optimizer. Queries over such indexes may produce error 2027 in the error log but will succeed. This affects only the performance of these queries, not the correctness of the results.

- Setting `ibmdb2i_system_trace_level = 16 (STRTRC)` may cause unpredictable failures including error 2088 on some operations. This is unlikely to affect any users, as this value is recommended only for serviceability purposes.

- `IBMDB2I` honors the `CASCADE`/`RESTRICT` option on the `DROP TABLE` statement.

- The use of `FLUSH TABLES WITH READ LOCK` is discouraged when using `IBMDB2I` tables. Due to differences in internal locking implementations, `FLUSH TABLES WITH READ LOCK` may produce deadlocks on `IBMDB2I` tables.

- Row-based replication is supported by `IBMDB2I`. Statement-based replication is not supported.

- Schema name lengths are limited to 10 characters in IBM i 5.4 and 30 characters in IBM i 6.1. If the schema name is mixed- or lower-case, two characters must be subtracted from the limit to account for surrounding quotation marks.

- The RENAME TABLE command cannot be used to move `IBMDB2I` tables from one database to another.

- The maximum length of the internal row format for `IBMDB2I` is 32767 bytes. Because the internal row format may differ from the MySQL row format due to data mapping differences (see Creating schemas and tables section), anticipating this limit may be difficult.

- The combined length of the index and table names must be less than or equal to 121 characters.

- Indexes over TEXT or BLOB columns with a maximum length greater than 255 characters are not supported. The ibmdb2i_map_blob_to_varchar option can be used to work around this limitation for TEXT fields up to 64K characters.

- Specific restrictions apply to certain data types as described in the following chart:

Table 14.9 Data Type Restrictions in IBMDB2I

MySQL data type	Restriction
`LONGBLOB` or `LONGTEXT`	The maximum length of a DB2 BLOB data type is 2GB.
`DATE`	`IBMDB2I` does not support the special date value of '0000-00-00'. The restrictions on `DATE` and `DATETIME` columns can be removed by setting the value of `ibmdb2i_compat_opt_allow_zero_date_vals` to 1.
`DATETIME`	`IBMDB2I` does not support the special datetime value of '0000-00-00 00:00:00'. The restrictions on `DATE` and `DATETIME` columns can be removed by setting the value of `ibmdb2i_compat_opt_allow_zero_date_vals` to 1.
`DECIMAL(p, s)` or `NUMERIC(p, s)`	If p is greater than 63 and s is greater than (p-63), the field definition is truncated to `DECIMAL(63, s-(p-63))`. If p is greater than 63 and s is less than or equal to (p-63), the definition is not supported.
`TIME`	By default, `IBMDB2I` only supports times in the range '00:00:00' to '23:59:59.' See the ibmdb2i_create_time_columns_as_tod option for more information.

- These MySQL statements are not supported by the `IBMDB2I` Engine:

  - `CACHE INDEX` and `LOAD INDEX INTO CACHE`

  - `HANDLER`

  - `CHECK TABLE`

  - `REPAIR TABLE`

  - `BACKUP-RESTORE TABLE`

- The `ucs2_spanish2_ci` and `utf8_spanish2_ci` collations are not supported by `IBMDB2I`. There are no plans to support these collations.

- The `ucs2_swedish_ci` and `utf8_swedish_ci` collations were added in MySQL 5.1.35. supported by `IBMDB2I`. As with other language-specific unicode collations, the support will be only be available on IBM i 6.1 and later releases.

14.7.8 Character sets and collations

DB2 for i only supports a single collation per index or foreign key constraint. A foreign key constraint must have the same collation as a primary key constraint, if one exists..

Character sets and collations supported by `IBMDB2I` are described in the list below. IBM i 6.1 is required for the most comprehensive collation support. Note that Chinese, Japanese, and Korean character sets are converted to UTF-16 for storage in DB2 for i; `utf8_general_ci` is converted to `UCS2` for storage in DB2 for i.

Table 14.10 Collation Compatibility in IBMDB2I and MySQL

MySQL Collation	Supported in IBM i 5.4	Supported in IBM i 6.1
armscii8_general_ci		
armscii8_bin		
ascii_general_ci		Yes
ascii_bin		Yes
big5_chinese_ci	Yes	Yes
big5_bin	Yes	Yes
cp1250_croatian_ci		Yes
cp1250_czech_cs		Yes
cp1250_general_ci		Yes
cp1250_polish_ci		Yes
cp1250_bin		Yes
cp1251_bulgarian_ci		Yes
cp1251_general_ci		Yes
cp1251_general_cs		Yes
cp1251_ukrainian_ci		
cp1251_bin		Yes
cp1256_general_ci		Yes
cp1256_bin		Yes
cp1257_general_ci		
cp1257_lithuanian_ci		
cp1257_bin		
cp850_general_ci	Yes	Yes
cp850_bin	Yes	Yes
cp852_general_ci		Yes
cp852_bin		Yes
cp866_general_ci		
cp866_bin		
cp932_japanese_ci	Yes	Yes
cp932_bin	Yes	Yes

MySQL Collation	Supported in IBM i 5.4	Supported in IBM i 6.1
dec8_swedish_ci		
dec8_bin		
eucjpms_japanese_ci		
eucjpms_bin		
euckr_korean_ci	Yes	Yes
euckr_bin	Yes	Yes
gb2312_chinese_ci	Yes	Yes
gb2312_bin	Yes	Yes
gbk_chinese_ci	Yes	Yes
gbk_bin	Yes	Yes
geostd8_general_ci		
geostd8_bin		
greek_general_ci	Yes	Yes
greek_bin	Yes	Yes
hebrew_general_ci	Yes	Yes
hebrew_bin	Yes	Yes
hp8_english_ci		
hp8_bin		
keybcs2_general_ci		
keybcs2_bin		
koi8r_general_ci		
koi8r_bin		
koi8u_general_ci		
koi8u_bin		
latin1_danish_ci	Yes	Yes
latin1_general_ci	Yes	Yes
latin1_general_cs	Yes	Yes
latin1_german1_ci	Yes	Yes
latin1_german2_ci		
latin1_spanish_ci	Yes	Yes
latin1_swedish_ci	Yes	Yes
latin1_bin	Yes	Yes
latin2_croatian_ci	Yes	Yes
latin2_czech_cs	Yes	Yes
latin2_general_ci	Yes	Yes
latin2_hungarian_ci	Yes	Yes
latin2_bin	Yes	Yes

MySQL Collation	Supported in IBM i 5.4	Supported in IBM i 6.1
latin5_turkish_ci	Yes	Yes
latin5_bin	Yes	Yes
latin7_estonian_cs		
latin7_general_ci		
latin7_general_cs		
latin7_bin		
macce_general_ci		Yes
macce_bin		Yes
macroman_general_ci		
macroman_bin		
sjis_japanese_ci	Yes	Yes
sjis_bin	Yes	Yes
swe7_swedish_ci		
swe7_bin		
tis620_thai_ci	Yes	Yes
tis620_bin	Yes	Yes
ucs2_czech_ci		Yes
ucs2_danish_ci		Yes
ucs2_esperanto_ci		Yes
ucs2_estonian_ci		Yes
ucs2_general_ci	Yes	Yes
ucs2_hungarian_ci		Yes
ucs2_icelandic_ci		Yes
ucs2_latvian_ci		Yes
ucs2_lithuanian_ci		Yes
ucs2_persian_ci		Yes
ucs2_polish_ci		Yes
ucs2_roman_ci		
ucs2_romanian_ci		Yes
ucs2_slovak_ci		Yes
ucs2_slovenian_ci		Yes
ucs2_spanish_ci		Yes
ucs2_spanish2_ci		Yes
ucs2_turkish_ci		Yes
ucs2_unicode_ci	Yes	Yes
ucs2_bin	Yes	Yes
ujis_japanese_ci	Yes	Yes

MySQL Collation	Supported in IBM i 5.4	Supported in IBM i 6.1
ujis_bin	Yes	Yes
utf8_czech_ci		Yes
utf8_danish_ci		Yes
utf8_esperanto_ci		Yes
utf8_estonian_ci		Yes
utf8_general_ci	Yes	Yes
utf8_hungarian_ci		Yes
utf8_icelandic_ci		Yes
utf8_latvian_ci		Yes
utf8_lithuanian_ci		Yes
utf8_persian_ci		Yes
utf8_polish_ci		Yes
utf8_roman_ci		
utf8_romanian_ci		Yes
utf8_slovak_ci		Yes
utf8_slovenian_ci		Yes
utf8_spanish_ci		Yes
utf8_spanish2_ci		Yes
utf8_turkish_ci		Yes
utf8_unicode_ci		Yes
utf8_bin	Yes	Yes

14.7.9 Error codes and trouble-shooting information

Errors reported by the `IBMDB2I` engine may originate from two locations. Error values under 2500 originate in DB2 for i. Error values over 2500 originate in the storage engine itself. Occasionally, errors are reported by `IBMDB2I` but, due to the architecture of MySQL, cannot be directly exposed to MySQL client interfaces. In these cases, issuing a `SHOW ERRORS` statement or referring to the MySQL error log may be necessary to determine the cause of a failure. Errors which originate in DB2 for i are usually encountered in the DB2 for i SQL Server Mode job (QSQSRVR) which services the MySQL client connection; additional information about failures can often be found by looking in the job log of the associated QSQSRVR job.

Following is the list of codes and messages for errors that occur in DB2 for i that are reported by the `IBMDB2I` engine. %d and %s represent numbers and strings, respectively, that are replaced when the message is displayed.

Table 14.11 Error Codes from IBMDB2I

Error Code Number	Error Message Text
0	Successful
2016	Thread ID is too long
2017	Error creating a SPACE memory object

Error Code Number	Error Message Text
2018	Error creating a FILE memory object
2019	Error creating a SPACE synchronization token
2020	Error creating a FILE synchronization token
2021	See message %-.7s in joblog for job %-.6s/%-.10s/%-.10s.
2022	Error unlocking a synchronization token when closing a connection
2023	Invalid action specified for an 'object lock' request
2024	Invalid action specified for a savepoint request
2025	Partial keys are not supported with an ICU sort sequence
2026	Error retrieving an ICU sort key
2027	Error converting single-byte sort sequence to UCS-2
2028	An unsupported collation was specified
2029	Validation failed for referenced table of foreign key constraint
2030	Error extracting table for constraint information
2031	Error extracting referenced table for constraint information
2032	Invalid action specified for a 'commitment control' request
2033	Invalid commitment control isolation level specified on 'open' request
2034	Invalid file handle
2036	Invalid option specified for returning data on 'read' request
2037	Invalid orientation specified for 'read' request
2038	Invalid option type specified for 'read' request
2039	Invalid isolation level for starting commitment control
2040	Error unlocking a synchronization token in module QMYALC
2041	Length of space for returned format is not long enough
2042	SQL XA transactions are currently unsupported by this interface
2043	The associated QSQSRVR job was killed or ended unexpectedly.
2044	Error unlocking a synchronization token in module QMYSEI
2045	Error unlocking a synchronization token in module QMYSPO
2046	Error converting input CCSID from short form to long form
2048	Error getting associated CCSID for CCSID conversion
2049	Error converting a string from one CCSID to another
2050	Error unlocking a synchronization token
2051	Error destroying a synchronization token
2052	Error locking a synchronization token
2053	Error recreating a synchronization token
2054	A space handle was not specified for a constraint request
2055	An SQL cursor was specified for a delete request

Error Code Number	Error Message Text
2057	Error on delete request because current UFCB for connection is not open
2058	An SQL cursor was specified for an object initialization request
2059	An SQL cursor was specified for an object override request
2060	A space handle was not specified for an object override request
2061	An SQL cursor was specified for an information request
2062	An SQL cursor was specified for an object lock request
2063	An SQL cursor was specified for an optimize request
2064	A data handle was not specified for a read request
2065	A row number handle was not specified for a read request
2066	A key handle was not specified for a read request
2067	An SQL cursor was specified for an row estimation request
2068	A space handle was not specified for a row estimation request
2069	An SQL cursor was specified for a release record request
2070	A statement handle was not specified for an 'execute immediate' request
2071	A statement handle was not specified for a 'prepare open' request
2072	An SQL cursor was specified for an update request
2073	The UFCB was not open for read
2074	Error on update request because current UFCB for connection is not open
2075	A data handle was not specified for an update request
2076	An SQL cursor was specified for a write request
2077	A data handle was not specified for a write request
2078	An unknown function was specified on a process request
2079	A share definition was not specified for an 'allocate share' request
2080	A share handle was not specified for an 'allocate share' request
2081	A use count handle was not specified for an 'allocate share' request
2082	A 'records per key' handle was not specified for an information request
2083	Error resolving LOB address
2084	Length of a LOB space is too small
2085	An unknown function was specified for a server request
2086	Object authorization failed. See message %-.7s in joblog for job %-.6s/%-.10s/%-.10s. for more information.
2088	Error locking mutex on server
2089	Error unlocking mutex on server
2090	Error checking for RDB name in RDB Directory
2091	Error creating mutex on server
2094	Error unlocking mutex
2095	Error connecting to server job

Error Code Number	Error Message Text
2096	Error connecting to server job
2098	Function check occurred while registering parameter spaces. See job log.
2101	End of block
2102	The file has changed and might not be compatible with the MySQL table definition
2103	Error giving pipe to server job
2104	There are open object locks when attempting to deallocate
2105	There is no open lock
2108	The maximum value for the auto_increment data type was exceeded
2109	Error occurred closing the pipe
2110	Error occurred taking a descriptor for the pipe
2111	Error writing to pipe
2112	Server was interrupted
2113	No pipe descriptor exists for reuse
2114	Error occurred during an SQL prepare statement
2115	Error occurred during an SQL open
2122	An unspecified error was returned from the system.

Following is the list of error codes and messages that occur within the `IBMDB2I` storage engine.

Table 14.12 Error Codes and Messages in IBMDB2I

Error Code Number	Error Message Text
2501	Error opening codeset conversion from %.64s to %.64s (errno = %d). **Resolution:** Alter the table definition to specify a character set that is supported by the `IBMDB2I` engine.
2502	Invalid %-.10s name '%-.128s. **Resolution:** If a field name, ensure that it is less than the maximum length of 126 characters.If an index name, ensure that the length of the index name plus the length of the table name is less than 121 characters.
2503	Unsupported move from '%-.128s' to '%-.128s' on RENAME TABLE statement. **Resolution:** Moving a table from one schema to another is not supported by the `IBMDB2I` engine. Create a new table in the 'to' schema, copy the data to the new table, and then drop the old table.
2504	The %-.64s character set is not supported. **Resolution:** Try using another character set.
2505	Auto_increment is not allowed for a partitioned table. **Resolution:** Remove the auto_increment attribute from the table or do not partition the table.
2506	Character set conversion error due to unknown encoding scheme %d. **Resolution:** Alter the table definition to ensure that character sets assigned to columns are supported by the `IBMDB2I` engine.

Error Code Number	Error Message Text
2508	Table '%-.128s' was not found by the storage engine. **Resolution:** A table definition exists in MySQL, but the correspondingtable in DB2 for i is not found. Delete the MySQL table or restore the DB2 table.
2509	Could not resolve to %-.128s in library %-.10s type %-.10s (errno = %d). **Resolution:** Restore the missing IBM i object to the system.
2510	Error on _PGMCALL for program %-.10s in library %-.10s (error = %d). **Resolution:** This is an internal error.
2511	Error on _ILECALL for API '%.128s' (error = %d). **Resolution:** This is an internal error.
2512	Error in iconv() function during character set conversion (errno = %d). **Resolution:** Ensure the text being inserted contains only valid code points for the associated character set. This may be caused by using ENCRYPT or COMPRESS on a text field, resulting in binary data containing invalid characters.
2513	Error from Get Encoding Scheme (QTQGESP) API: %d, %d, %d **Resolution:** This is an internal error.
2514	Error from Get Related Default CCSID (QTQGRDC) API: %d, %d, %d. **Resolution:** This is an internal error.
2515	Data out of range for column '%.192s'. **Resolution:** DB2 for i does not support a zero value for DATE and DATETIME data types. Specify a new value for the column.
2516	Schema name '%.128s' exceeds maximum length of %d characters. **Resolution:** Change the schema name so that its length does not exceed the maximum. For mixed case or lowercase names, permit 2 characters for outer quotation marks.
2517	Multiple collations not supported in a single index. **Resolution:** DB2 for i only supports sort sequences at the table or index level, so all character-based columns in the primary key or index must be using the same collation. Alter the table definition so that all columns use the same collation.
2518	Sort sequence was not found. **Resolution:** Alter the table to use a collation that is supported by the `IBMDB2I` engine.
2519	One or more characters in column %.128s were substituted during conversion. **Resolution:** This is a warning that during the conversion of data from MySQL to DB2 some characters were replaced with substitute characters.
2520	A decimal column exceeded the maximum precision. Data may be truncated. **Resolution:** A decimal column specified on a CREATE TABLE or ALTER TABLE command has greater precision than DB2 permits. Data stored in this column may be truncated. Change the column specification to have a precision less than or equal to 63.
2521	Some data returned by DB2 for table %s could not be converted for MySQL. **Resolution:** This is a warning that some data could not be converted from DB2 to MySQL. Data was likely inserted into the table using DB2 interfaces that is valid data for DB2 but is invalid for MySQL.
2523	Column %.128s contains characters that cannot be converted. **Resolution:** An error occurred converting data from the MySQL character set to the associated DB2 coded character set identifier (CCSID).Omit the incompatible characters or alter the table to specify a different character set for the column.
2524	An invalid name was specified for ibmdb2i_rdb_name. **Resolution:** Specify a valid relational database (RDB) name.

Error Code Number	Error Message Text
2525	A duplicate key was encountered for index '%.128s'. **Resolution:** : Specify a unique key value for the row. Generally, this error occurs if a unique constraint or index has been applied to the table from a non-MySQL interface.
2528	Some attribute(s) defined for column '%.128s' may not be honored by accesses from DB2.

14.8 The MERGE Storage Engine

The `MERGE` storage engine, also known as the `MRG_MyISAM` engine, is a collection of identical `MyISAM` tables that can be used as one. "Identical" means that all tables have identical column and index information. You cannot merge `MyISAM` tables in which the columns are listed in a different order, do not have exactly the same columns, or have the indexes in different order. However, any or all of the `MyISAM` tables can be compressed with `myisampack`. See Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables". Differences in table options such as `AVG_ROW_LENGTH`, `MAX_ROWS`, or `PACK_KEYS` do not matter.

An alternative to a `MERGE` table is a partitioned table, which stores partitions of a single table in separate files. Partitioning enables some operations to be performed more efficiently and is not limited to the `MyISAM` storage engine. For more information, see Chapter 18, *Partitioning*.

When you create a `MERGE` table, MySQL creates two files on disk. The files have names that begin with the table name and have an extension to indicate the file type. An `.frm` file stores the table format, and an `.MRG` file contains the names of the underlying `MyISAM` tables that should be used as one. The tables do not have to be in the same database as the `MERGE` table.

You can use `SELECT`, `DELETE`, `UPDATE`, and `INSERT` on `MERGE` tables. You must have `SELECT`, `DELETE`, and `UPDATE` privileges on the `MyISAM` tables that you map to a `MERGE` table.

Note

The use of `MERGE` tables entails the following security issue: If a user has access to `MyISAM` table `t`, that user can create a `MERGE` table `m` that accesses `t`. However, if the user's privileges on `t` are subsequently revoked, the user can continue to access `t` by doing so through `m`.

Use of `DROP TABLE` with a `MERGE` table drops only the `MERGE` specification. The underlying tables are not affected.

To create a `MERGE` table, you must specify a `UNION=(list-of-tables)` option that indicates which `MyISAM` tables to use. You can optionally specify an `INSERT_METHOD` option to control how inserts into the `MERGE` table take place. Use a value of `FIRST` or `LAST` to cause inserts to be made in the first or last underlying table, respectively. If you specify no `INSERT_METHOD` option or if you specify it with a value of `NO`, inserts into the `MERGE` table are not permitted and attempts to do so result in an error.

The following example shows how to create a `MERGE` table:

```
mysql> CREATE TABLE t1 (
    ->    a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->    message CHAR(20)) ENGINE=MyISAM;
mysql> CREATE TABLE t2 (
    ->    a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->    message CHAR(20)) ENGINE=MyISAM;
mysql> INSERT INTO t1 (message) VALUES ('Testing'),('table'),('t1');
mysql> INSERT INTO t2 (message) VALUES ('Testing'),('table'),('t2');
```

```
mysql> CREATE TABLE total (
    ->     a INT NOT NULL AUTO_INCREMENT,
    ->     message CHAR(20), INDEX(a))
    ->     ENGINE=MERGE UNION=(t1,t2) INSERT_METHOD=LAST;
```

Column `a` is indexed as a `PRIMARY KEY` in the underlying `MyISAM` tables, but not in the `MERGE` table. There it is indexed but not as a `PRIMARY KEY` because a `MERGE` table cannot enforce uniqueness over the set of underlying tables. (Similarly, a column with a `UNIQUE` index in the underlying tables should be indexed in the `MERGE` table but not as a `UNIQUE` index.)

After creating the `MERGE` table, you can use it to issue queries that operate on the group of tables as a whole:

```
mysql> SELECT * FROM total;
+---+---------+
| a | message |
+---+---------+
| 1 | Testing |
| 2 | table   |
| 3 | t1      |
| 1 | Testing |
| 2 | table   |
| 3 | t2      |
+---+---------+
```

To remap a `MERGE` table to a different collection of `MyISAM` tables, you can use one of the following methods:

- `DROP` the `MERGE` table and re-create it.

- Use `ALTER TABLE` *tbl_name* `UNION=(...)` to change the list of underlying tables.

  Beginning with MySQL 5.1.24, it is also possible to use `ALTER TABLE ... UNION=()` (that is, with an empty `UNION` clause) to remove all of the underlying tables. However, in this case, the table is effectively empty and inserts fail because there is no underlying table to take new rows. Such a table might be useful as a template for creating new `MERGE` tables with `CREATE TABLE ... LIKE`.

As of MySQL 5.1.15, the underlying table definitions and indexes must conform more closely than previously to the definition of the `MERGE` table. Conformance is checked when a table that is part of a `MERGE` table is opened, not when the `MERGE` table is created. If any table fails the conformance checks, the operation that triggered the opening of the table fails. This means that changes to the definitions of tables within a `MERGE` may cause a failure when the `MERGE` table is accessed. The conformance checks applied to each table are:

- The underlying table and the `MERGE` table must have the same number of columns.

- The column order in the underlying table and the `MERGE` table must match.

- Additionally, the specification for each corresponding column in the parent `MERGE` table and the underlying tables are compared and must satisfy these checks:

  - The column type in the underlying table and the `MERGE` table must be equal.

  - The column length in the underlying table and the `MERGE` table must be equal.

  - The column of the underlying table and the `MERGE` table can be `NULL`.

- The underlying table must have at least as many indexes as the `MERGE` table. The underlying table may have more indexes than the `MERGE` table, but cannot have fewer.

> **Note**
>
> A known issue exists where indexes on the same columns must be in identical order, in both the `MERGE` table and the underlying `MyISAM` table. See Bug #33653.

Each index must satisfy these checks:

- The index type of the underlying table and the `MERGE` table must be the same.

- The number of index parts (that is, multiple columns within a compound index) in the index definition for the underlying table and the `MERGE` table must be the same.

- For each index part:

  - Index part lengths must be equal.

  - Index part types must be equal.

  - Index part languages must be equal.

  - Check whether index parts can be `NULL`.

For information about the table checks applied prior to MySQL 5.1.15, see Section 14.8.2, "MERGE Table Problems".

As of MySQL 5.1.20, if a `MERGE` table cannot be opened or used because of a problem with an underlying table, `CHECK TABLE` displays information about which table caused the problem.

Additional Resources

- A forum dedicated to the `MERGE` storage engine is available at http://forums.mysql.com/list.php?93.

14.8.1 MERGE Table Advantages and Disadvantages

`MERGE` tables can help you solve the following problems:

- Easily manage a set of log tables. For example, you can put data from different months into separate tables, compress some of them with `myisampack`, and then create a `MERGE` table to use them as one.

- Obtain more speed. You can split a large read-only table based on some criteria, and then put individual tables on different disks. A `MERGE` table structured this way could be much faster than using a single large table.

- Perform more efficient searches. If you know exactly what you are looking for, you can search in just one of the underlying tables for some queries and use a `MERGE` table for others. You can even have many different `MERGE` tables that use overlapping sets of tables.

- Perform more efficient repairs. It is easier to repair individual smaller tables that are mapped to a `MERGE` table than to repair a single large table.

- Instantly map many tables as one. A `MERGE` table need not maintain an index of its own because it uses the indexes of the individual tables. As a result, `MERGE` table collections are *very* fast to create or remap. (You must still specify the index definitions when you create a `MERGE` table, even though no indexes are created.)

- If you have a set of tables from which you create a large table on demand, you can instead create a `MERGE` table from them on demand. This is much faster and saves a lot of disk space.

- Exceed the file size limit for the operating system. Each `MyISAM` table is bound by this limit, but a collection of `MyISAM` tables is not.

- You can create an alias or synonym for a `MyISAM` table by defining a `MERGE` table that maps to that single table. There should be no really notable performance impact from doing this (only a couple of indirect calls and `memcpy()` calls for each read).

The disadvantages of `MERGE` tables are:

- You can use only identical `MyISAM` tables for a `MERGE` table.

- Some `MyISAM` features are unavailable in `MERGE` tables. For example, you cannot create `FULLTEXT` indexes on `MERGE` tables. (You can create `FULLTEXT` indexes on the underlying `MyISAM` tables, but you cannot search the `MERGE` table with a full-text search.)

- If the `MERGE` table is nontemporary, all underlying `MyISAM` tables must be nontemporary. If the `MERGE` table is temporary, the `MyISAM` tables can be any mix of temporary and nontemporary.

- `MERGE` tables use more file descriptors than `MyISAM` tables. If 10 clients are using a `MERGE` table that maps to 10 tables, the server uses (10 × 10) + 10 file descriptors. (10 data file descriptors for each of the 10 clients, and 10 index file descriptors shared among the clients.)

- Index reads are slower. When you read an index, the `MERGE` storage engine needs to issue a read on all underlying tables to check which one most closely matches a given index value. To read the next index value, the `MERGE` storage engine needs to search the read buffers to find the next value. Only when one index buffer is used up does the storage engine need to read the next index block. This makes `MERGE` indexes much slower on `eq_ref` searches, but not much slower on `ref` searches. For more information about `eq_ref` and `ref`, see Section 13.8.2, "EXPLAIN Syntax".

14.8.2 MERGE Table Problems

The following are known problems with `MERGE` tables:

- In versions of MySQL Server prior to 5.1.23, it was possible to create temporary merge tables with nontemporary child MyISAM tables.

  From versions 5.1.23, MERGE children were locked through the parent table. If the parent was temporary, it was not locked and so the children were not locked either. Parallel use of the MyISAM tables corrupted them.

- If you use `ALTER TABLE` to change a `MERGE` table to another storage engine, the mapping to the underlying tables is lost. Instead, the rows from the underlying `MyISAM` tables are copied into the altered table, which then uses the specified storage engine.

- The `INSERT_METHOD` table option for a `MERGE` table indicates which underlying `MyISAM` table to use for inserts into the `MERGE` table. However, use of the `AUTO_INCREMENT` table option for that `MyISAM` table has no effect for inserts into the `MERGE` table until at least one row has been inserted directly into the `MyISAM` table.

- A `MERGE` table cannot maintain uniqueness constraints over the entire table. When you perform an `INSERT`, the data goes into the first or last `MyISAM` table (as determined by the `INSERT_METHOD` option). MySQL ensures that unique key values remain unique within that `MyISAM` table, but not over all the underlying tables in the collection.

- Because the `MERGE` engine cannot enforce uniqueness over the set of underlying tables, `REPLACE` does not work as expected. The two key facts are:

  - `REPLACE` can detect unique key violations only in the underlying table to which it is going to write (which is determined by the `INSERT_METHOD` option). This differs from violations in the `MERGE` table itself.

  - If `REPLACE` detects a unique key violation, it will change only the corresponding row in the underlying table it is writing to; that is, the first or last table, as determined by the `INSERT_METHOD` option.

  Similar considerations apply for `INSERT ... ON DUPLICATE KEY UPDATE`.

- `MERGE` tables do not support partitioning. That is, you cannot partition a `MERGE` table, nor can any of a `MERGE` table's underlying `MyISAM` tables be partitioned.

- You should not use `ANALYZE TABLE`, `REPAIR TABLE`, `OPTIMIZE TABLE`, `ALTER TABLE`, `DROP TABLE`, `DELETE` without a `WHERE` clause, or `TRUNCATE TABLE` on any of the tables that are mapped into an open `MERGE` table. If you do so, the `MERGE` table may still refer to the original table and yield unexpected results. To work around this problem, ensure that no `MERGE` tables remain open by issuing a `FLUSH TABLES` statement prior to performing any of the named operations.

  The unexpected results include the possibility that the operation on the `MERGE` table will report table corruption. If this occurs after one of the named operations on the underlying `MyISAM` tables, the corruption message is spurious. To deal with this, issue a `FLUSH TABLES` statement after modifying the `MyISAM` tables.

- `DROP TABLE` on a table that is in use by a `MERGE` table does not work on Windows because the `MERGE` storage engine's table mapping is hidden from the upper layer of MySQL. Windows does not permit open files to be deleted, so you first must flush all `MERGE` tables (with `FLUSH TABLES`) or drop the `MERGE` table before dropping the table.

- As of MySQL 5.1.15, the definition of the `MyISAM` tables and the `MERGE` table are checked when the tables are accessed (for example, as part of a `SELECT` or `INSERT` statement). The checks ensure that the definitions of the tables and the parent `MERGE` table definition match by comparing column order, types, sizes and associated indexes. If there is a difference between the tables, an error is returned and the statement fails. Because these checks take place when the tables are opened, any changes to the definition of a single table, including column changes, column ordering, and engine alterations will cause the statement to fail.

  Prior to MySQL 5.1.15, table checks are applied as follows:

  - When you create or alter `MERGE` table, there is no check to ensure that the underlying tables are existing `MyISAM` tables and have identical structures. When the `MERGE` table is used, MySQL checks that the row length for all mapped tables is equal, but this is not foolproof. If you create a `MERGE` table from dissimilar `MyISAM` tables, you are very likely to run into strange problems.

  - Similarly, if you create a `MERGE` table from non-`MyISAM` tables, or if you drop an underlying table or alter it to be a non-`MyISAM` table, no error for the `MERGE` table occurs until later when you attempt to use it.

  - Because the underlying `MyISAM` tables need not exist when the `MERGE` table is created, you can create the tables in any order, as long as you do not use the `MERGE` table until all of its underlying tables are in place. Also, if you can ensure that a `MERGE` table will not be used during a given period, you can perform maintenance operations on the underlying tables, such as backing up or restoring them, altering them, or dropping and recreating them. It is not necessary to redefine the `MERGE` table temporarily to exclude the underlying tables while you are operating on them.

- The order of indexes in the `MERGE` table and its underlying tables should be the same. If you use `ALTER TABLE` to add a `UNIQUE` index to a table used in a `MERGE` table, and then use `ALTER TABLE` to add a nonunique index on the `MERGE` table, the index ordering is different for the tables if there was already a nonunique index in the underlying table. (This happens because `ALTER TABLE` puts `UNIQUE` indexes before nonunique indexes to facilitate rapid detection of duplicate keys.) Consequently, queries on tables with such indexes may return unexpected results.

- If you encounter an error message similar to `ERROR 1017 (HY000): Can't find file: 'tbl_name.MRG' (errno: 2)`, it generally indicates that some of the underlying tables do not use the `MyISAM` storage engine. Confirm that all of these tables are `MyISAM`.

- The maximum number of rows in a `MERGE` table is 2^{64} (~1.844E+19; the same as for a `MyISAM` table), provided that the server was built using the `--with-big-tables` option. (All standard MySQL 5.1 standard binaries are built with this option; for more information, see Section 2.11.4, "MySQL Source-Configuration Options".) It is not possible to merge multiple `MyISAM` tables into a single `MERGE` table that would have more than this number of rows.

- The `MERGE` storage engine does not support `INSERT DELAYED` statements.

- Use of underlying `MyISAM` tables of differing row formats with a parent `MERGE` table is currently known to fail. See Bug #32364.

- As of MySQL 5.1.23, you cannot change the union list of a nontemporary `MERGE` table when `LOCK TABLES` is in effect. The following does *not* work:

```
CREATE TABLE m1 ... ENGINE=MRG_MYISAM ...;
LOCK TABLES t1 WRITE, t2 WRITE, m1 WRITE;
ALTER TABLE m1 ... UNION=(t1,t2) ...;
```

However, you can do this with a temporary `MERGE` table.

- As of MySQL 5.1.23, you cannot create a `MERGE` table with `CREATE ... SELECT`, neither as a temporary `MERGE` table, nor as a nontemporary `MERGE` table. For example:

```
CREATE TABLE m1 ... ENGINE=MRG_MYISAM ... SELECT ...;
```

Attempts to do this result in an error: `tbl_name` is not `BASE TABLE`.

- In some cases, differing `PACK_KEYS` table option values among the `MERGE` and underlying tables cause unexpected results if the underlying tables contain `CHAR` or `BINARY` columns. As a workaround, use `ALTER TABLE` to ensure that all involved tables have the same `PACK_KEYS` value. (Bug #50646)

14.9 The MEMORY Storage Engine

The `MEMORY` storage engine (formerly known as `HEAP`) creates special-purpose tables with contents that are stored in memory. Because the data is vulnerable to crashes, hardware issues, or power outages, only use these tables as temporary work areas or read-only caches for data pulled from other tables.

Table 14.13 `MEMORY` Storage Engine Features

Storage limits	RAM	Transactions	No	Locking granularity	Table
MVCC	No	Geospatial data type support	No	Geospatial indexing support	No
B-tree indexes	Yes	T-tree indexes	No	Hash indexes	Yes
Full-text search indexes	No	Clustered indexes	No	Data caches	N/A

Index caches	N/A	Compressed data	No	Encrypted data[a]	Yes
Cluster database support	No	Replication support[b]	Yes	Foreign key support	No
Backup / point-in-time recovery[c]	Yes	Query cache support	Yes	Update statistics for data dictionary	Yes

[a]Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and higher.

[b]Implemented in the server, rather than in the storage engine.

[c]Implemented in the server, rather than in the storage engine.

When to Use MEMORY or MySQL Cluster. Developers looking to deploy applications that use the `MEMORY` storage engine for important, highly available, or frequently updated data should consider whether MySQL Cluster is a better choice. A typical use case for the `MEMORY` engine involves these characteristics:

- Operations involving transient, non-critical data such as session management or caching. When the MySQL server halts or restarts, the data in `MEMORY` tables is lost.

- In-memory storage for fast access and low latency. Data volume can fit entirely in memory without causing the operating system to swap out virtual memory pages.

- A read-only or read-mostly data access pattern (limited updates).

MySQL Cluster offers the same features as the `MEMORY` engine with higher performance levels, and provides additional features not available with `MEMORY`:

- Row-level locking and multiple-thread operation for low contention between clients.

- Scalability even with statement mixes that include writes.

- Optional disk-backed operation for data durability.

- Shared-nothing architecture and multiple-host operation with no single point of failure, enabling 99.999% availability.

- Automatic data distribution across nodes; application developers need not craft custom sharding or partitioning solutions.

- Support for variable-length data types (including `BLOB` and `TEXT`) not supported by `MEMORY`.

For a white paper with more detailed comparison of the `MEMORY` storage engine and MySQL Cluster, see Scaling Web Services with MySQL Cluster: An Alternative to the MySQL Memory Storage Engine. This white paper includes a performance study of the two technologies and a step-by-step guide describing how existing `MEMORY` users can migrate to MySQL Cluster.

Performance Characteristics

`MEMORY` performance is constrained by contention resulting from single-thread execution and table lock overhead when processing updates. This limits scalability when load increases, particularly for statement mixes that include writes.

Despite the in-memory processing for `MEMORY` tables, they are not necessarily faster than `InnoDB` tables on a busy server, for general-purpose queries, or under a read/write workload. In particular, the table locking involved with performing updates can slow down concurrent usage of `MEMORY` tables from multiple sessions.

Depending on the kinds of queries performed on a `MEMORY` table, you might create indexes as either the default hash data structure (for looking up single values based on a unique key), or a general-purpose B-

tree data structure (for all kinds of queries involving equality, inequality, or range operators such as less than or greater than). The following sections illustrate the syntax for creating both kinds of indexes. A common performance issue is using the default hash indexes in workloads where B-tree indexes are more efficient.

Physical Characteristics of MEMORY Tables

The `MEMORY` storage engine associates each table with one disk file, which stores the table definition (not the data). The file name begins with the table name and has an extension of `.frm`.

`MEMORY` tables have the following characteristics:

- Space for `MEMORY` tables is allocated in small blocks. Tables use 100% dynamic hashing for inserts. No overflow area or extra key space is needed. No extra space is needed for free lists. Deleted rows are put in a linked list and are reused when you insert new data into the table. `MEMORY` tables also have none of the problems commonly associated with deletes plus inserts in hashed tables.

- `MEMORY` tables use a fixed-length row-storage format. Variable-length types such as `VARCHAR` are stored using a fixed length.

- `MEMORY` tables cannot contain `BLOB` or `TEXT` columns.

- `MEMORY` includes support for `AUTO_INCREMENT` columns.

- Non-`TEMPORARY MEMORY` tables are shared among all clients, just like any other non-`TEMPORARY` table.

DDL Operations for MEMORY Tables

To create a `MEMORY` table, specify the clause `ENGINE=MEMORY` on the `CREATE TABLE` statement.

```
CREATE TABLE t (i INT) ENGINE = MEMORY;
```

As indicated by the engine name, `MEMORY` tables are stored in memory. They use hash indexes by default, which makes them very fast for single-value lookups, and very useful for creating temporary tables. However, when the server shuts down, all rows stored in `MEMORY` tables are lost. The tables themselves continue to exist because their definitions are stored in `.frm` files on disk, but they are empty when the server restarts.

This example shows how you might create, use, and remove a `MEMORY` table:

```
mysql> CREATE TABLE test ENGINE=MEMORY
    ->     SELECT ip,SUM(downloads) AS down
    ->     FROM log_table GROUP BY ip;
mysql> SELECT COUNT(ip),AVG(down) FROM test;
mysql> DROP TABLE test;
```

The maximum size of `MEMORY` tables is limited by the `max_heap_table_size` system variable, which has a default value of 16MB. To enforce different size limits for `MEMORY` tables, change the value of this variable. The value in effect for `CREATE TABLE`, or a subsequent `ALTER TABLE` or `TRUNCATE TABLE`, is the value used for the life of the table. A server restart also sets the maximum size of existing `MEMORY` tables to the global `max_heap_table_size` value. You can set the size for individual tables as described later in this section.

Indexes

The `MEMORY` storage engine supports both `HASH` and `BTREE` indexes. You can specify one or the other for a given index by adding a `USING` clause as shown here:

```
CREATE TABLE lookup
    (id INT, INDEX USING HASH (id))
    ENGINE = MEMORY;
CREATE TABLE lookup
    (id INT, INDEX USING BTREE (id))
    ENGINE = MEMORY;
```

For general characteristics of B-tree and hash indexes, see Section 8.3.1, "How MySQL Uses Indexes".

MEMORY tables can have up to 64 indexes per table, 16 columns per index and a maximum key length of 3072 bytes.

If a MEMORY table hash index has a high degree of key duplication (many index entries containing the same value), updates to the table that affect key values and all deletes are significantly slower. The degree of this slowdown is proportional to the degree of duplication (or, inversely proportional to the index cardinality). You can use a BTREE index to avoid this problem.

MEMORY tables can have nonunique keys. (This is an uncommon feature for implementations of hash indexes.)

Columns that are indexed can contain NULL values.

User-Created and Temporary Tables

MEMORY table contents are stored in memory, which is a property that MEMORY tables share with internal temporary tables that the server creates on the fly while processing queries. However, the two types of tables differ in that MEMORY tables are not subject to storage conversion, whereas internal temporary tables are:

- If an internal temporary table becomes too large, the server automatically converts it to on-disk storage, as described in Section 8.4.4, "Internal Temporary Table Use in MySQL".

- User-created MEMORY tables are never converted to disk tables.

Loading Data

To populate a MEMORY table when the MySQL server starts, you can use the --init-file option. For example, you can put statements such as INSERT INTO ... SELECT or LOAD DATA INFILE into this file to load the table from a persistent data source. See Section 5.1.3, "Server Command Options", and Section 13.2.6, "LOAD DATA INFILE Syntax".

For loading data into MEMORY tables accessed by other sessions concurrently, MEMORY supports INSERT DELAYED. See Section 13.2.5.2, "INSERT DELAYED Syntax".

MEMORY Tables and Replication

A server's MEMORY tables become empty when it is shut down and restarted. If the server is a replication master, its slaves are not aware that these tables have become empty, so you see out-of-date content if you select data from the tables on the slaves. To synchronize master and slave MEMORY tables, when a MEMORY table is used on a master for the first time since it was started, a DELETE statement is written to the master's binary log, to empty the table on the slaves also. The slave still has outdated data in the table during the interval between the master's restart and its first use of the table. To avoid this interval when a direct query to the slave could return stale data, use the --init-file option to populate the MEMORY table on the master at startup.

Managing Memory Use

The server needs sufficient memory to maintain all `MEMORY` tables that are in use at the same time.

Memory is not reclaimed if you delete individual rows from a `MEMORY` table. Memory is reclaimed only when the entire table is deleted. Memory that was previously used for deleted rows is re-used for new rows within the same table. To free all the memory used by a `MEMORY` table when you no longer require its contents, execute `DELETE` or `TRUNCATE TABLE` to remove all rows, or remove the table altogether using `DROP TABLE`. To free up the memory used by deleted rows, use `ALTER TABLE ENGINE=MEMORY` to force a table rebuild.

The memory needed for one row in a `MEMORY` table is calculated using the following expression:

```
SUM_OVER_ALL_BTREE_KEYS(max_length_of_key + sizeof(char*) * 4)
+ SUM_OVER_ALL_HASH_KEYS(sizeof(char*) * 2)
+ ALIGN(length_of_row+1, sizeof(char*))
```

`ALIGN()` represents a round-up factor to cause the row length to be an exact multiple of the `char` pointer size. `sizeof(char*)` is 4 on 32-bit machines and 8 on 64-bit machines.

As mentioned earlier, the `max_heap_table_size` system variable sets the limit on the maximum size of `MEMORY` tables. To control the maximum size for individual tables, set the session value of this variable before creating each table. (Do not change the global `max_heap_table_size` value unless you intend the value to be used for `MEMORY` tables created by all clients.) The following example creates two `MEMORY` tables, with a maximum size of 1MB and 2MB, respectively:

```
mysql> SET max_heap_table_size = 1024*1024;
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t1 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.01 sec)

mysql> SET max_heap_table_size = 1024*1024*2;
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t2 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.00 sec)
```

Both tables revert to the server's global `max_heap_table_size` value if the server restarts.

You can also specify a `MAX_ROWS` table option in `CREATE TABLE` statements for `MEMORY` tables to provide a hint about the number of rows you plan to store in them. This does not enable the table to grow beyond the `max_heap_table_size` value, which still acts as a constraint on maximum table size. For maximum flexibility in being able to use `MAX_ROWS`, set `max_heap_table_size` at least as high as the value to which you want each `MEMORY` table to be able to grow.

Additional Resources

A forum dedicated to the `MEMORY` storage engine is available at http://forums.mysql.com/list.php?92.

14.10 The EXAMPLE Storage Engine

The `EXAMPLE` storage engine is a stub engine that does nothing. Its purpose is to serve as an example in the MySQL source code that illustrates how to begin writing new storage engines. As such, it is primarily of interest to developers.

To enable the `EXAMPLE` storage engine if you build MySQL from source, invoke `configure` with the `--with-example-storage-engine` option.

To examine the source for the `EXAMPLE` engine, look in the `storage/example` directory of a MySQL source distribution.

When you create an `EXAMPLE` table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. No other files are created. No data can be stored into the table. Retrievals return an empty result.

```
mysql> CREATE TABLE test (i INT) ENGINE = EXAMPLE;
Query OK, 0 rows affected (0.78 sec)

mysql> INSERT INTO test VALUES(1),(2),(3);
ERROR 1031 (HY000): Table storage engine for 'test' doesn't »
                    have this option

mysql> SELECT * FROM test;
Empty set (0.31 sec)
```

The `EXAMPLE` storage engine does not support indexing.

14.11 The FEDERATED Storage Engine

The `FEDERATED` storage engine lets you access data from a remote MySQL database without using replication or cluster technology. Querying a local `FEDERATED` table automatically pulls the data from the remote (federated) tables. No data is stored on the local tables.

To include the `FEDERATED` storage engine if you build MySQL from source, invoke `configure` with the `--with-federated-storage-engine` option.

Beginning with MySQL 5.1.26, the `FEDERATED` storage engine is not enabled by default in the running server; to enable `FEDERATED`, you must start the MySQL server binary using the `--federated` option.

To examine the source for the `FEDERATED` engine, look in the `storage/federated` directory of a MySQL source distribution.

14.11.1 FEDERATED Storage Engine Overview

When you create a table using one of the standard storage engines (such as `MyISAM`, `CSV` or `InnoDB`), the table consists of the table definition and the associated data. When you create a `FEDERATED` table, the table definition is the same, but the physical storage of the data is handled on a remote server.

A `FEDERATED` table consists of two elements:

- A *remote server* with a database table, which in turn consists of the table definition (stored in the `.frm` file) and the associated table. The table type of the remote table may be any type supported by the remote `mysqld` server, including `MyISAM` or `InnoDB`.

- A *local server* with a database table, where the table definition matches that of the corresponding table on the remote server. The table definition is stored within the `.frm` file. However, there is no data file on the local server. Instead, the table definition includes a connection string that points to the remote table.

When executing queries and statements on a `FEDERATED` table on the local server, the operations that would normally insert, update or delete information from a local data file are instead sent to the remote

server for execution, where they update the data file on the remote server or return matching rows from the remote server.

The basic structure of a `FEDERATED` table setup is shown in Figure 14.1, "FEDERATED Table Structure".

Figure 14.1 FEDERATED Table Structure
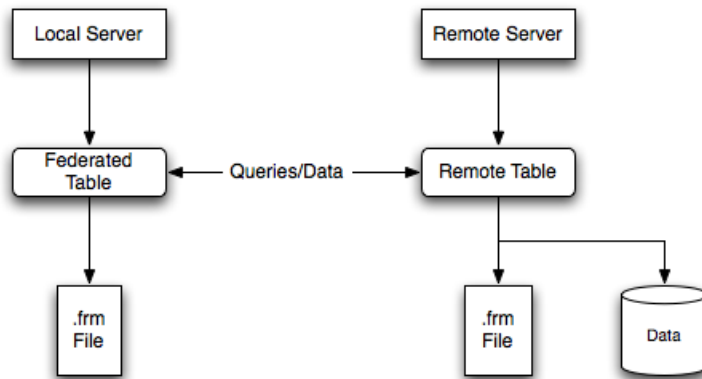
When a client issues an SQL statement that refers to a `FEDERATED` table, the flow of information between the local server (where the SQL statement is executed) and the remote server (where the data is physically stored) is as follows:

1. The storage engine looks through each column that the `FEDERATED` table has and constructs an appropriate SQL statement that refers to the remote table.

2. The statement is sent to the remote server using the MySQL client API.

3. The remote server processes the statement and the local server retrieves any result that the statement produces (an affected-rows count or a result set).

4. If the statement produces a result set, each column is converted to internal storage engine format that the `FEDERATED` engine expects and can use to display the result to the client that issued the original statement.

The local server communicates with the remote server using MySQL client C API functions. It invokes `mysql_real_query()` to send the statement. To read a result set, it uses `mysql_store_result()` and fetches rows one at a time using `mysql_fetch_row()`.

14.11.2 How to Create FEDERATED Tables

To create a `FEDERATED` table you should follow these steps:

1. Create the table on the remote server. Alternatively, make a note of the table definition of an existing table, perhaps using the `SHOW CREATE TABLE` statement.

2. Create the table on the local server with an identical table definition, but adding the connection information that links the local table to the remote table.

For example, you could create the following table on the remote server:

```
CREATE TABLE test_table (
    id       INT(20) NOT NULL AUTO_INCREMENT,
```

```
    name   VARCHAR(32) NOT NULL DEFAULT '',
    other  INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
)
ENGINE=MyISAM
DEFAULT CHARSET=latin1;
```

To create the local table that will be federated to the remote table, there are two options available. You can either create the local table and specify the connection string (containing the server name, login, password) to be used to connect to the remote table using the CONNECTION, or you can use an existing connection that you have previously created using the CREATE SERVER statement.

> **Important**
>
> When you create the local table it *must* have an identical field definition to the remote table.

> **Note**
>
> You can improve the performance of a FEDERATED table by adding indexes to the table on the host. The optimization will occur because the query sent to the remote server will include the contents of the WHERE clause and will be sent to the remote server and subsequently executed locally. This reduces the network traffic that would otherwise request the entire table from the server for local processing.

14.11.2.1 Creating a FEDERATED Table Using CONNECTION

To use the first method, you must specify the CONNECTION string after the engine type in a CREATE TABLE statement. For example:

```
CREATE TABLE federated_table (
    id     INT(20) NOT NULL AUTO_INCREMENT,
    name   VARCHAR(32) NOT NULL DEFAULT '',
    other  INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
)
ENGINE=FEDERATED
DEFAULT CHARSET=latin1
CONNECTION='mysql://fed_user@remote_host:9306/federated/test_table';
```

> **Note**
>
> CONNECTION replaces the COMMENT used in some previous versions of MySQL.

The CONNECTION string contains the information required to connect to the remote server containing the table that will be used to physically store the data. The connection string specifies the server name, login credentials, port number and database/table information. In the example, the remote table is on the server remote_host, using port 9306. The name and port number should match the host name (or IP address) and port number of the remote MySQL server instance you want to use as your remote table.

The format of the connection string is as follows:

```
scheme://user_name[:password]@host_name[:port_num]/db_name/tbl_name
```

Where:

- *scheme*: A recognized connection protocol. Only `mysql` is supported as the *scheme* value at this point.

- *user_name*: The user name for the connection. This user must have been created on the remote server, and must have suitable privileges to perform the required actions (`SELECT`, `INSERT`, `UPDATE`, and so forth) on the remote table.

- *password*: (Optional) The corresponding password for *user_name*.

- *host_name*: The host name or IP address of the remote server.

- *port_num*: (Optional) The port number for the remote server. The default is 3306.

- *db_name*: The name of the database holding the remote table.

- *tbl_name*: The name of the remote table. The name of the local and the remote table do not have to match.

Sample connection strings:

```
CONNECTION='mysql://username:password@hostname:port/database/tablename'
CONNECTION='mysql://username@hostname/database/tablename'
CONNECTION='mysql://username:password@hostname/database/tablename'
```

14.11.2.2 Creating a FEDERATED Table Using CREATE SERVER

If you are creating a number of `FEDERATED` tables on the same server, or if you want to simplify the process of creating `FEDERATED` tables, you can use the `CREATE SERVER` statement to define the server connection parameters, just as you would with the `CONNECTION` string.

The format of the `CREATE SERVER` statement is:

```
CREATE SERVER
server_name
FOREIGN DATA WRAPPER wrapper_name
OPTIONS (option [, option] ...)
```

The *server_name* is used in the connection string when creating a new `FEDERATED` table.

For example, to create a server connection identical to the `CONNECTION` string:

```
CONNECTION='mysql://fed_user@remote_host:9306/federated/test_table';
```

You would use the following statement:

```
CREATE SERVER fedlink
FOREIGN DATA WRAPPER mysql
OPTIONS (USER 'fed_user', HOST 'remote_host', PORT 9306, DATABASE 'federated');
```

To create a `FEDERATED` table that uses this connection, you still use the `CONNECTION` keyword, but specify the name you used in the `CREATE SERVER` statement.

```
CREATE TABLE test_table (
    id      INT(20) NOT NULL AUTO_INCREMENT,
    name    VARCHAR(32) NOT NULL DEFAULT '',
    other   INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
```

```
)
ENGINE=FEDERATED
DEFAULT CHARSET=latin1
CONNECTION='fedlink/test_table';
```

The connection name in this example contains the name of the connection (`fedlink`) and the name of the table (`test_table`) to link to, separated by a slash. If you specify only the connection name without a table name, the table name of the local table is used instead.

For more information on `CREATE SERVER`, see Section 13.1.16, "CREATE SERVER Syntax".

The `CREATE SERVER` statement accepts the same arguments as the `CONNECTION` string. The `CREATE SERVER` statement updates the rows in the `mysql.servers` table. See the following table for information on the correspondence between parameters in a connection string, options in the `CREATE SERVER` statement, and the columns in the `mysql.servers` table. For reference, the format of the `CONNECTION` string is as follows:

```
scheme://user_name[:password]@host_name[:port_num]/db_name/tbl_name
```

Description	CONNECTION string	CREATE SERVER option	mysql.servers column
Connection scheme	scheme	wrapper_name	Wrapper
Remote user	user_name	USER	Username
Remote password	password	PASSWORD	Password
Remote host	host_name	HOST	Host
Remote port	port_num	PORT	Port
Remote database	db_name	DATABASE	Db

14.11.3 FEDERATED Storage Engine Notes and Tips

You should be aware of the following points when using the `FEDERATED` storage engine:

- `FEDERATED` tables may be replicated to other slaves, but you must ensure that the slave servers are able to use the user/password combination that is defined in the `CONNECTION` string (or the row in the `mysql.servers` table) to connect to the remote server.

The following items indicate features that the `FEDERATED` storage engine does and does not support:

- The remote server must be a MySQL server.

- The remote table that a `FEDERATED` table points to *must* exist before you try to access the table through the `FEDERATED` table.

- It is possible for one `FEDERATED` table to point to another, but you must be careful not to create a loop.

- A `FEDERATED` table does not support indexes in the usual sense; because access to the table data is handled remotely, it is actually the remote table that makes use of indexes. This means that, for a query that cannot use any indexes and so requires a full table scan, the server fetches all rows from the remote table and filters them locally. This occurs regardless of any `WHERE` or `LIMIT` used with this `SELECT` statement; these clauses are applied locally to the returned rows.

  Queries that fail to use indexes can thus cause poor performance and network overload. In addition, since returned rows must be stored in memory, such a query can also lead to the local server swapping, or even hanging.

- Care should be taken when creating a `FEDERATED` table since the index definition from an equivalent `MyISAM` or other table may not be supported. For example, creating a `FEDERATED` table with an index prefix on `VARCHAR`, `TEXT` or `BLOB` columns will fail. The following definition in `MyISAM` is valid:

  ```
  CREATE TABLE `T1`(`A` VARCHAR(100),UNIQUE KEY(`A`(30))) ENGINE=MYISAM;
  ```

  The key prefix in this example is incompatible with the `FEDERATED` engine, and the equivalent statement will fail:

  ```
  CREATE TABLE `T1`(`A` VARCHAR(100),UNIQUE KEY(`A`(30))) ENGINE=FEDERATED
    CONNECTION='MYSQL://127.0.0.1:3306/TEST/T1';
  ```

  If possible, you should try to separate the column and index definition when creating tables on both the remote server and the local server to avoid these index issues.

- Internally, the implementation uses `SELECT`, `INSERT`, `UPDATE`, and `DELETE`, but not `HANDLER`.

- The `FEDERATED` storage engine supports `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE TABLE`, and indexes. It does not support `ALTER TABLE`, or any Data Definition Language statements that directly affect the structure of the table, other than `DROP TABLE`. The current implementation does not use prepared statements.

- `FEDERATED` accepts `INSERT ... ON DUPLICATE KEY UPDATE` statements, but if a duplicate-key violation occurs, the statement fails with an error.

- Performance on a `FEDERATED` table when performing bulk inserts (for example, on a `INSERT INTO ... SELECT ...` statement) is slower than with other table types because each selected row is treated as an individual `INSERT` statement on the `FEDERATED` table.

- Transactions are not supported.

- Before MySQL 5.1.21, for a multiple-row insert into a `FEDERATED` table that refers to a remote transactional table, if the insert failed for a row due to constraint failure, the remote table would contain a partial commit (the rows preceding the failed one) instead of rolling back the statement completely. This occurred because the rows were treated as individual inserts.

  As of MySQL 5.1.21, `FEDERATED` performs bulk-insert handling such that multiple rows are sent to the remote table in a batch. This provides a performance improvement and enables the remote table to perform improvement. Also, if the remote table is transactional, it enables the remote storage engine to perform statement rollback properly should an error occur. This capability has the following limitations:

  - The size of the insert cannot exceed the maximum packet size between servers. If the insert exceeds this size, it is broken into multiple packets and the rollback problem can occur.

  - Bulk-insert handling does not occur for `INSERT ... ON DUPLICATE KEY UPDATE`.

- There is no way for the `FEDERATED` engine to know if the remote table has changed. The reason for this is that this table must work like a data file that would never be written to by anything other than the database system. The integrity of the data in the local table could be breached if there was any change to the remote database.

- When using a `CONNECTION` string, you cannot use an '@' character in the password. You can get round this limitation by using the `CREATE SERVER` statement to create a server connection.

- The `insert_id` and `timestamp` options are not propagated to the data provider.

- Any `DROP TABLE` statement issued against a `FEDERATED` table drops only the local table, not the remote table.

- `FEDERATED` tables do not work with the query cache.

- User-defined partitioning is not supported for `FEDERATED` tables. Beginning with MySQL 5.1.15, it is no longer possible to create such tables at all.

14.11.4 FEDERATED Storage Engine Resources

The following additional resources are available for the `FEDERATED` storage engine:

- A forum dedicated to the `FEDERATED` storage engine is available at http://forums.mysql.com/list.php? 105.

14.12 The ARCHIVE Storage Engine

The `ARCHIVE` storage engine is used for storing large amounts of data without indexes in a very small footprint.

Table 14.14 `ARCHIVE` Storage Engine Features

Storage limits	None	Transactions	No	Locking granularity	Row
MVCC	No	Geospatial data type support	Yes	Geospatial indexing support	No
B-tree indexes	No	T-tree indexes	No	Hash indexes	No
Full-text search indexes	No	Clustered indexes	No	Data caches	No
Index caches	No	Compressed data	Yes	Encrypted data[a]	Yes
Cluster database support	No	Replication support[b]	Yes	Foreign key support	No
Backup / point-in-time recovery[c]	Yes	Query cache support	Yes	Update statistics for data dictionary	Yes

[a]Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and higher.
[b]Implemented in the server, rather than in the storage engine.
[c]Implemented in the server, rather than in the storage engine.

The `ARCHIVE` storage engine is included in MySQL binary distributions. To enable this storage engine if you build MySQL from source, invoke `configure` with the `--with-archive-storage-engine` option.

To examine the source for the `ARCHIVE` engine, look in the `storage/archive` directory of a MySQL source distribution.

You can check whether the `ARCHIVE` storage engine is available with the `SHOW ENGINES` statement.

When you create an `ARCHIVE` table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. The storage engine creates other files, all having names beginning with the table name. The data file has an extension of `.ARZ`. (Prior to MySQL 5.1.15, a metadata file with an extension of `.ARM` is created as well.) An `.ARN` file may appear during optimization operations.

The `ARCHIVE` engine supports `INSERT`, `REPLACE`, and `SELECT`, but not `DELETE` or `UPDATE`. It does support `ORDER BY` operations, `BLOB` columns, and basically all but spatial data types (see Section 11.5.1, "Spatial Data Types"). The `ARCHIVE` engine uses row-level locking.

As of MySQL 5.1.6, the `ARCHIVE` engine supports the `AUTO_INCREMENT` column attribute. The `AUTO_INCREMENT` column can have either a unique or nonunique index. Attempting to create an index

on any other column results in an error. The `ARCHIVE` engine also supports the `AUTO_INCREMENT` table option in `CREATE TABLE` statements to specify the initial sequence value for a new table or reset the sequence value for an existing table, respectively.

`ARCHIVE` does not support inserting a value into an `AUTO_INCREMENT` column less than the current maximum column value. Attempts to do so result in an `ER_DUP_KEY` error.

As of MySQL 5.1.6, the `ARCHIVE` engine ignores `BLOB` columns if they are not requested and scans past them while reading. Formerly, the following two statements had the same cost, but as of 5.1.6, the second is much more efficient than the first:

```
SELECT a, b, blob_col FROM archive_table;
SELECT a, b FROM archive_table;
```

Storage: Rows are compressed as they are inserted. The `ARCHIVE` engine uses `zlib` lossless data compression (see http://www.zlib.net/). You can use `OPTIMIZE TABLE` to analyze the table and pack it into a smaller format (for a reason to use `OPTIMIZE TABLE`, see later in this section). The engine also supports `CHECK TABLE`. There are several types of insertions that are used:

- An `INSERT` statement just pushes rows into a compression buffer, and that buffer flushes as necessary. The insertion into the buffer is protected by a lock. A `SELECT` forces a flush to occur, unless the only insertions that have come in were `INSERT DELAYED` (those flush as necessary). See Section 13.2.5.2, "INSERT DELAYED Syntax".

- A bulk insert is visible only after it completes, unless other inserts occur at the same time, in which case it can be seen partially. A `SELECT` never causes a flush of a bulk insert unless a normal insert occurs while it is loading.

Retrieval: On retrieval, rows are uncompressed on demand; there is no row cache. A `SELECT` operation performs a complete table scan: When a `SELECT` occurs, it finds out how many rows are currently available and reads that number of rows. `SELECT` is performed as a consistent read. Note that lots of `SELECT` statements during insertion can deteriorate the compression, unless only bulk or delayed inserts are used. To achieve better compression, you can use `OPTIMIZE TABLE` or `REPAIR TABLE`. The number of rows in `ARCHIVE` tables reported by `SHOW TABLE STATUS` is always accurate. See Section 13.7.2.5, "OPTIMIZE TABLE Syntax", Section 13.7.2.6, "REPAIR TABLE Syntax", and Section 13.7.5.38, "SHOW TABLE STATUS Syntax".

> **Warning**
>
> **Known issue**: After a binary upgrade to MySQL 5.1 from a MySQL 5.0 installation that contains `ARCHIVE` tables:
>
> - Before MySQL 5.1.42, accessing those tables will cause the server to crash, even if you have run `mysql_upgrade` or `CHECK TABLE ... FOR UPGRADE`.
>
> - As of MySQL 5.1.42, the server will not open 5.0 `ARCHIVE` tables at all.
>
> In either case, the solution is to use `mysqldump` to dump all 5.0 `ARCHIVE` tables before upgrading, and reload them into MySQL 5.1 after upgrading. This problem is fixed in MySQL 5.6.4: The server can open `ARCHIVE` tables created in MySQL 5.0. However, it remains the recommended upgrade procedure to dump 5.0 `ARCHIVE` tables before upgrading and reload after upgrading.

Additional Resources

- A forum dedicated to the `ARCHIVE` storage engine is available at http://forums.mysql.com/list.php?112.

14.13 The CSV Storage Engine

The `CSV` storage engine stores data in text files using comma-separated values format.

To enable the `CSV` storage engine if you build MySQL from source, invoke `configure` with the `--with-csv-storage-engine` option.

To examine the source for the `CSV` engine, look in the `storage/csv` directory of a MySQL source distribution.

When you create a `CSV` table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. The storage engine also creates a data file. Its name begins with the table name and has a `.CSV` extension. The data file is a plain text file. When you store data into the table, the storage engine saves it into the data file in comma-separated values format.

```
mysql> CREATE TABLE test (i INT NOT NULL, c CHAR(10) NOT NULL)
    -> ENGINE = CSV;
Query OK, 0 rows affected (0.12 sec)

mysql> INSERT INTO test VALUES(1,'record one'),(2,'record two');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM test;
+------+------------+
| i    | c          |
+------+------------+
|    1 | record one |
|    2 | record two |
+------+------------+
2 rows in set (0.00 sec)
```

Starting with MySQL 5.1.9, creating a CSV table also creates a corresponding Metafile that stores the state of the table and the number of rows that exist in the table. The name of this file is the same as the name of the table with the extension `CSM`.

If you examine the `test.CSV` file in the database directory created by executing the preceding statements, its contents should look like this:

```
"1","record one"
"2","record two"
```

This format can be read, and even written, by spreadsheet applications such as Microsoft Excel or StarOffice Calc.

14.13.1 Repairing and Checking CSV Tables

Functionality introduced in version 5.1.9

The CSV storage engines supports the `CHECK` and `REPAIR` statements to verify and if possible repair a damaged CSV table.

When running the `CHECK` statement, the CSV file will be checked for validity by looking for the correct field separators, escaped fields (matching or missing quotation marks), the correct number of fields compared to the table definition and the existence of a corresponding CSV metafile. The first invalid row discovered will report an error. Checking a valid table produces output like that shown below:

```
mysql> check table csvtest;
+--------------+-------+----------+----------+
```

```
| Table        | Op     | Msg_type | Msg_text |
+--------------+-------+----------+----------+
| test.csvtest | check | status   | OK       |
+--------------+-------+----------+----------+
1 row in set (0.00 sec)
```

A check on a corrupted table returns a fault:

```
mysql> check table csvtest;
+--------------+-------+----------+----------+
| Table        | Op    | Msg_type | Msg_text |
+--------------+-------+----------+----------+
| test.csvtest | check | error    | Corrupt  |
+--------------+-------+----------+----------+
1 row in set (0.01 sec)
```

If the check fails, the table is marked as crashed (corrupt). Once a table has been marked as corrupt, it is automatically repaired when you next run `CHECK` or execute a `SELECT` statement. The corresponding corrupt status and new status will be displayed when running `CHECK`:

```
mysql> check table csvtest;
+--------------+-------+----------+---------------------------+
| Table        | Op    | Msg_type | Msg_text                  |
+--------------+-------+----------+---------------------------+
| test.csvtest | check | warning  | Table is marked as crashed |
| test.csvtest | check | status   | OK                        |
+--------------+-------+----------+---------------------------+
2 rows in set (0.08 sec)
```

To repair a table you can use `REPAIR`, this copies as many valid rows from the existing CSV data as possible, and then replaces the existing CSV file with the recovered rows. Any rows beyond the corrupted data are lost.

```
mysql> repair table csvtest;
+--------------+--------+----------+----------+
| Table        | Op     | Msg_type | Msg_text |
+--------------+--------+----------+----------+
| test.csvtest | repair | status   | OK       |
+--------------+--------+----------+----------+
1 row in set (0.02 sec)
```

> **Warning**
>
> During repair, only the rows from the CSV file up to the first damaged row are copied to the new table. All other rows from the first damaged row to the end of the table are removed, even valid rows.

14.13.2 CSV Limitations

The `CSV` storage engine does not support indexing.

Partitioning is not supported for tables using the `CSV` storage engine. Beginning with MySQL 5.1.12, it is no longer possible to create partitioned `CSV` tables. (See Bug #19307)

Beginning with MySQL 5.1.23, all tables that you create using the `CSV` storage engine must have the `NOT NULL` attribute on all columns. However, for backward compatibility, you can continue to use tables with nullable columns that were created in previous MySQL releases. (Bug #32050)

14.14 The BLACKHOLE Storage Engine

The `BLACKHOLE` storage engine acts as a "black hole" that accepts data but throws it away and does not store it. Retrievals always return an empty result:

```
mysql> CREATE TABLE test(i INT, c CHAR(10)) ENGINE = BLACKHOLE;
Query OK, 0 rows affected (0.03 sec)

mysql> INSERT INTO test VALUES(1,'record one'),(2,'record two');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM test;
Empty set (0.00 sec)
```

To enable the BLACKHOLE storage engine if you build MySQL from source, invoke configure with the --with-blackhole-storage-engine option.

To examine the source for the BLACKHOLE engine, look in the sql directory of a MySQL source distribution.

When you create a BLACKHOLE table, the server creates a table format file in the database directory. The file begins with the table name and has an .frm extension. There are no other files associated with the table.

The BLACKHOLE storage engine supports all kinds of indexes. That is, you can include index declarations in the table definition.

You can check whether the BLACKHOLE storage engine is available with the SHOW ENGINES statement.

Inserts into a BLACKHOLE table do not store any data, but if statement based binary logging is enabled, the SQL statements are logged and replicated to slave servers. This can be useful as a repeater or filter mechanism.

> **Note**
>
> When using the row based format for the binary log, updates and deletes are skipped, and neither logged nor applied. For this reason, you should use STATEMENT for the binary logging format, and not ROW or MIXED.

Suppose that your application requires slave-side filtering rules, but transferring all binary log data to the slave first results in too much traffic. In such a case, it is possible to set up on the master host a "dummy" slave process whose default storage engine is BLACKHOLE, depicted as follows:
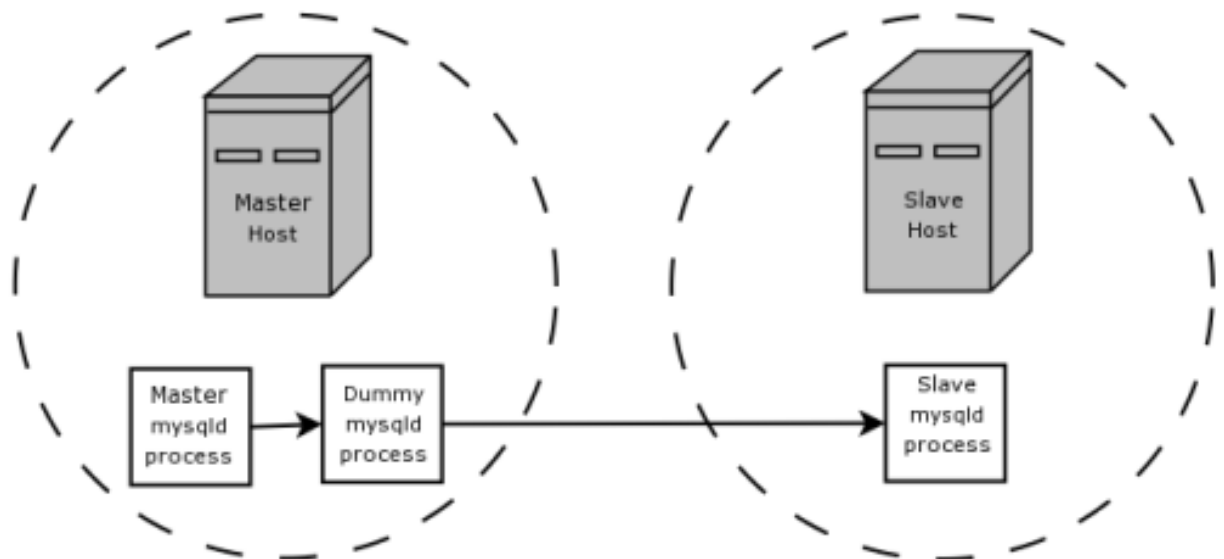
The master writes to its binary log. The "dummy" `mysqld` process acts as a slave, applying the desired combination of `replicate-do-*` and `replicate-ignore-*` rules, and writes a new, filtered binary log of its own. (See Section 16.1.3, "Replication and Binary Logging Options and Variables".) This filtered log is provided to the slave.

The dummy process does not actually store any data, so there is little processing overhead incurred by running the additional `mysqld` process on the replication master host. This type of setup can be repeated with additional replication slaves.

`INSERT` triggers for `BLACKHOLE` tables work as expected. However, because the `BLACKHOLE` table does not actually store any data, `UPDATE` and `DELETE` triggers are not activated: The `FOR EACH ROW` clause in the trigger definition does not apply because there are no rows.

Other possible uses for the `BLACKHOLE` storage engine include:

- Verification of dump file syntax.

- Measurement of the overhead from binary logging, by comparing performance using `BLACKHOLE` with and without binary logging enabled.

- `BLACKHOLE` is essentially a "no-op" storage engine, so it could be used for finding performance bottlenecks not related to the storage engine itself.

The `BLACKHOLE` storage engine does not support `INSERT DELAYED`, `LOCK TABLES`, or `UNLOCK TABLES` statements prior to MySQL 5.1.19.

As of MySQL 5.1.4, the `BLACKHOLE` engine is transaction-aware, in the sense that committed transactions are written to the binary log and rolled-back transactions are not.

Blackhole Engine and Auto Increment Columns

The Blackhole engine is a no-op engine. Any operations performed on a table using Blackhole will have no effect. This should be born in mind when considering the behavior of primary key columns that auto increment. The engine will not automatically increment field values, and does not retain auto increment field state. This has important implications in replication.

Consider the following replication scenario where all three of the following conditions apply:

1. On a master server there is a blackhole table with an auto increment field that is a primary key.

2. On a slave the same table exists but using the MyISAM engine.

3. Inserts are performed into the master's table without explicitly setting the auto increment value in the `INSERT` statement itself or through using a `SET INSERT_ID` statement.

In this scenario replication will fail with a duplicate entry error on the primary key column.

In statement based replication, the value of `INSERT_ID` in the context event will always be the same. Replication will therefore fail due to trying insert a row with a duplicate value for a primary key column.

In row based replication, the value that the engine returns for the row always be the same for each insert. This will result in the slave attempting to replay two insert log entries using the same value for the primary key column, and so replication will fail.

Column Filtering

When using row-based replication, (`binlog_format=ROW`), a slave where the last columns are missing from a table is supported, as described in the section Section 16.4.1.10, "Replication with Differing Table Definitions on Master and Slave".

This filtering works on the slave side, that is, the columns are copied to the slave before they are filtered out. There are at least two cases where it is not desirable to copy the columns to the slave:

1. If the data is confidential, so the slave server should not have access to it.

2. If the master has many slaves, filtering before sending to the slaves may reduce network traffic.

Master column filtering can be achieved using the `BLACKHOLE` engine. This is carried out in a way similar to how master table filtering is achieved - by using the `BLACKHOLE` engine and the `--replicate-do-table` or `--replicate-ignore-table` option.

The setup for the master is:

```
CREATE TABLE t1 (public_col_1, ..., public_col_N,
                 secret_col_1, ..., secret_col_M) ENGINE=MyISAM;
```

The setup for the trusted slave is:

```
CREATE TABLE t1 (public_col_1, ..., public_col_N) ENGINE=BLACKHOLE;
```

The setup for the untrusted slave is:

```
CREATE TABLE t1 (public_col_1, ..., public_col_N) ENGINE=MyISAM;
```

Chapter 15 High Availability and Scalability

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Data is the currency of today's web, mobile, social, enterprise and cloud applications. Ensuring data is always available is a top priority for any organization. Minutes of downtime can result in significant loss of revenue and reputation.

There is no "one size fits all" approach to delivering High Availability (HA). Unique application attributes, business requirements, operational capabilities and legacy infrastructure can all influence HA technology selection. And technology is only one element in delivering HA: people and processes are just as critical as the technology itself.

MySQL is deployed into many applications demanding availability and scalability. **Availability** refers to the ability to cope with, and if necessary recover from, failures on the host, including failures of MySQL, the operating system, or the hardware and maintenance activity that may otherwise cause downtime. Scalability refers to the ability to spread both the database and the load of your application queries across multiple MySQL servers.

Because each application has different operational and availability requirements, MySQL offers a range of certified and supported solutions, delivering the appropriate levels of High Availability (HA) and scalability to meet service level requirements. Such solutions extend from replication, through virtualization and geographically redundant, multi-data center solutions delivering 99.999% uptime.

Selecting the right high availability solution for an application largely depends on:

- The level of availability required.

- The type of application being deployed.

- Accepted best practices within your own environment.

The primary solutions supported by MySQL include:

- MySQL Replication. Learn more: Chapter 16, *Replication*.

- MySQL Fabric. Learn more: MySQL Fabric.

- MySQL Cluster. Learn more: Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*.

- Oracle Clusterware Agent for MySQL. Learn more about Oracle Clusterware.

- MySQL with Solaris Cluster. Learn more about Solaris Cluster.

Further options are available using third-party solutions.

Each architecture used to achieve highly available database services is differentiated by the levels of uptime it offers. These architectures can be grouped into three main categories:

- Data Replication.

- Clustered & Virtualized Systems.

- Shared-Nothing, Geographically-Replicated Clusters.

As illustrated in the following figure, each of these architectures offers progressively higher levels of uptime, which must be balanced against potentially greater levels of cost and complexity that each can incur. Simply deploying a high availability architecture is not a guarantee of actually delivering HA. In fact, a poorly implemented and maintained shared-nothing cluster could easily deliver lower levels of availability than a simple data replication solution.

Figure 15.1 Tradeoffs: Cost and Complexity versus Availability
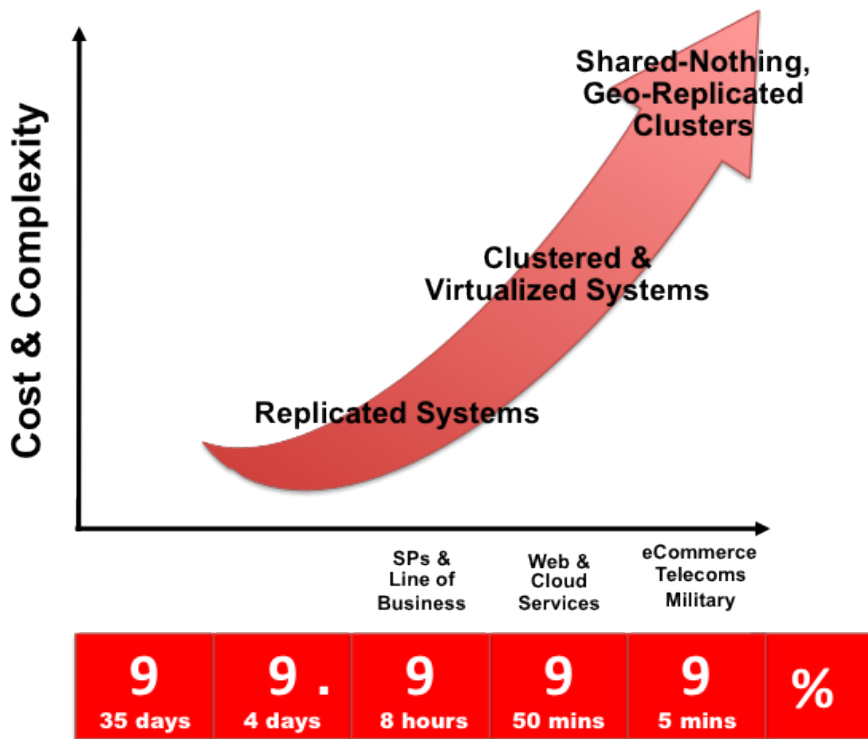
The following table compares the HA and Scalability capabilities of the various MySQL solutions:

Table 15.1 Feature Comparison of MySQL HA Solutions

Requirement	MySQL Replication	MySQL Cluster
Availability		
Platform Support	All Supported by MySQL Server (http://www.mysql.com/	All Supported by MySQL Cluster (http://www.mysql.com/support/supportedplatforms/cluster.html)

Requirement	MySQL Replication	MySQL Cluster
	support/supportedplatforms/database.html)	
Automated IP Failover	No	Depends on Connector and Configuration
Automated Database Failover	No	Yes
Automatic Data Resynchronization	No	Yes
Typical Failover Time	User / Script Dependent	1 Second and Less
Synchronous Replication	No, Asynchronous and Semisynchronous	Yes
Shared Storage	No, Distributed	No, Distributed
Geographic redundancy support	Yes	Yes, via MySQL Replication
Update Schema On-Line	No	Yes
Scalability		
Number of Nodes	One Master, Multiple Slaves	255
Built-in Load Balancing	Reads, via MySQL Replication	Yes, Reads and Writes
Supports Read-Intensive Workloads	Yes	Yes
Supports Write-Intensive Workloads	Yes, via Application-Level Sharding	Yes, via Auto-Sharding
Scale On-Line (add nodes, repartition, etc.)	No	Yes

15.1 Using MySQL within an Amazon EC2 Instance

The Amazon Elastic Compute Cloud (EC2) service provides virtual servers that you can build and deploy to run a variety of different applications and services, including MySQL. The EC2 service is based around the Xen framework, supporting x86, Linux based, platforms with individual instances of a virtual machine referred to as an Amazon Machine Image (AMI). You have complete (root) access to the AMI instance that you create, enabling you to configure and install your AMI in any way you choose.

To use EC2, you create an AMI based on the configuration and applications that you intend to use, and upload the AMI to the Amazon Simple Storage Service (S3). From the S3 resource, you can deploy one or more copies of the AMI to run as an instance within the EC2 environment. The EC2 environment provides management and control of the instance and contextual information about the instance while it is running.

Because you can create and control the AMI, the configuration, and the applications, you can deploy and create any environment you choose. This includes a basic MySQL server in addition to more extensive replication, HA and scalability scenarios that enable you to take advantage of the EC2 environment, and the ability to deploy additional instances as the demand for your MySQL services and applications grow.

To aid the deployment and distribution of work, three different Amazon EC2 instances are available, small (identified as `m1.small`), large (`m1.large`) and extra large (`m1.xlarge`). The different types provide different levels of computing power measured in EC2 computer units (ECU). A summary of the different instance configurations is shown in the following table.

EC2 Attribute	Small	Large	Extra Large
Platform	32-bit	64-bit	64-bit

EC2 Attribute	Small	Large	Extra Large
CPU cores	1	2	4
ECUs	1	4	8
RAM	1.7GB	7.5GB	15GB
Storage	150GB	840GB	1680GB
I/O Performance	Medium	High	High

The typical model for deploying and using MySQL within the EC2 environment is to create a basic AMI that you can use to hold your database data and application. Once the basic environment for your database and application has been created you can then choose to deploy the AMI to a suitable instance. Here the flexibility of having an AMI that can be re-deployed from the small to the large or extra large EC2 instance makes it easy to upgrade the hardware environment without rebuilding your application or database stack.

To get started with MySQL on EC2, including information on how to set up and install MySQL within an EC2 installation and how to port and migrate your data to the running instance, see Section 15.1.1, "Setting Up MySQL on an EC2 AMI".

For tips and advice on how to create a scalable EC2 environment using MySQL, including guides on setting up replication, see Section 15.1.3, "Deploying a MySQL Database Using EC2".

15.1.1 Setting Up MySQL on an EC2 AMI

There are many different ways of setting up an EC2 AMI with MySQL, including using any of the pre-configured AMIs supplied by Amazon.

The default *Getting Started* AMI provided by Amazon uses Fedora Core 4, and you can install MySQL by using `yum`:

```
shell> yum install mysql
```

This installs both the MySQL server and the Perl DBD::mysql driver for the Perl DBI API.

Alternatively, you can use one of the AMIs that include MySQL within the standard installation.

Finally, you can also install a standard version of MySQL downloaded from the MySQL Web site. The installation process and instructions are identical to any other installation of MySQL on Linux. See Chapter 2, *Installing and Upgrading MySQL*.

The standard configuration for MySQL places the data files in the default location, `/var/lib/mysql`. The default data directory on an EC2 instance is `/mnt` (although on the large and extra large instance you can alter this configuration). You must edit `/etc/my.cnf` to set the `datadir` option to point to the larger storage area.

> **Important**
>
> The first time you use the main storage location within an EC2 instance it needs to be initialized. The initialization process starts automatically the first time you write to the device. You can start using the device right away, but the write performance of the new device is significantly lower on the initial writes until the initialization process has finished.
>
> To avoid this problem when setting up a new instance, you should start the initialization process before populating your MySQL database. One way to do this is to use `dd` to write to the file system:

```
root-shell> dd if=/dev/zero of=initialize bs=1024M count=50
```

The preceding creates a 50GB on the file system and starts the initialization process. Delete the file once the process has finished.

The initialization process can be time-consuming. On the small instance, initialization takes between two and three hours. For the large and extra large drives, the initialization can be 10 or 20 hours, respectively.

In addition to configuring the correct storage location for your MySQL data files, also consider setting the following other settings in your instance before you save the instance configuration for deployment:

• Set the MySQL server ID, so that when you use it for replication, the ID information is set correctly.

• Enabling binary logging, so that replication can be initialized without starting and stopping the server.

• Set the caching and memory parameters for your storage engines. There are no limitations or restrictions on what storage engines you use in your EC2 environment. Choose a configuration, possibly using one of the standard configurations provided with MySQL appropriate for the instance on which you expect to deploy. The large and extra large instances have RAM that can be dedicated to caching. Be aware that if you choose to install `memcached` on the servers as part of your application stack you must ensure there is enough memory for both MySQL and `memcached`.

Once you have configured your AMI with MySQL and the rest of your application stack, save the AMI so that you can deploy and reuse the instance.

Once you have your application stack configured in an AMI, populating your MySQL database with data should be performed by creating a dump of your database using `mysqldump`, transferring the dump to the EC2 instance, and then reloading the information into the EC2 instance database.

Before using your instance with your application in a production situation, be aware of the limitations of the EC2 instance environment. See Section 15.1.2, "EC2 Instance Limitations". To begin using your MySQL AMI, consult the notes on deployment. See Section 15.1.3, "Deploying a MySQL Database Using EC2".

15.1.2 EC2 Instance Limitations

Be aware of the following limitations of the EC2 instances before deploying your applications. Although these shouldn't affect your ability to deploy within the Amazon EC2 environment, they may alter the way you setup and configure your environment to support your application.

• Data stored within instances is not persistent. If you create an instance and populate the instance with data, then the data only remains in place while the machine is running, and does not survive a reboot. If you shut down the instance, any data it contained is lost.

To ensure that you do not lose information, take regular backups using `mysqldump`. If the data being stored is critical, consider using replication to keep a "live" backup of your data in the event of a failure. When creating a backup, write the data to the Amazon S3 service to avoid the transfer charges applied when copying data offsite.

• EC2 instances are not persistent. If the hardware on which an instance is running fails, the instance is shut down. This can lead to loss of data or service.

However, if you use EBS, you can attach an EBS storage volume to an EC2 instance, and that EBS volume is persistent. Like a disk, an EBS volume can fail, but it is possible to create point-in-time snapshots of the volume. Snapshots are persisted to Amazon S3 and can be used to restore data in the event of volume failure.

- To replicate your EC2 instances to a non-EC2 environment, be aware of the transfer costs to and from the EC2 service. Data transfer between different EC2 instances is free, so using replication within the EC2 environment does not incur additional charges.

- Certain HA features are either not directly supported, or have limiting factors or problems that could reduce their utility. For example, using DRBD or MySQL Cluster might not work. The default storage configuration is also not redundant. You can use software-based RAID to improve redundancy, but this implies a further performance hit.

15.1.3 Deploying a MySQL Database Using EC2

Because you cannot guarantee the uptime and availability of your EC2 instances, when deploying MySQL within the EC2 environment, use an approach that enables you to easily distribute work among your EC2 instances. There are a number of ways of doing this. Using sharding techniques, where you split the application across multiple servers dedicating specific blocks of your dataset and users to different servers is an effective way of doing this. As a general rule, it is easier to create more EC2 instances to support more users than to upgrade the instance to a larger machine.

The EC2 architecture works best when you treat the EC2 instances as temporary, cache-based solutions, rather than as a long-term, high availability solution. In addition to using multiple machines, take advantage of other services, such as `memcached` to provide additional caching for your application to help reduce the load on the MySQL server so that it can concentrate on writes. On the large and extra large instances within EC2, the RAM available can provide a large memory cache for data.

Most types of scale-out topology that you would use with your own hardware can be used and applied within the EC2 environment. However, use the limitations and advice already given to ensure that any potential failures do not lose you any data. Also, because the relative power of each EC2 instance is so low, be prepared to alter your application to use sharding and add further EC2 instances to improve the performance of your application.

For example, take the typical scale-out environment shown following, where a single master replicates to one or more slaves (three in this example), with a web server running on each replication slave.
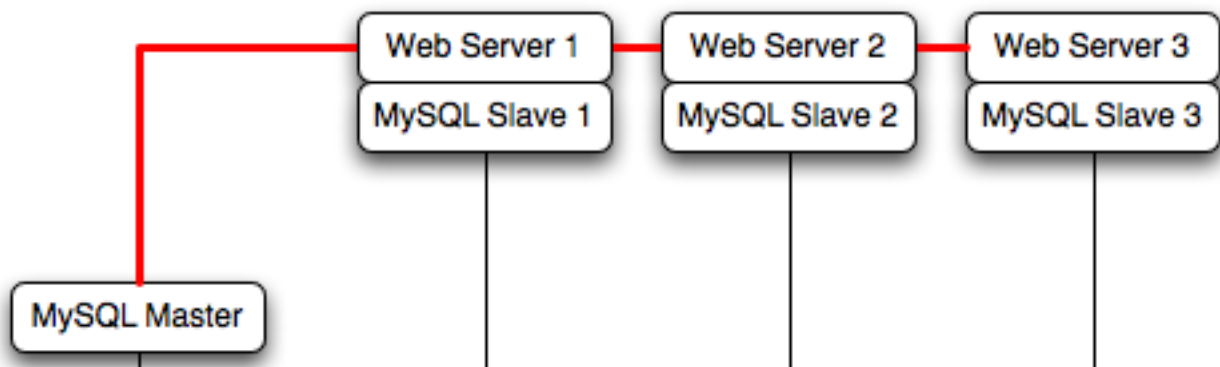
You can reproduce this structure completely within the EC2 environment, using an EC2 instance for the master, and one instance for each of the web and MySQL slave servers.

Note

Within the EC2 environment, internal (private) IP addresses used by the EC2 instances are constant. Always use these internal addresses and names when communicating between instances. Only use public IP addresses when

> communicating with the outside world - for example, when publicizing your
> application.

To ensure reliability of your database, add at least one replication slave dedicated to providing an active
backup and storage to the Amazon S3 facility. You can see an example of this in the following topology.
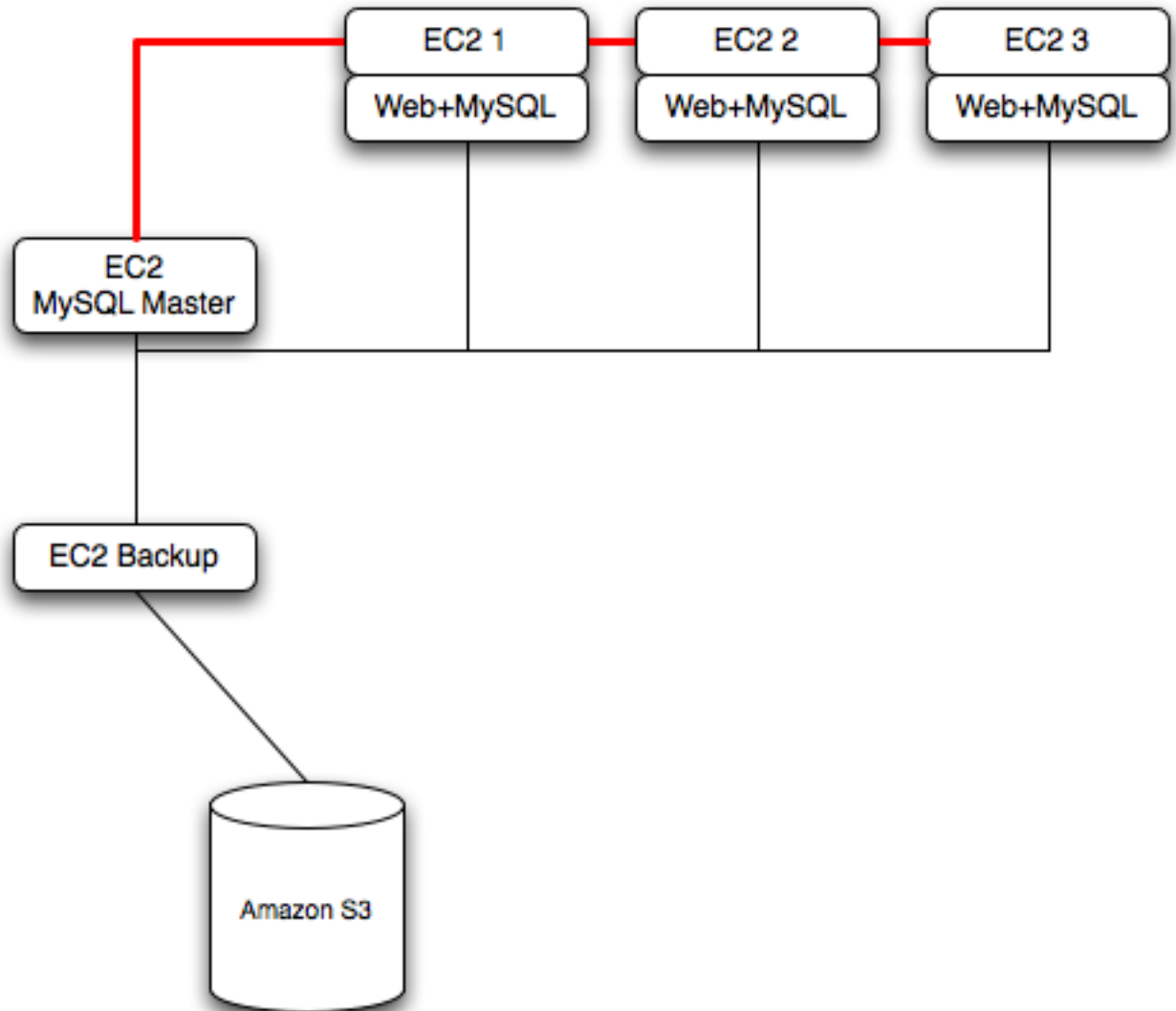
Using `memcached` within your EC2 instances should provide better performance. The large and extra
large instances have a significant amount of RAM. To use `memcached` in your application, when loading
information from the database, first check whether the item exists in the cache. If the data you are looking
for exists in the cache, use it. If not, reload the data from the database and populate the cache.

Sharding divides up data in your entire database by allocating individual machines or machine groups to
provide a unique set of data according to an appropriate group. For example, you might put all users with a
surname ending in the letters A-D onto a single server. When a user connects to the application and their
surname is known, queries can be redirected to the appropriate MySQL server.

When using sharding with EC2, separate the web server and MySQL server into separate EC2 instances,
and then apply the sharding decision logic into your application. Once you know which MySQL server you

should be using for accessing the data you then distribute queries to the appropriate server. You can see a sample of this in the following illustration.
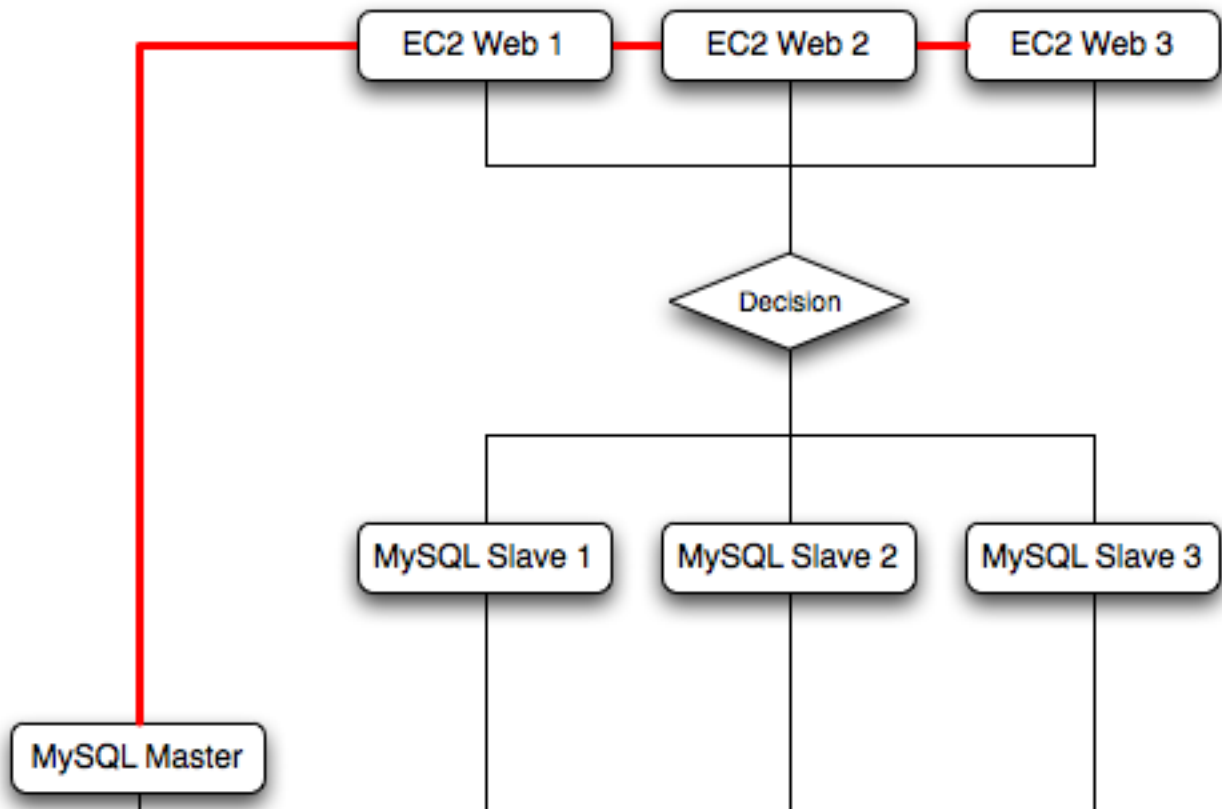
Warning

With sharding and EC2, be careful that the potential for failure of an instance does not affect your application. If the EC2 instance that provides the MySQL server for a particular shard fails, then all of the data on that shard becomes unavailable.

15.2 Using ZFS Replication

To support high availability environments, providing an instant copy of the information on both the currently active machine and the hot backup is a critical part of the HA solution. There are many solutions to this problem, such as Chapter 16, *Replication*.

The ZFS file system provides functionality to create a snapshot of the file system contents, transfer the snapshot to another machine, and extract the snapshot to recreate the file system. You can create a snapshot at any time, and you can create as many snapshots as you like. By continually creating, transferring, and restoring snapshots, you can provide synchronization between one or more machines in a fashion similar to DRBD.

The following example shows a simple Solaris system running with a single ZFS pool, mounted at `/scratchpool`:

```
Filesystem            size   used  avail capacity  Mounted on
/dev/dsk/c0d0s0       4.6G   3.7G   886M    82%    /
/devices               0K     0K     0K     0%    /devices
```

```
ctfs                     0K     0K     0K    0%    /system/contract
proc                     0K     0K     0K    0%    /proc
mnttab                   0K     0K     0K    0%    /etc/mnttab
swap                    1.4G   892K   1.4G    1%    /etc/svc/volatile
objfs                    0K     0K     0K    0%    /system/object
/usr/lib/libc/libc_hwcap1.so.1
                        4.6G   3.7G   886M   82%    /lib/libc.so.1
fd                       0K     0K     0K    0%    /dev/fd
swap                    1.4G    40K   1.4G    1%    /tmp
swap                    1.4G    28K   1.4G    1%    /var/run
/dev/dsk/c0d0s7          26G   913M    25G    4%    /export/home
scratchpool              16G    24K    16G    1%    /scratchpool
```

The MySQL data is stored in a directory on `/scratchpool`. To help demonstrate some of the basic replication functionality, there are also other items stored in `/scratchpool` as well:

```
total 17
drwxr-xr-x  31 root     bin           50 Jul 21 07:32 DTT/
drwxr-xr-x   4 root     bin            5 Jul 21 07:32 SUNWmlib/
drwxr-xr-x  14 root     sys           16 Nov  5 09:56 SUNWspro/
drwxrwxrwx  19 1000     1000          40 Nov  6 19:16 emacs-22.1/
```

To create a snapshot of the file system, you use `zfs snapshot`, specifying the pool and the snapshot name:

```
root-shell> zfs snapshot scratchpool@snap1
```

To list the snapshots already taken:

```
root-shell> zfs list -t snapshot
NAME                USED  AVAIL  REFER  MOUNTPOINT
scratchpool@snap1      0     -   24.5K  -
scratchpool@snap2      0     -   24.5K  -
```

The snapshots themselves are stored within the file system metadata, and the space required to keep them varies as time goes on because of the way the snapshots are created. The initial creation of a snapshot is very quick, because instead of taking an entire copy of the data and metadata required to hold the entire snapshot, ZFS records only the point in time and metadata of when the snapshot was created.

As more changes to the original file system are made, the size of the snapshot increases because more space is required to keep the record of the old blocks. If you create lots of snapshots, say one per day, and then delete the snapshots from earlier in the week, the size of the newer snapshots might also increase, as the changes that make up the newer state have to be included in the more recent snapshots, rather than being spread over the seven snapshots that make up the week.

You cannot directly back up the snapshots because they exist within the file system metadata rather than as regular files. To get the snapshot into a format that you can copy to another file system, tape, and so on, you use the `zfs send` command to create a stream version of the snapshot.

For example, to write the snapshot out to a file:

```
root-shell> zfs send scratchpool@snap1 >/backup/scratchpool-snap1
```

Or tape:

```
root-shell> zfs send scratchpool@snap1 >/dev/rmt/0
```

You can also write out the incremental changes between two snapshots using `zfs send`:

```
root-shell> zfs send scratchpool@snap1 scratchpool@snap2 >/backup/scratchpool-changes
```

To recover a snapshot, you use `zfs recv`, which applies the snapshot information either to a new file system, or to an existing one.

15.2.1 Using ZFS for File System Replication

Because `zfs send` and `zfs recv` use streams to exchange data, you can use them to replicate information from one system to another by combining `zfs send`, `ssh`, and `zfs recv`.

For example, to copy a snapshot of the `scratchpool` file system to a new file system called `slavepool` on a new server, you would use the following command. This sequence combines the snapshot of `scratchpool`, the transmission to the slave machine (using `ssh` with login credentials), and the recovery of the snapshot on the slave using `zfs recv`:

```
root-shell> zfs send scratchpool@snap1 |ssh id@host pfexec zfs recv -F slavepool
```

The first part of the pipeline, `zfs send scratchpool@snap1`, streams the snapshot. The `ssh` command, and the command that it executes on the other server, `pfexec zfs recv -F slavepool`, receives the streamed snapshot data and writes it to slavepool. In this instance, I've specified the `-F` option which forces the snapshot data to be applied, and is therefore destructive. This is fine, as I'm creating the first version of my replicated file system.

On the slave machine, the replicated file system contains the exact same content:

```
root-shell> ls -al /slavepool/
total 23
drwxr-xr-x   6 root      root             7 Nov  8 09:13 ./
drwxr-xr-x  29 root      root            34 Nov  9 07:06 ../
drwxr-xr-x  31 root      bin             50 Jul 21 07:32 DTT/
drwxr-xr-x   4 root      bin              5 Jul 21 07:32 SUNWmlib/
drwxr-xr-x  14 root      sys             16 Nov  5 09:56 SUNWspro/
drwxrwxrwx  19 1000      1000            40 Nov  6 19:16 emacs-22.1/
```

Once a snapshot has been created, to synchronize the file system again, you create a new snapshot and then use the incremental snapshot feature of `zfs send` to send the changes between the two snapshots to the slave machine again:

```
root-shell> zfs send -i scratchpool@snapshot1 scratchpool@snapshot2 |ssh id@host pfexec zfs recv slavepool
```

This operation only succeeds if the file system on the slave machine has not been modified at all. You cannot apply the incremental changes to a destination file system that has changed. In the example above, the `ls` command would cause problems by changing the metadata, such as the last access time for files or directories.

To prevent changes on the slave file system, set the file system on the slave to be read-only:

```
root-shell> zfs set readonly=on slavepool
```

Setting `readonly` means that you cannot change the file system on the slave by normal means, including the file system metadata. Operations that would normally update metadata (like our `ls`) silently perform their function without attempting to update the file system state.

In essence, the slave file system is nothing but a static copy of the original file system. However, even when configured to be read-only, a file system can have snapshots applied to it. With the file system set to read only, re-run the initial copy:

```
root-shell> zfs send scratchpool@snap1 |ssh id@host pfexec zfs recv -F slavepool
```

Now you can make changes to the original file system and replicate them to the slave.

15.2.2 Configuring MySQL for ZFS Replication

Configuring MySQL on the source file system is a case of creating the data on the file system that you intend to replicate. The configuration file in the example below has been updated to use `/scratchpool/mysql-data` as the data directory, and now you can initialize the tables:

```
root-shell> mysql_install_db --defaults-file=/etc/mysql/5.5/my.cnf --user=mysql
```

To synchronize the initial information, perform a new snapshot and then send an incremental snapshot to the slave using `zfs send`:

```
root-shell> zfs snapshot scratchpool@snap2
root-shell> zfs send -i scratchpool@snap1 scratchpool@snap2|ssh id@host pfexec zfs recv slavepool
```

Doublecheck that the slave has the data by looking at the MySQL data directory on the `slavepool`:

```
root-shell> ls -al /slavepool/mysql-data/
```

Now you can start up MySQL, create some data, and then replicate the changes using `zfs send`/ `zfs recv` to the slave to synchronize the changes.

The rate at which you perform the synchronization depends on your application and environment. The limitation is the speed required to perform the snapshot and then to send the changes over the network.

To automate the process, create a script that performs the snapshot, send, and receive operation, and use `cron` to synchronize the changes at set times or intervals.

15.2.3 Handling MySQL Recovery with ZFS

When using ZFS replication to provide a constant copy of your data, ensure that you can recover your tables, either manually or automatically, in the event of a failure of the original system.

In the event of a failure, follow this sequence:

1. Stop the script on the master, if it is still up and running.

2. Set the slave file system to be read/write:

    ```
    root-shell> zfs set readonly=off slavepool
    ```

3. Start up `mysqld` on the slave. If you are using `InnoDB`, you get auto-recovery, if it is needed, to make sure the table data is correct, as shown here when I started up from our mid-INSERT snapshot:

    ```
    InnoDB: The log sequence number in ibdata files does not match
    InnoDB: the log sequence number in the ib_logfiles!
    081109 15:59:59  InnoDB: Database was not shut down normally!
    InnoDB: Starting crash recovery.
    InnoDB: Reading tablespace information from the .ibd files...
    InnoDB: Restoring possible half-written data pages from the doublewrite
    InnoDB: buffer...
    081109 16:00:03  InnoDB: Started; log sequence number 0 1142807951
    081109 16:00:03 [Note] /slavepool/mysql-5.0.67-solaris10-i386/bin/mysqld: ready for connections.
    Version: '5.0.67'  socket: '/tmp/mysql.sock'  port: 3306  MySQL Community Server (GPL)
    ```

Use `InnoDB` tables and a regular synchronization schedule to reduce the risk for significant data loss. On MyISAM tables, you might need to run `REPAIR TABLE`, and you might even have lost some information.

15.3 Using MySQL with `memcached`

`memcached` is a simple, highly scalable key-based cache that stores data and objects wherever dedicated or spare RAM is available for quick access by applications, without going through layers of parsing or disk I/O. To use, you run the `memcached` command on one or more hosts and then use the shared cache to store objects. For more usage instructions, see Section 15.3.2, "Using `memcached`"

Benefits of using `memcached` include:

- Because all information is stored in RAM, the access speed is faster than loading the information each time from disk.

- Because the "value" portion of the key-value pair does not have any data type restrictions, you can cache data such as complex structures, documents, images, or a mixture of such things.

- If you use the in-memory cache to hold transient information, or as a read-only cache for information also stored in a database, the failure of any `memcached` server is not critical. For persistent data, you can fall back to an alternative lookup method using database queries, and reload the data into RAM on a different server.

The typical usage environment is to modify your application so that information is read from the cache provided by `memcached`. If the information is not in `memcached`, then the data is loaded from the MySQL database and written into the cache so that future requests for the same object benefit from the cached data.

For a typical deployment layout, see Figure 15.2, "`memcached` Architecture Overview".

Figure 15.2 `memcached` Architecture Overview
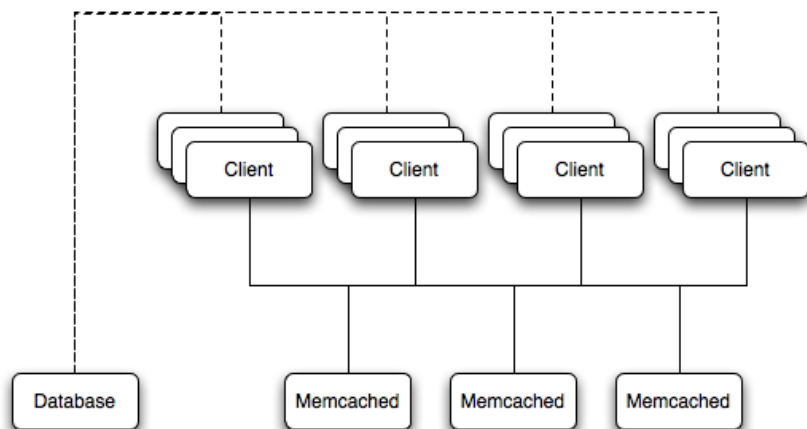
In the example structure, any of the clients can contact one of the `memcached` servers to request a given key. Each client is configured to talk to all of the servers shown in the illustration. Within the client, when the request is made to store the information, the key used to reference the data is hashed and this hash is then used to select one of the `memcached` servers. The selection of the `memcached` server takes place on the client before the server is contacted, keeping the process lightweight.

The same algorithm is used again when a client requests the same key. The same key generates the same hash, and the same `memcached` server is selected as the source for the data. Using this method, the cached data is spread among all of the `memcached` servers, and the cached information is accessible

from any client. The result is a distributed, memory-based, cache that can return information, particularly complex data and structures, much faster than natively reading the information from the database.

The data held within a traditional `memcached` server is never stored on disk (only in RAM, which means there is no persistence of data), and the RAM cache is always populated from the backing store (a MySQL database). If a `memcached` server fails, the data can always be recovered from the MySQL database.

15.3.1 Installing `memcached`

You can build and install `memcached` from the source code directly, or you can use an existing operating system package or installation.

Installing `memcached` from a Binary Distribution

To install `memcached` on a Red Hat, or Fedora host, use `yum`:

```
root-shell> yum install memcached
```

> **Note**
>
> On CentOS, you may be able to obtain a suitable RPM from another source, or use the source tarball.

To install `memcached` on a Debian or Ubuntu host, use `apt-get`:

```
root-shell> apt-get install memcached
```

To install `memcached` on a Gentoo host, use `emerge`:

```
root-shell> emerge install memcached
```

Building `memcached` from Source

On other Unix-based platforms, including Solaris, AIX, HP-UX and OS X, and Linux distributions not mentioned already, you must install from source. For Linux, make sure you have a 2.6-based kernel, which includes the improved `epoll` interface. For all platforms, ensure that you have `libevent` 1.1 or higher installed. You can obtain `libevent` from `libevent` web page.

You can obtain the source for `memcached` from `memcached` Web site.

To build `memcached`, follow these steps:

1. Extract the `memcached` source package:

   ```
   shell> gunzip -c memcached-1.2.5.tar.gz | tar xf -
   ```

2. Change to the `memcached-1.2.5 directory`:

   ```
   shell> cd memcached-1.2.5
   ```

3. Run `configure`

   ```
   shell> ./configure
   ```

   Some additional options you might specify to the `configure`:

- `--prefix`

  To specify a different installation directory, use the `--prefix` option:

  ```
  shell> ./configure --prefix=/opt
  ```

  The default is to use the `/usr/local` directory.

- `--with-libevent`

  If you have installed `libevent` and `configure` cannot find the library, use the `--with-libevent` option to specify the location of the installed library.

- `--enable-64bit`

  To build a 64-bit version of `memcached` (which enables you to use a single instance with a large RAM allocation), use `--enable-64bit`.

- `--enable-threads`

  To enable multi-threading support in `memcached`, which improves the response times on servers with a heavy load, use `--enable-threads`. You must have support for the POSIX threads within your operating system to enable thread support. For more information on the threading support, see Section 15.3.2.8, "`memcached` Thread Support".

- `--enable-dtrace`

  `memcached` includes a range of DTrace threads that can be used to monitor and benchmark a `memcached` instance. For more information, see Section 15.3.2.6, "Using `memcached` and DTrace".

4. Run `make` to build `memcached`:

   ```
   shell> make
   ```

5. Run `make install` to install `memcached`:

   ```
   shell> make install
   ```

15.3.2 Using `memcached`

To start using `memcached`, start the `memcached` service on one or more servers. Running `memcached` sets up the server, allocates the memory and starts listening for connections from clients.

> **Note**
>
> You do not need to be a privileged user (`root`) to run `memcached` except to listen on one of the privileged TCP/IP ports (below 1024). You must, however, use a user that has not had their memory limits restricted using `setrlimit` or similar.

To start the server, run `memcached` as a nonprivileged (that is, non-`root`) user:

```
shell> memcached
```

By default, `memcached` uses the following settings:

- Memory allocation of 64MB

- Listens for connections on all network interfaces, using port 11211

- Supports a maximum of 1024 simultaneous connections

Typically, you would specify the full combination of options that you want when starting `memcached`, and normally provide a startup script to handle the initialization of `memcached`. For example, the following line starts `memcached` with a maximum of 1024MB RAM for the cache, listening on port 11211 on the IP address 192.168.0.110, running as a background daemon:

```
shell> memcached -d -m 1024 -p 11211 -l 192.168.0.110
```

To ensure that `memcached` is started up on boot, check the init script and configuration parameters.

15.3.2.1 `memcached` Command-Line Options

`memcached` supports the following options:

- `-u user`

  If you start `memcached` as `root`, use the `-u` option to specify the user for executing `memcached`:

  ```
  shell> memcached -u memcache
  ```

- `-m memory`

  Set the amount of memory allocated to `memcached` for object storage. Default is 64MB.

  To increase the amount of memory allocated for the cache, use the `-m` option to specify the amount of RAM to be allocated (in megabytes). The more RAM you allocate, the more data you can store and therefore the more effective your cache is.

  > **Warning**
  >
  > Do not specify a memory allocation larger than your available RAM. If you specify too large a value, then some RAM allocated for `memcached` uses swap space, and not physical RAM. This may lead to delays when storing and retrieving values, because data is swapped to disk, instead of storing the data directly in RAM.
  >
  > You can use the output of the `vmstat` command to get the free memory, as shown in `free` column:
  >
  > ```
  > shell> vmstat
  > kthr      memory            page            disk          faults      cpu
  > r b w   swap  free  re  mf pi po fr de sr s1 s2 -- --   in   sy   cs us sy id
  > 0 0 0 5170504 3450392 2   7  2  0  0  0  4  0  0  0  0  296   54  199  0  0 100
  > ```

  For example, to allocate 3GB of RAM:

  ```
  shell> memcached -m 3072
  ```

  On 32-bit x86 systems where you are using PAE to access memory above the 4GB limit, you cannot allocate RAM beyond the maximum process size. You can get around this by running multiple instances of `memcached`, each listening on a different port:

```
shell> memcached -m 1024 -p11211
shell> memcached -m 1024 -p11212
shell> memcached -m 1024 -p11213
```

> **Note**
>
> On all systems, particularly 32-bit, ensure that you leave enough room for both `memcached` application in addition to the memory setting. For example, if you have a dedicated `memcached` host with 4GB of RAM, do not set the memory size above 3500MB. Failure to do this may cause either a crash or severe performance issues.

- `-l interface`

  Specify a network interface/address to listen for connections. The default is to listen on all available address (`INADDR_ANY`).

  ```
  shell> memcached -l 192.168.0.110
  ```

  Support for IPv6 address support was added in `memcached` 1.2.5.

- `-p port`

  Specify the TCP port to use for connections. Default is 18080.

  ```
  shell> memcached -p 18080
  ```

- `-U port`

  Specify the UDP port to use for connections. Default is 11211, 0 switches UDP off.

  ```
  shell> memcached -U 18080
  ```

- `-s socket`

  Specify a Unix socket to listen on.

  If you are running `memcached` on the same server as the clients, you can disable the network interface and use a local Unix socket using the `-s` option:

  ```
  shell> memcached -s /tmp/memcached
  ```

  Using a Unix socket automatically disables network support, and saves network ports (allowing more ports to be used by your web server or other process).

- `-a mask`

  Specify the access mask to be used for the Unix socket, in octal. Default is 0700.

- `-c connections`

  Specify the maximum number of simultaneous connections to the `memcached` service. The default is 1024.

```
shell> memcached -c 2048
```

Use this option, either to reduce the number of connections (to prevent overloading `memcached` service) or to increase the number to make more effective use of the server running `memcached` server.

- `-t threads`

  Specify the number of threads to use when processing incoming requests.

  By default, `memcached` is configured to use 4 concurrent threads. The threading improves the performance of storing and retrieving data in the cache, using a locking system to prevent different threads overwriting or updating the same values. To increase or decrease the number of threads, use the `-t` option:

```
shell> memcached -t 8
```

- `-d`

  Run `memcached` as a daemon (background) process:

```
shell> memcached -d
```

- `-r`

  Maximize the size of the core file limit. In the event of a failure, this attempts to dump the entire memory space to disk as a core file, up to any limits imposed by `setrlimit`.

- `-M`

  Return an error to the client when the memory has been exhausted. This replaces the normal behavior of removing older items from the cache to make way for new items.

- `-k`

  Lock down all paged memory. This reserves the memory before use, instead of allocating new slabs of memory as new items are stored in the cache.

  > **Note**
  >
  > There is a user-level limit on how much memory you can lock. Trying to allocate more than the available memory fails. You can set the limit for the user you started the daemon with (not for the `-u user` user) within the shell by using `ulimit -S -l NUM_KB`

- `-v`

  Verbose mode. Prints errors and warnings while executing the main event loop.

- `-vv`

  Very verbose mode. In addition to information printed by `-v`, also prints each client command and the response.

- `-vvv`

  Extremely verbose mode. In addition to information printed by `-vv`, also show the internal state transitions.

- `-h`

  Print the help message and exit.

- `-i`

  Print the `memcached` and `libevent` license.

- `-I mem`

  Specify the maximum size permitted for storing an object within the `memcached` instance. The size supports a unit postfix (`k` for kilobytes, `m` for megabytes). For example, to increase the maximum supported object size to 32MB:

  ```
  shell> memcached -I 32m
  ```

  The maximum object size you can specify is 128MB, the default remains at 1MB.

  This option was added in 1.4.2.

- `-b`

  Set the backlog queue limit. The backlog queue configures how many network connections can be waiting to be processed by `memcached`. Increasing this limit may reduce errors received by the client that it is not able to connect to the `memcached` instance, but does not improve the performance of the server. The default is 1024.

- `-P pidfile`

  Save the process ID of the `memcached` instance into `file`.

- `-f`

  Set the chunk size growth factor. When allocating new memory chunks, the allocated size of new chunks is determined by multiplying the default slab size by this factor.

  To see the effects of this option without extensive testing, use the `-vv` command-line option to show the calculated slab sizes. For more information, see Section 15.3.2.9, "`memcached` Logs".

- `-n bytes`

  The minimum space allocated for the key+value+flags information. The default is 48 bytes.

- `-L`

  On systems that support large memory pages, enables large memory page use. Using large memory pages enables `memcached` to allocate the item cache in one large chunk, which can improve the performance by reducing the number misses when accessing memory.

- `-C`

  Disable the use of compare and swap (CAS) operations.

  This option was added in `memcached` 1.3.x.

- `-D char`

Set the default character to be used as a delimiter between the key prefixes and IDs. This is used for the per-prefix statistics reporting (see Section 15.3.4, "Getting `memcached` Statistics"). The default is the colon (`:`). If this option is used, statistics collection is turned on automatically. If not used, you can enable stats collection by sending the `stats detail on` command to the server.

This option was added in `memcached` 1.3.x.

- `-R num`

Sets the maximum number of requests per event process. The default is 20.

- `-B protocol`

Set the binding protocol, that is, the default `memcached` protocol support for client connections. Options are `ascii`, `binary` or `auto`. Automatic (`auto`) is the default.

This option was added in `memcached` 1.4.0.

15.3.2.2 `memcached` Deployment

When using `memcached` you can use a number of different potential deployment strategies and topologies. The exact strategy to use depends on your application and environment. When developing a system for deploying `memcached` within your system, keep in mind the following points:

- `memcached` is only a caching mechanism. It shouldn't be used to store information that you cannot otherwise afford to lose and then load from a different location.

- There is no security built into the `memcached` protocol. At a minimum, make sure that the servers running `memcached` are only accessible from inside your network, and that the network ports being used are blocked (using a firewall or similar). If the information on the `memcached` servers that is being stored is any sensitive, then encrypt the information before storing it in `memcached`.

- `memcached` does not provide any sort of failover. Because there is no communication between different `memcached` instances. If an instance fails, your application must capable of removing it from the list, reloading the data and then writing data to another `memcached` instance.

- Latency between the clients and the `memcached` can be a problem if you are using different physical machines for these tasks. If you find that the latency is a problem, move the `memcached` instances to be on the clients.

- Key length is determined by the `memcached` server. The default maximum key size is 250 bytes.

- Try to use at least two `memcached` instances, especially for multiple clients, to avoid having a single point of failure. Ideally, create as many `memcached` nodes as possible. When adding and removing `memcached` instances from a pool, the hashing and distribution of key/value pairs may be affected. For information on how to avoid problems, see Section 15.3.2.5, "`memcached` Hashing/Distribution Types".

15.3.2.3 Using Namespaces

The `memcached` cache is a very simple massive key/value storage system, and as such there is no way of compartmentalizing data automatically into different sections. For example, if you are storing information by the unique ID returned from a MySQL database, then storing the data from two different tables could run into issues because the same ID might be valid in both tables.

Some interfaces provide an automated mechanism for creating *namespaces* when storing information into the cache. In practice, these namespaces are merely a prefix before a given ID that is applied every time a value is stored or retrieve from the cache.

You can implement the same basic principle by using keys that describe the object and the unique identifier within the key that you supply when the object is stored. For example, when storing user data, prefix the ID of the user with `user:` or `user-`.

Note

Using namespaces or prefixes only controls the keys stored/retrieved. There is no security within `memcached`, and therefore no way to enforce that a particular client only accesses keys with a particular namespace. Namespaces are only useful as a method of identifying data and preventing corruption of key/value pairs.

15.3.2.4 Data Expiry

There are two types of data expiry within a `memcached` instance. The first type is applied at the point when you store a new key/value pair into the `memcached` instance. If there is not enough space within a suitable slab to store the value, then an existing least recently used (LRU) object is removed (evicted) from the cache to make room for the new item.

The LRU algorithm ensures that the object that is removed is one that is either no longer in active use or that was used so long ago that its data is potentially out of date or of little value. However, in a system where the memory allocated to `memcached` is smaller than the number of regularly used objects required in the cache, a lot of expired items could be removed from the cache even though they are in active use. You use the statistics mechanism to get a better idea of the level of evictions (expired objects). For more information, see Section 15.3.4, "Getting `memcached` Statistics".

You can change this eviction behavior by setting the `-M` command-line option when starting `memcached`. This option forces an error to be returned when the memory has been exhausted, instead of automatically evicting older data.

The second type of expiry system is an explicit mechanism that you can set when a key/value pair is inserted into the cache, or when deleting an item from the cache. Using an expiration time can be a useful way of ensuring that the data in the cache is up to date and in line with your application needs and requirements.

A typical scenario for explicitly setting the expiry time might include caching session data for a user when accessing a Web site. `memcached` uses a lazy expiry mechanism where the explicit expiry time that has been set is compared with the current time when the object is requested. Only objects that have not expired are returned.

You can also set the expiry time when explicitly deleting an object from the cache. In this case, the expiry time is really a timeout and indicates the period when any attempts to set the value for a given key are rejected.

15.3.2.5 `memcached` Hashing/Distribution Types

The `memcached` client interface supports a number of different distribution algorithms that are used in multi-server configurations to determine which host should be used when setting or getting data from a given `memcached` instance. When you get or set a value, a hash is constructed from the supplied key and then used to select a host from the list of configured servers. Because the hashing mechanism uses the supplied key as the basis for the hash, the same server is selected during both set and get operations.

You can think of this process as follows. Given an array of servers (a, b, and c), the client uses a hashing algorithm that returns an integer based on the key being stored or retrieved. The resulting value is then used to select a server from the list of servers configured in the client. Most standard client hashing within `memcache` clients uses a simple modulus calculation on the value against the number of configured `memcached` servers. You can summarize the process in pseudocode as:

```
@memcservers = ['a.memc','b.memc','c.memc'];
$value = hash($key);
$chosen = $value % length(@memcservers);
```

Replacing the above with values:

```
@memcservers = ['a.memc','b.memc','c.memc'];
$value = hash('myid');
$chosen = 7009 % 3;
```

In the above example, the client hashing algorithm chooses the server at index 1 (`7009 % 3 = 1`), and store or retrieve the key and value with that server.

> **Note**
>
> This selection and hashing process is handled automatically by the `memcached` client you are using; you need only provide the list of `memcached` servers to use.

You can see a graphical representation of this below in Figure 15.3, "`memcached` Hash Selection".

Figure 15.3 `memcached` Hash Selection
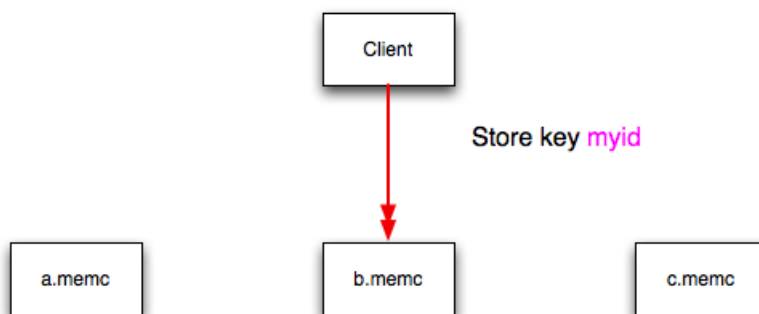
The same hashing and selection process takes place during any operation on the specified key within the `memcached` client.

Using this method provides a number of advantages:

- The hashing and selection of the server to contact is handled entirely within the client. This eliminates the need to perform network communication to determine the right machine to contact.

- Because the determination of the `memcached` server occurs entirely within the client, the server can be selected automatically regardless of the operation being executed (set, get, increment, etc.).

- Because the determination is handled within the client, the hashing algorithm returns the same value for a given key; values are not affected or reset by differences in the server environment.

- Selection is very fast. The hashing algorithm on the key value is quick and the resulting selection of the server is from a simple array of available machines.

- Using client-side hashing simplifies the distribution of data over each `memcached` server. Natural distribution of the values returned by the hashing algorithm means that keys are automatically spread over the available servers.

Providing that the list of servers configured within the client remains the same, the same stored key returns the same value, and therefore selects the same server.

However, if you do not use the same hashing mechanism then the same data may be recorded on different servers by different interfaces, both wasting space on your `memcached` and leading to potential differences in the information.

> **Note**
>
> One way to use a multi-interface compatible hashing mechanism is to use the `libmemcached` library and the associated interfaces. Because the interfaces for the different languages (including C, Ruby, Perl and Python) use the same client library interface, they always generate the same hash code from the ID.

The problem with client-side selection of the server is that the list of the servers (including their sequential order) *must* remain consistent on each client using the `memcached` servers, and the servers must be available. If you try to perform an operation on a key when:

- A new `memcached` instance has been added to the list of available instances

- A `memcached` instance has been removed from the list of available instances

- The order of the `memcached` instances has changed

When the hashing algorithm is used on the given key, but with a different list of servers, the hash calculation may choose a different server from the list.

If a new `memcached` instance is added into the list of servers, as `new.memc` is in the example below, then a GET operation using the same key, `myid`, can result in a cache-miss. This is because the same value is computed from the key, which selects the same index from the array of servers, but index 2 now points to the new server, not the server `c.memc` where the data was originally stored. This would result in a cache miss, even though the key exists within the cache on another `memcached` instance.

Figure 15.4 `memcached` Hash Selection with New `memcached` instance
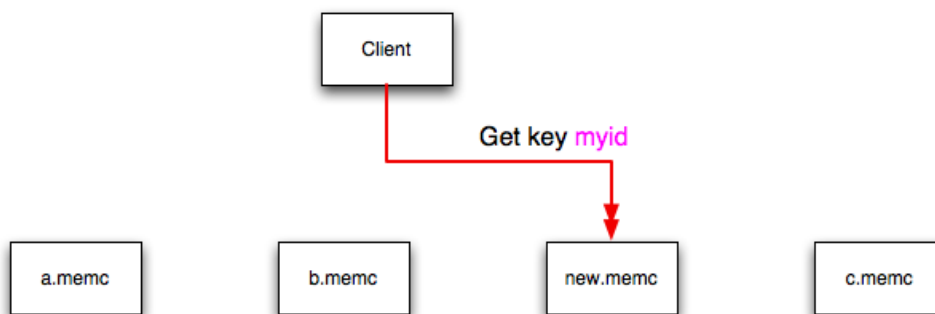
This means that servers `c.memc` and `new.memc` both contain the information for key `myid`, but the information stored against the key in eachs server may be different in each instance. A more significant problem is a much higher number of cache-misses when retrieving data, as the addition of a new server changes the distribution of keys, and this in turn requires rebuilding the cached data on the `memcached` instances, causing an increase in database reads.

The same effect can occur if you actively manage the list of servers configured in your clients, adding and removing the configured `memcached` instances as each instance is identified as being available. For example, removing a `memcached` instance when the client notices that the instance can no longer be contacted can cause the server selection to fail as described here.

To prevent this causing significant problems and invalidating your cache, you can select the hashing algorithm used to select the server. There are two common types of hashing algorithm, *consistent* and *modula*.

With *consistent* hashing algorithms, the same key when applied to a list of servers always uses the same server to store or retrieve the keys, even if the list of configured servers changes. This means that you can add and remove servers from the configure list and always use the same server for a given key. There are two types of consistent hashing algorithms available, Ketama and Wheel. Both types are supported by `libmemcached`, and implementations are available for PHP and Java.

Any consistent hashing algorithm has some limitations. When you add servers to an existing list of configured servers, keys are distributed to the new servers as part of the normal distribution. When you remove servers from the list, the keys are re-allocated to another server within the list, meaning that the cache needs to be re-populated with the information. Also, a consistent hashing algorithm does not resolve the issue where you want consistent selection of a server across multiple clients, but where each client contains a different list of servers. The consistency is enforced only within a single client.

With a *modula* hashing algorithm, the client selects a server by first computing the hash and then choosing a server from the list of configured servers. As the list of servers changes, so the server selected when using a modula hashing algorithm also changes. The result is the behavior described above; changes to the list of servers mean that different servers are selected when retrieving data, leading to cache misses and increase in database load as the cache is re-seeded with information.

If you use only a single `memcached` instance for each client, or your list of `memcached` servers configured for a client never changes, then the selection of a hashing algorithm is irrelevant, as it has no noticeable effect.

If you change your servers regularly, or you use a common set of servers that are shared among a large number of clients, then using a consistent hashing algorithm should help to ensure that your cache data is not duplicated and the data is evenly distributed.

15.3.2.6 Using `memcached` and DTrace

`memcached` includes a number of different DTrace probes that can be used to monitor the operation of the server. The probes included can monitor individual connections, slab allocations, and modifications to the hash table when a key/value pair is added, updated, or removed.

For more information on DTrace and writing DTrace scripts, read the DTrace User Guide.

Support for DTrace probes was added to `memcached` 1.2.6 includes a number of DTrace probes that can be used to help monitor your application. DTrace is supported on Solaris 10, OpenSolaris, OS X 10.5 and FreeBSD. To enable the DTrace probes in `memcached`, build from source and use the `--enable-dtrace` option. For more information, see Section 15.3.1, "Installing `memcached`".

The probes supported by `memcached` are:

- `conn-allocate(connid)`

  Fired when a connection object is allocated from the connection pool.

  - `connid`: The connection ID.

- `conn-release(connid)`

  Fired when a connection object is released back to the connection pool.

  Arguments:

- `connid`: The connection ID.

- `conn-create(ptr)`

  Fired when a new connection object is being created (that is, there are no free connection objects in the connection pool).

  Arguments:

  - `ptr`: A pointer to the connection. object

- `conn-destroy(ptr)`

  Fired when a connection object is being destroyed.

  Arguments:

  - `ptr`: A pointer to the connection object.

- `conn-dispatch(connid, threadid)`

  Fired when a connection is dispatched from the main or connection-management thread to a worker thread.

  Arguments:

  - `connid`: The connection ID.

  - `threadid`: The thread ID.

- `slabs-allocate(size, slabclass, slabsize, ptr)`

  Allocate memory from the slab allocator.

  Arguments:

  - `size`: The requested size.

  - `slabclass`: The allocation is fulfilled in this class.

  - `slabsize`: The size of each item in this class.

  - `ptr`: A pointer to allocated memory.

- `slabs-allocate-failed(size, slabclass)`

  Failed to allocate memory (out of memory).

  Arguments:

  - `size`: The requested size.

  - `slabclass`: The class that failed to fulfill the request.

- `slabs-slabclass-allocate(slabclass)`

  Fired when a slab class needs more space.

Arguments:

- `slabclass`: The class that needs more memory.

- `slabs-slabclass-allocate-failed(slabclass)`

  Failed to allocate memory (out of memory).

  Arguments:

  - `slabclass`: The class that failed to grab more memory.

- `slabs-free(size, slabclass, ptr)`

  Release memory.

  Arguments:

  - `size`: The amount of memory to release, in bytes.

  - `slabclass`: The class the memory belongs to.

  - `ptr`: A pointer to the memory to release.

- `assoc-find(key, depth)`

  Fired when we have searched the hash table for a named key. These two elements provide an insight into how well the hash function operates. Traversals are a sign of a less optimal function, wasting CPU capacity.

  Arguments:

  - `key`: The key searched for.

  - `depth`: The depth in the list of hash table.

- `assoc-insert(key, nokeys)`

  Fired when a new item has been inserted.

  Arguments:

  - `key`: The key just inserted.

  - `nokeys`: The total number of keys currently being stored, including the key for which insert was called.

- `assoc-delete(key, nokeys)`

  Fired when a new item has been removed.

  Arguments:

  - `key`: The key just deleted.

  - `nokeys`: The total number of keys currently being stored, excluding the key for which delete was called.

- `item-link(key, size)`

Fired when an item is being linked in the cache.

Arguments:

- `key`: The items key.

- `size`: The size of the data.

- `item-unlink(key, size)`

  Fired when an item is being deleted.

  Arguments:

  - `key`: The items key.

  - `size`: The size of the data.

- `item-remove(key, size)`

  Fired when the refcount for an item is reduced.

  Arguments:

  - `key`: The item's key.

  - `size`: The size of the data.

- `item-update(key, size)`

  Fired when the "last referenced" time is updated.

  Arguments:

  - `key`: The item's key.

  - `size`: The size of the data.

- `item-replace(oldkey, oldsize, newkey, newsize)`

  Fired when an item is being replaced with another item.

  Arguments:

  - `oldkey`: The key of the item to replace.

  - `oldsize`: The size of the old item.

  - `newkey`: The key of the new item.

  - `newsize`: The size of the new item.

- `process-command-start(connid, request, size)`

  Fired when the processing of a command starts.

  Arguments:

- `connid`: The connection ID.

- `request`: The incoming request.

- `size`: The size of the request.

- `process-command-end(connid, response, size)`

  Fired when the processing of a command is done.

  Arguments:

  - `connid`: The connection ID.

  - `response`: The response to send back to the client.

  - `size`: The size of the response.

- `command-get(connid, key, size)`

  Fired for a `get` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The size of the key's data (or -1 if not found).

- `command-gets(connid, key, size, casid)`

  Fired for a `gets` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The size of the key's data (or -1 if not found).

  - `casid`: The casid for the item.

- `command-add(connid, key, size)`

  Fired for a `add` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The new size of the key's data (or -1 if not found).

- `command-set(connid, key, size)`

Fired for a `set` command.

Arguments:

- `connid`: The connection ID.

- `key`: The requested key.

- `size`: The new size of the key's data (or -1 if not found).

- `command-replace(connid, key, size)`

  Fired for a `replace` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The new size of the key's data (or -1 if not found).

- `command-prepend(connid, key, size)`

  Fired for a `prepend` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The new size of the key's data (or -1 if not found).

- `command-append(connid, key, size)`

  Fired for a `append` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The new size of the key's data (or -1 if not found).

- `command-cas(connid, key, size, casid)`

  Fired for a `cas` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `size`: The size of the key's data (or -1 if not found).

- `casid`: The cas ID requested.

- `command-incr(connid, key, val)`

  Fired for `incr` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `val`: The new value.

- `command-decr(connid, key, val)`

  Fired for `decr` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `val`: The new value.

- `command-delete(connid, key, exptime)`

  Fired for a `delete` command.

  Arguments:

  - `connid`: The connection ID.

  - `key`: The requested key.

  - `exptime`: The expiry time.

15.3.2.7 Memory Allocation within `memcached`

When you first start `memcached`, the memory that you have configured is not automatically allocated. Instead, `memcached` only starts allocating and reserving physical memory once you start saving information into the cache.

When you start to store data into the cache, `memcached` does not allocate the memory for the data on an item by item basis. Instead, a slab allocation is used to optimize memory usage and prevent memory fragmentation when information expires from the cache.

With slab allocation, memory is reserved in blocks of 1MB. The slab is divided up into a number of blocks of equal size. When you try to store a value into the cache, `memcached` checks the size of the value that you are adding to the cache and determines which slab contains the right size allocation for the item. If a slab with the item size already exists, the item is written to the block within the slab.

If the new item is bigger than the size of any existing blocks, then a new slab is created, divided up into blocks of a suitable size. If an existing slab with the right block size already exists, but there are no free blocks, a new slab is created. If you update an existing item with data that is larger than the existing block allocation for that key, then the key is re-allocated into a suitable slab.

For example, the default size for the smallest block is 88 bytes (40 bytes of value, and the default 48 bytes for the key and flag data). If the size of the first item you store into the cache is less than 40 bytes, then a slab with a block size of 88 bytes is created and the value stored.

If the size of the data that you intend to store is larger than this value, then the block size is increased by the chunk size factor until a block size large enough to hold the value is determined. The block size is always a function of the scale factor, rounded up to a block size which is exactly divisible into the chunk size.

For a sample of the structure, see Figure 15.5, "Memory Allocation in `memcached`".

Figure 15.5 Memory Allocation in `memcached`
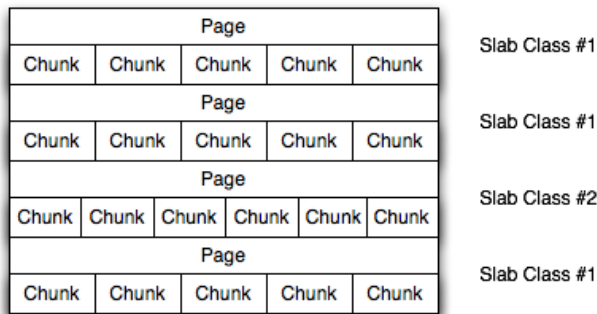
The result is that you have multiple pages allocated within the range of memory allocated to `memcached`. Each page is 1MB in size (by default), and is split into a different number of chunks, according to the chunk size required to store the key/value pairs. Each instance has multiple pages allocated, and a page is always created when a new item needs to be created requiring a chunk of a particular size. A slab may consist of multiple pages, and each page within a slab contains an equal number of chunks.

The chunk size of a new slab is determined by the base chunk size combined with the chunk size growth factor. For example, if the initial chunks are 104 bytes in size, and the default chunk size growth factor is used (1.25), then the next chunk size allocated would be the best power of 2 fit for 104*1.25, or 136 bytes.

Allocating the pages in this way ensures that memory does not get fragmented. However, depending on the distribution of the objects that you store, it may lead to an inefficient distribution of the slabs and chunks if you have significantly different sized items. For example, having a relatively small number of items within each chunk size may waste a lot of memory with just few chunks in each allocated page.

You can tune the growth factor to reduce this effect by using the `-f` command line option, which adapts the growth factor applied to make more effective use of the chunks and slabs allocated. For information on how to determine the current slab allocation statistics, see Section 15.3.4.2, "`memcached` Slabs Statistics".

If your operating system supports it, you can also start `memcached` with the `-L` command line option. This option preallocates all the memory during startup using large memory pages. This can improve performance by reducing the number of misses in the CPU memory cache.

15.3.2.8 `memcached` Thread Support

If you enable the thread implementation within when building `memcached` from source, then `memcached` uses multiple threads in addition to the `libevent` system to handle requests.

When enabled, the threading implementation operates as follows:

- Threading is handled by wrapping functions within the code to provide basic protection from updating the same global structures at the same time.

- Each thread uses its own instance of the `libevent` to help improve performance.

- TCP/IP connections are handled with a single thread listening on the TCP/IP socket. Each connection is then distributed to one of the active threads on a simple round-robin basis. Each connection then operates solely within this thread while the connection remains open.

- For UDP connections, all the threads listen to a single UDP socket for incoming requests. Threads that are not currently dealing with another request ignore the incoming packet. One of the remaining, nonbusy, threads reads the request and sends the response. This implementation can lead to increased CPU load as threads wake from sleep to potentially process the request.

Using threads can increase the performance on servers that have multiple CPU cores available, as the requests to update the hash table can be spread between the individual threads. To minimize overhead from the locking mechanism employed, experiment with different thread values to achieve the best performance based on the number and type of requests within your given workload.

15.3.2.9 `memcached` Logs

If you enable verbose mode, using the `-v`, `-vv`, or `-vvv` options, then the information output by `memcached` includes details of the operations being performed.

Without the verbose options, `memcached` normally produces no output during normal operating.

- **Output when using `-v`**

  The lowest verbosity level shows you:

  - Errors and warnings

  - Transient errors

  - Protocol and socket errors, including exhausting available connections

  - Each registered client connection, including the socket descriptor number and the protocol used.

    For example:

    ```
    32: Client using the ascii protocol
    33: Client using the ascii protocol
    ```

    The socket descriptor is only valid while the client remains connected. Non-persistent connections may not be effectively represented.

  Examples of the error messages output at this level include:

  ```
  <%d send buffer was %d, now %d
  Can't listen for events on fd %d
  Can't read from libevent pipe
  Catastrophic: event fd doesn't match conn fd!
  Couldn't build response
  Couldn't realloc input buffer
  Couldn't update event
  Failed to build UDP headers
  Failed to read, and not due to blocking
  Too many open connections
  Unexpected state %d
  ```

- **Output when using `-vv`**

When using the second level of verbosity, you get more detailed information about protocol operations, keys updated, chunk and network operatings and details.

During the initial start-up of `memcached` with this level of verbosity, you are shown the sizes of the individual slab classes, the chunk sizes, and the number of entries per slab. These do not show the allocation of the slabs, just the slabs that would be created when data is added. You are also given information about the listen queues and buffers used to send information. A sample of the output generated for a TCP/IP based system with the default memory and growth factors is given below:

```
shell> memcached -vv
slab class   1: chunk size      80 perslab 13107
slab class   2: chunk size     104 perslab 10082
slab class   3: chunk size     136 perslab  7710
slab class   4: chunk size     176 perslab  5957
slab class   5: chunk size     224 perslab  4681
slab class   6: chunk size     280 perslab  3744
slab class   7: chunk size     352 perslab  2978
slab class   8: chunk size     440 perslab  2383
slab class   9: chunk size     552 perslab  1899
slab class  10: chunk size     696 perslab  1506
slab class  11: chunk size     872 perslab  1202
slab class  12: chunk size    1096 perslab   956
slab class  13: chunk size    1376 perslab   762
slab class  14: chunk size    1720 perslab   609
slab class  15: chunk size    2152 perslab   487
slab class  16: chunk size    2696 perslab   388
slab class  17: chunk size    3376 perslab   310
slab class  18: chunk size    4224 perslab   248
slab class  19: chunk size    5280 perslab   198
slab class  20: chunk size    6600 perslab   158
slab class  21: chunk size    8256 perslab   127
slab class  22: chunk size   10320 perslab   101
slab class  23: chunk size   12904 perslab    81
slab class  24: chunk size   16136 perslab    64
slab class  25: chunk size   20176 perslab    51
slab class  26: chunk size   25224 perslab    41
slab class  27: chunk size   31536 perslab    33
slab class  28: chunk size   39424 perslab    26
slab class  29: chunk size   49280 perslab    21
slab class  30: chunk size   61600 perslab    17
slab class  31: chunk size   77000 perslab    13
slab class  32: chunk size   96256 perslab    10
slab class  33: chunk size 120320 perslab     8
slab class  34: chunk size 150400 perslab     6
slab class  35: chunk size 188000 perslab     5
slab class  36: chunk size 235000 perslab     4
slab class  37: chunk size 293752 perslab     3
slab class  38: chunk size 367192 perslab     2
slab class  39: chunk size 458992 perslab     2
<26 server listening (auto-negotiate)
<29 server listening (auto-negotiate)
<30 send buffer was 57344, now 2097152
<31 send buffer was 57344, now 2097152
<30 server listening (udp)
<30 server listening (udp)
<31 server listening (udp)
<30 server listening (udp)
<30 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
```

Using this verbosity level can be a useful way to check the effects of the growth factor used on slabs with different memory allocations, which in turn can be used to better tune the growth factor to suit the data you are storing in the cache. For example, if you set the growth factor to 4 (quadrupling the size of each slab):

```
shell> memcached -f 4 -m 1g -vv
slab class   1: chunk size     80 perslab 13107
slab class   2: chunk size    320 perslab  3276
slab class   3: chunk size   1280 perslab   819
slab class   4: chunk size   5120 perslab   204
slab class   5: chunk size  20480 perslab    51
slab class   6: chunk size  81920 perslab    12
slab class   7: chunk size 327680 perslab     3
...
```

During use of the cache, this verbosity level also prints out detailed information on the storage and recovery of keys and other information. An example of the output during a typical set/get and increment/decrement operation is shown below.

```
32: Client using the ascii protocol
<32 set my_key 0 0 10
>32 STORED
<32 set object_key 1 0 36
>32 STORED
<32 get my_key
>32 sending key my_key
>32 END
<32 get object_key
>32 sending key object_key
>32 END
<32 set key 0 0 6
>32 STORED
<32 incr key 1
>32 789544
<32 decr key 1
>32 789543
<32 incr key 2
>32 789545
<32 set my_key 0 0 10
>32 STORED
<32 set object_key 1 0 36
>32 STORED
<32 get my_key
>32 sending key my_key
>32 END
<32 get object_key
>32 sending key object_key1 1 36

>32 END
<32 set key 0 0 6
>32 STORED
<32 incr key 1
>32 789544
<32 decr key 1
>32 789543
<32 incr key 2
>32 789545
```

During client communication, for each line, the initial character shows the direction of flow of the information. The < for communication from the client to the `memcached` server and > for communication back to the client. The number is the numeric socket descriptor for the connection.

- **Output when using `-vvv`**

  This level of verbosity includes the transitions of connections between different states in the event library while reading and writing content to/from the clients. It should be used to diagnose and identify issues in client communication. For example, you can use this information to determine if `memcached` is taking a long time to return information to the client, during the read of the client operation or before returning and completing the operation. An example of the typical sequence for a set operation is provided below:

  ```
  <32 new auto-negotiating client connection
  32: going from conn_new_cmd to conn_waiting
  32: going from conn_waiting to conn_read
  32: going from conn_read to conn_parse_cmd
  32: Client using the ascii protocol
  <32 set my_key 0 0 10
  32: going from conn_parse_cmd to conn_nread
  > NOT FOUND my_key
  >32 STORED
  32: going from conn_nread to conn_write
  32: going from conn_write to conn_new_cmd
  32: going from conn_new_cmd to conn_waiting
  32: going from conn_waiting to conn_read
  32: going from conn_read to conn_closing
  <32 connection closed.
  ```

  All of the verbosity levels in `memcached` are designed to be used during debugging or examination of issues. The quantity of information generated, particularly when using `-vvv`, is significant, particularly on a busy server. Also be aware that writing the error information out, especially to disk, may negate some of the performance gains you achieve by using `memcached`. Therefore, use in production or deployment environments is not recommended.

15.3.3 Developing a `memcached` Application

A number of language interfaces let applications store and retrieve information with `memcached` servers. You can write `memcached` applications in popular languages such as Perl, PHP, Python, Ruby, C, and Java.

Data stored into a `memcached` server is referred to by a single string (the key), with storage into the cache and retrieval from the cache using the key as the reference. The cache therefore operates like a large associative array or hash table. It is not possible to structure or otherwise organize the information stored in the cache. To emulate database notions such as multiple tables or composite key values, you must encode the extra information into the strings used as keys. For example, to store or look up the address corresponding to a specific latitude and longitude, you might turn those two numeric values into a single comma-separated string to use as a key.

15.3.3.1 Basic `memcached` Operations

The interface to `memcached` supports the following methods for storing and retrieving information in the cache, and these are consistent across all the different APIs, although the language specific mechanics might be different:

- `get(key)`: Retrieves information from the cache. Returns the value associated with the key if the specified key exists. Returns `NULL`, `nil`, `undefined`, or the closest equivalent in the corresponding language, if the specified key does not exist.

- `set(key, value [, expiry])`: Sets the item associated with a key in the cache to the specified value. This either updates an existing item if the key already exists, or adds a new key/value pair if the key doesn't exist. If the expiry time is specified, then the item expires (and is deleted) when the expiry

time is reached. The time is specified in seconds, and is taken as a relative time if the value is less than 30 days (30*24*60*60), or an absolute time (epoch) if larger than this value.

- `add(key, value [, expiry])`: Adds the key and associated value to the cache, if the specified key does not already exist.

- `replace(key, value [, expiry])`: Replaces the item associated with the specified `key`, only if the key already exists. The new value is given by the `value` parameter.

- `delete(key [, time])`: Deletes the `key` and its associated item from the cache. If you supply a `time`, then adding another item with the specified `key` is blocked for the specified period.

- `incr(key , value)`: Increments the item associated with the `key` by the specified `value`.

- `decr(key , value)`: Decrements the item associated with the `key` by the specified `value`.

- `flush_all`: Invalidates (or expires) all the current items in the cache. Technically they still exist (they are not deleted), but they are silently destroyed the next time you try to access them.

In all implementations, most or all of these functions are duplicated through the corresponding native language interface.

When practical, use `memcached` to store full items, rather than caching a single column value from the database. For example, when displaying a record about an object (invoice, user history, or blog post), load all the data for the associated entry from the database, and compile it into the internal structure that would normally be required by the application. Save the complete object in the cache.

Complex data structures cannot be stored directly. Most interfaces serialize the data for you, that is, put it in a textual form that can reconstruct the original pointers and nesting. Perl uses `Storable`, PHP uses `serialize`, Python uses `cPickle` (or `Pickle`) and Java uses the `Serializable` interface. In most cases, the serialization interface used is customizable. To share data stored in `memcached` instances between different language interfaces, consider using a common serialization solution such as JSON (Javascript Object Notation).

15.3.3.2 Using `memcached` as a MySQL Caching Layer

When using `memcached` to cache MySQL data, your application must retrieve data from the database and load the appropriate key-value pairs into the cache. Then, subsequent lookups can be done directly from the cache.

Because MySQL has its own in-memory caching mechanisms for queried data, such as the `InnoDB` buffer pool and the MySQL query cache, look for opportunities beyond loading individual column values or rows into the cache. Prefer to cache composite values, such as those retrieved from multiple tables through a join query, or result sets assembled from multiple rows.

> **Caution**
>
> Limit the information in the cache to non-sensitive data, because there is no security required to access or update the information within a `memcached` instance. Anybody with access to the machine has the ability to read, view and potentially update the information. To keep the data secure, encrypt the information before caching it. To restrict the users capable of connecting to the server, either disable network access, or use IPTables or similar techniques to restrict access to the `memcached` ports to a select set of hosts.

You can introduce `memcached` to an existing application, even if caching was not part of the original design. In many languages and environments the changes to the application will be just a few lines, first

to attempt to read from the cache when loading data, fall back to the old method if the information is not cached, and to update the cache with information once the data has been read.

The general sequence for using `memcached` in any language as a caching solution for MySQL is as follows:

1. Request the item from the cache.

2. If the item exists, use the item data.

3. If the item does not exist, load the data from MySQL, and store the value into the cache. This means the value is available to the next client that requests it from the cache.

For a flow diagram of this sequence, see Figure 15.6, "Typical `memcached` Application Flowchart".

Figure 15.6 Typical `memcached` Application Flowchart
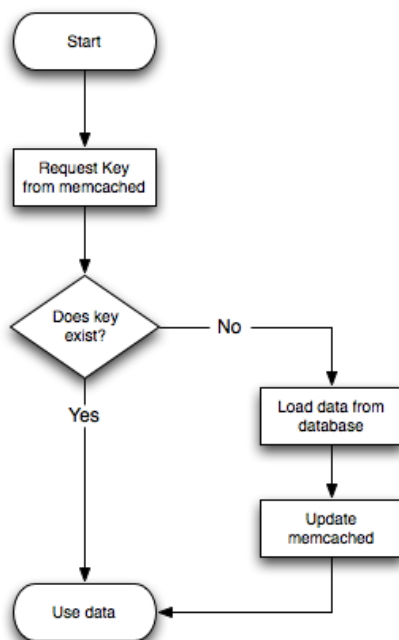
Adapting Database Best Practices to `memcached` Applications

The most direct way to cache MySQL data is to use a 2-column table, where the first column is a primary key. Because of the uniqueness requirements for `memcached` keys, make sure your database schema makes appropriate use of primary keys and unique constraints.

If you combine multiple column values into a single `memcached` item value, choose data types to make it easy to parse the value back into its components, for example by using a separator character between numeric values.

The queries that map most easily to `memcached` lookups are those with a single `WHERE` clause, using an `=` or `IN` operator. For complicated `WHERE` clauses, or those using operators such as `<`, `>`, `BETWEEN`, or `LIKE`, `memcached` does not provide a simple or efficient way to scan through or filter the keys or associated values, so typically you perform those operations as SQL queries on the underlying database.

15.3.3.3 Using `libmemcached` with C and C++

The `libmemcached` library provides both C and C++ interfaces to `memcached` and is also the basis for a number of different additional API implementations, including Perl, Python and Ruby. Understanding the core `libmemcached` functions can help when using these other interfaces.

The C library is the most comprehensive interface library for `memcached` and provides functions and operational systems not always exposed in interfaces not based on the `libmemcached` library.

The different functions can be divided up according to their basic operation. In addition to functions that interface to the core API, a number of utility functions provide extended functionality, such as appending and prepending data.

To build and install `libmemcached`, download the `libmemcached` package, run `configure`, and then build and install:

```
shell> tar xjf libmemcached-0.21.tar.gz
shell> cd libmemcached-0.21
shell> ./configure
shell> make
shell> make install
```

On many Linux operating systems, you can install the corresponding `libmemcached` package through the usual `yum`, `apt-get`, or similar commands.

To build an application that uses the library, first set the list of servers. Either directly manipulate the servers configured within the main `memcached_st` structure, or separately populate a list of servers, and then add this list to the `memcached_st` structure. The latter method is used in the following example. Once the server list has been set, you can call the functions to store or retrieve data. A simple application for setting a preset value to `localhost` is provided here:

```
#include <stdio.h>
#include <string.h>
#include <unistd.h>
#include <libmemcached/memcached.h>

int main(int argc, char *argv[])
{
  memcached_server_st *servers = NULL;
  memcached_st *memc;
  memcached_return rc;
  char *key= "keystring";
  char *value= "keyvalue";

  memcached_server_st *memcached_servers_parse (char *server_strings);
  memc= memcached_create(NULL);

  servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
  rc= memcached_server_push(memc, servers);

  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Added server successfully\n");
  else
    fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));

  rc= memcached_set(memc, key, strlen(key), value, strlen(value), (time_t)0, (uint32_t)0);

  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Key stored successfully\n");
  else
```

```
    fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));

  return 0;
}
```

To test the success of an operation, use the return value, or populated result code, for a given function. The value is always set to `MEMCACHED_SUCCESS` if the operation succeeded. In the event of a failure, use the `memcached_strerror()` function to translate the result code into a printable string.

To build the application, specify the `memcached` library:

```
shell> gcc -o memc_basic memc_basic.c -lmemcached
```

Running the above sample application, after starting a `memcached` server, should return a success message:

```
shell> memc_basic
Added server successfully
Key stored successfully
```

`libmemcached` Base Functions

The base `libmemcached` functions let you create, destroy and clone the main `memcached_st` structure that is used to interface with the `memcached` servers. The main functions are defined below:

```
memcached_st *memcached_create (memcached_st *ptr);
```

Creates a new `memcached_st` structure for use with the other `libmemcached` API functions. You can supply an existing, static, `memcached_st` structure, or `NULL` to have a new structured allocated. Returns a pointer to the created structure, or `NULL` on failure.

```
void memcached_free (memcached_st *ptr);
```

Frees the structure and memory allocated to a previously created `memcached_st` structure.

```
memcached_st *memcached_clone(memcached_st *clone, memcached_st *source);
```

Clones an existing `memcached` structure from the specified `source`, copying the defaults and list of servers defined in the structure.

`libmemcached` Server Functions

The `libmemcached` API uses a list of servers, stored within the `memcached_server_st` structure, to act as the list of servers used by the rest of the functions. To use `memcached`, you first create the server list, and then apply the list of servers to a valid `libmemcached` object.

Because the list of servers, and the list of servers within an active `libmemcached` object can be manipulated separately, you can update and manage server lists while an active `libmemcached` interface is running.

The functions for manipulating the list of servers within a `memcached_st` structure are:

```
memcached_return
   memcached_server_add (memcached_st *ptr,
```

```
                        char *hostname,
                        unsigned int port);
```

Adds a server, using the given `hostname` and `port` into the `memcached_st` structure given in `ptr`.

```
memcached_return
   memcached_server_add_unix_socket (memcached_st *ptr,
                                     char *socket);
```

Adds a Unix socket to the list of servers configured in the `memcached_st` structure.

```
unsigned int memcached_server_count (memcached_st *ptr);
```

Returns a count of the number of configured servers within the `memcached_st` structure.

```
memcached_server_st *
   memcached_server_list (memcached_st *ptr);
```

Returns an array of all the defined hosts within a `memcached_st` structure.

```
memcached_return
   memcached_server_push (memcached_st *ptr,
                          memcached_server_st *list);
```

Pushes an existing list of servers onto list of servers configured for a current `memcached_st` structure. This adds servers to the end of the existing list, and duplicates are not checked.

The `memcached_server_st` structure can be used to create a list of `memcached` servers which can then be applied individually to `memcached_st` structures.

```
memcached_server_st *
   memcached_server_list_append (memcached_server_st *ptr,
                                 char *hostname,
                                 unsigned int port,
                                 memcached_return *error);
```

Adds a server, with `hostname` and `port`, to the server list in `ptr`. The result code is handled by the `error` argument, which should point to an existing `memcached_return` variable. The function returns a pointer to the returned list.

```
unsigned int memcached_server_list_count (memcached_server_st *ptr);
```

Returns the number of the servers in the server list.

```
void memcached_server_list_free (memcached_server_st *ptr);
```

Frees the memory associated with a server list.

```
memcached_server_st *memcached_servers_parse (char *server_strings);
```

Parses a string containing a list of servers, where individual servers are separated by a comma, space, or both, and where individual servers are of the form `server[:port]`. The return value is a server list structure.

`libmemcached` Set Functions

The set-related functions within `libmemcached` provide the same functionality as the core functions supported by the `memcached` protocol. The full definition for the different functions is the same for all the base functions (`add`, `replace`, `prepend`, `append`). For example, the function definition for `memcached_set()` is:

```
memcached_return
   memcached_set (memcached_st *ptr,
                  const char *key,
                  size_t key_length,
                  const char *value,
                  size_t value_length,
                  time_t expiration,
                  uint32_t flags);
```

The `ptr` is the `memcached_st` structure. The `key` and `key_length` define the key name and length, and `value` and `value_length` the corresponding value and length. You can also set the expiration and optional flags. For more information, see Controlling `libmemcached` Behaviors.

This table outlines the remainder of the set-related `libmemcached` functions and the equivalent core functions supported by the `memcached` protocol.

`libmemcached` Function	Equivalent Core Function
`memcached_set(memc, key, key_length, value, value_length, expiration, flags)`	Generic `set()` operation.
`memcached_add(memc, key, key_length, value, value_length, expiration, flags)`	Generic `add()` function.
`memcached_replace(memc, key, key_length, value, value_length, expiration, flags)`	Generic `replace()`.
`memcached_prepend(memc, key, key_length, value, value_length, expiration, flags)`	Prepends the specified `value` before the current value of the specified `key`.
`memcached_append(memc, key, key_length, value, value_length, expiration, flags)`	Appends the specified `value` after the current value of the specified `key`.
`memcached_cas(memc, key, key_length, value, value_length, expiration, flags, cas)`	Overwrites the data for a given key as long as the corresponding `cas` value is still the same within the server.
`memcached_set_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the generic `set()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_add_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the generic `add()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_replace_by_key(memc, master_key, master_key_length, key,`	Similar to the generic `replace()`, but has the option of an additional master key that can be used to identify an individual server.

`libmemcached` Function	Equivalent Core Function
`key_length, value, value_length, expiration, flags)`	
`memcached_prepend_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the `memcached_prepend()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_append_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the `memcached_append()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_cas_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the `memcached_cas()`, but has the option of an additional master key that can be used to identify an individual server.

The `by_key` methods add two further arguments that define the master key, to be used and applied during the hashing stage for selecting the servers. You can see this in the following definition:

```
memcached_return
    memcached_set_by_key(memcached_st *ptr,
                         const char *master_key,
                         size_t master_key_length,
                         const char *key,
                         size_t key_length,
                         const char *value,
                         size_t value_length,
                         time_t expiration,
                         uint32_t flags);
```

All the functions return a value of type `memcached_return`, which you can compare against the `MEMCACHED_SUCCESS` constant.

`libmemcached` Get Functions

The `libmemcached` functions provide both direct access to a single item, and a multiple-key request mechanism that provides much faster responses when fetching a large number of keys simultaneously.

The main get-style function, which is equivalent to the generic `get()` is `memcached_get()`. This function returns a string pointer, pointing to the value associated with the specified key.

```
char *memcached_get (memcached_st *ptr,
                     const char *key, size_t key_length,
                     size_t *value_length,
                     uint32_t *flags,
                     memcached_return *error);
```

A multi-key get, `memcached_mget()`, is also available. Using a multiple key get operation is much quicker to do in one block than retrieving the key values with individual calls to `memcached_get()`. To start the multi-key get, call `memcached_mget()`:

```
memcached_return
    memcached_mget (memcached_st *ptr,
                    char **keys, size_t *key_length,
                    unsigned int number_of_keys);
```

The return value is the success of the operation. The `keys` parameter should be an array of strings containing the keys, and `key_length` an array containing the length of each corresponding key. `number_of_keys` is the number of keys supplied in the array.

To fetch the individual values, use `memcached_fetch()` to get each corresponding value.

```
char *memcached_fetch (memcached_st *ptr,
                       const char *key, size_t *key_length,
                       size_t *value_length,
                       uint32_t *flags,
                       memcached_return *error);
```

The function returns the key value, with the `key`, `key_length` and `value_length` parameters being populated with the corresponding key and length information. The function returns `NULL` when there are no more values to be returned. A full example, including the populating of the key data and the return of the information is provided here.

```
#include <stdio.h>
#include <sstring.h>
#include <unistd.h>
#include <libmemcached/memcached.h>

int main(int argc, char *argv[])
{
  memcached_server_st *servers = NULL;
  memcached_st *memc;
  memcached_return rc;
  char *keys[]= {"huey", "dewey", "louie"};
  size_t key_length[3];
  char *values[]= {"red", "blue", "green"};
  size_t value_length[3];
  unsigned int x;
  uint32_t flags;

  char return_key[MEMCACHED_MAX_KEY];
  size_t return_key_length;
  char *return_value;
  size_t return_value_length;

  memc= memcached_create(NULL);

  servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
  rc= memcached_server_push(memc, servers);

  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Added server successfully\n");
  else
    fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));

  for(x= 0; x < 3; x++)
    {
      key_length[x] = strlen(keys[x]);
      value_length[x] = strlen(values[x]);

      rc= memcached_set(memc, keys[x], key_length[x], values[x],
                        value_length[x], (time_t)0, (uint32_t)0);
      if (rc == MEMCACHED_SUCCESS)
        fprintf(stderr,"Key %s stored successfully\n",keys[x]);
      else
        fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));
    }

  rc= memcached_mget(memc, keys, key_length, 3);
```

```
   if (rc == MEMCACHED_SUCCESS)
     {
       while ((return_value= memcached_fetch(memc, return_key, &return_key_length,
                                     &return_value_length, &flags, &rc)) != NULL)
        {
          if (rc == MEMCACHED_SUCCESS)
            {
               fprintf(stderr,"Key %s returned %s\n",return_key, return_value);
            }
        }
     }

  return 0;
}
```

Running the above application produces the following output:

```
shell> memc_multi_fetch
Added server successfully
Key huey stored successfully
Key dewey stored successfully
Key louie stored successfully
Key huey returned red
Key dewey returned blue
Key louie returned green
```

Controlling `libmemcached` Behaviors

The behavior of `libmemcached` can be modified by setting one or more behavior flags. These can either be set globally, or they can be applied during the call to individual functions. Some behaviors also accept an additional setting, such as the hashing mechanism used when selecting servers.

To set global behaviors:

```
memcached_return
    memcached_behavior_set (memcached_st *ptr,
                            memcached_behavior flag,
                            uint64_t data);
```

To get the current behavior setting:

```
uint64_t
    memcached_behavior_get (memcached_st *ptr,
                            memcached_behavior flag);
```

The following table describes `libmemcached` behavior flags.

Behavior	Description
MEMCACHED_BEHAVIOR_NO_BLOCK	Caused `libmemcached` to use asynchronous I/O.
MEMCACHED_BEHAVIOR_TCP_NODELAY	Turns on no-delay for network sockets.
MEMCACHED_BEHAVIOR_HASH	Without a value, sets the default hashing algorithm for keys to use MD5. Other valid values include MEMCACHED_HASH_DEFAULT, MEMCACHED_HASH_MD5, MEMCACHED_HASH_CRC, MEMCACHED_HASH_FNV1_64, MEMCACHED_HASH_FNV1A_64, MEMCACHED_HASH_FNV1_32, and MEMCACHED_HASH_FNV1A_32.
MEMCACHED_BEHAVIOR_DISTRIBUTION	Changes the method of selecting the server used to store a given value. The default method

Behavior	Description
	is `MEMCACHED_DISTRIBUTION_MODULA`. You can enable consistent hashing by setting `MEMCACHED_DISTRIBUTION_CONSISTENT`. `MEMCACHED_DISTRIBUTION_CONSISTENT` is an alias for the value `MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA`.
`MEMCACHED_BEHAVIOR_CACHE_LOOKUPS`	Cache the lookups made to the DNS service. This can improve the performance if you are using names instead of IP addresses for individual hosts.
`MEMCACHED_BEHAVIOR_SUPPORT_CAS`	Support CAS operations. By default, this is disabled because it imposes a performance penalty.
`MEMCACHED_BEHAVIOR_KETAMA`	Sets the default distribution to `MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA` and the hash to `MEMCACHED_HASH_MD5`.
`MEMCACHED_BEHAVIOR_POLL_TIMEOUT`	Modify the timeout value used by `poll()`. Supply a `signed int` pointer for the timeout value.
`MEMCACHED_BEHAVIOR_BUFFER_REQUESTS`	Buffers IO requests instead of them being sent. A get operation, or closing the connection causes the data to be flushed.
`MEMCACHED_BEHAVIOR_VERIFY_KEY`	Forces `libmemcached` to verify that a specified key is valid.
`MEMCACHED_BEHAVIOR_SORT_HOSTS`	If set, hosts added to the list of configured hosts for a `memcached_st` structure are placed into the host list in sorted order. This breaks consistent hashing if that behavior has been enabled.
`MEMCACHED_BEHAVIOR_CONNECT_TIMEOUT`	In nonblocking mode this changes the value of the timeout during socket connection.

`libmemcached` Command-Line Utilities

In addition to the main C library interface, `libmemcached` also includes a number of command-line utilities that can be useful when working with and debugging `memcached` applications.

All of the command-line tools accept a number of arguments, the most critical of which is `servers`, which specifies the list of servers to connect to when returning information.

The main tools are:

- `memcat`: Display the value for each ID given on the command line:

```
shell> memcat --servers=localhost hwkey
Hello world
```

- `memcp`: Copy the contents of a file into the cache, using the file name as the key:

```
shell> echo "Hello World" > hwkey
shell> memcp --servers=localhost hwkey
shell> memcat --servers=localhost hwkey
Hello world
```

- `memrm`: Remove an item from the cache:

```
shell> memcat --servers=localhost hwkey
Hello world
shell> memrm --servers=localhost hwkey
shell> memcat --servers=localhost hwkey
```

- `memslap`: Test the load on one or more `memcached` servers, simulating get/set and multiple client operations. For example, you can simulate the load of 100 clients performing get operations:

```
shell> memslap --servers=localhost --concurrency=100 --flush --test=get
memslap --servers=localhost --concurrency=100 --flush --test=get Threads connecting to servers 100
 Took 13.571 seconds to read data
```

- `memflush`: Flush (empty) the contents of the `memcached` cache.

```
shell> memflush --servers=localhost
```

15.3.3.4 Using MySQL and `memcached` with Perl

The `Cache::Memcached` module provides a native interface to the Memcache protocol, and provides support for the core functions offered by `memcached`. Install the module using your operating system's package management system, or using `CPAN`:

```
root-shell> perl -MCPAN -e 'install Cache::Memcached'
```

To use `memcached` from Perl through the `Cache::Memcached` module, first create a new `Cache::Memcached` object that defines the list of servers and other parameters for the connection. The only argument is a hash containing the options for the cache interface. For example, to create a new instance that uses three `memcached` servers:

```
use Cache::Memcached;

my $cache = new Cache::Memcached {
    'servers' => [
        '192.168.0.100:11211',
        '192.168.0.101:11211',
        '192.168.0.102:11211',
 ],
};
```

> **Note**
>
> When using the `Cache::Memcached` interface with multiple servers, the API automatically performs certain operations across all the servers in the group. For example, getting statistical information through `Cache::Memcached` returns a hash that contains data on a host-by-host basis, as well as generalized statistics for all the servers in the group.

You can set additional properties on the cache object instance when it is created by specifying the option as part of the option hash. Alternatively, you can use a corresponding method on the instance:

- `servers` or method `set_servers()`: Specifies the list of the servers to be used. The servers list should be a reference to an array of servers, with each element as the address and port number combination (separated by a colon). You can also specify a local connection through a Unix socket (for example `/tmp/sock/memcached`). To specify the server with a weight (indicating how much more frequently the server should be used during hashing), specify an array reference with the `memcached` server instance and a weight number. Higher numbers give higher priority.

- `compress_threshold` or method `set_compress_threshold()`: Specifies the threshold when values are compressed. Values larger than the specified number are automatically compressed (using `zlib`) during storage and retrieval.

- `no_rehash` or method `set_norehash()`: Disables finding a new server if the original choice is unavailable.

- `readonly` or method `set_readonly()`: Disables writes to the `memcached` servers.

Once the `Cache::Memcached` object instance has been configured, you can use the `set()` and `get()` methods to store and retrieve information from the `memcached` servers. Objects stored in the cache are automatically serialized and deserialized using the `Storable` module.

The `Cache::Memcached` interface supports the following methods for storing/retrieving data, and relate to the generic methods as shown in the table.

`Cache::Memcached` Function	Equivalent Generic Method
`get()`	Generic `get()`.
`get_multi(keys)`	Gets multiple `keys` from memcache using just one query. Returns a hash reference of key/value pairs.
`set()`	Generic `set()`.
`add()`	Generic `add()`.
`replace()`	Generic `replace()`.
`delete()`	Generic `delete()`.
`incr()`	Generic `incr()`.
`decr()`	Generic `decr()`.

Below is a complete example for using `memcached` with Perl and the `Cache::Memcached` module:

```perl
#!/usr/bin/perl

use Cache::Memcached;
use DBI;
use Data::Dumper;

# Configure the memcached server

my $cache = new Cache::Memcached {
    'servers' => [
                  'localhost:11211',
                  ],
    };

# Get the film name from the command line
# memcached keys must not contain spaces, so create
# a key name by replacing spaces with underscores

my $filmname = shift or die "Must specify the film name\n";
my $filmkey = $filmname;
$filmkey =~ s/ /_/;

# Load the data from the cache

my $filmdata = $cache->get($filmkey);

# If the data wasn't in the cache, then we load it from the database
```

```
if (!defined($filmdata))
{
    $filmdata = load_filmdata($filmname);

    if (defined($filmdata))
    {

# Set the data into the cache, using the key

 if ($cache->set($filmkey,$filmdata))
        {
            print STDERR "Film data loaded from database and cached\n";
        }
        else
        {
            print STDERR "Couldn't store to cache\n";
 }
    }
    else
    {
      die "Couldn't find $filmname\n";
    }
}
else
{
    print STDERR "Film data loaded from Memcached\n";
}

sub load_filmdata
{
    my ($filmname) = @_;

    my $dsn = "DBI:mysql:database=sakila;host=localhost;port=3306";

    $dbh = DBI->connect($dsn, 'sakila','password');

    my ($filmbase) = $dbh->selectrow_hashref(sprintf('select * from film where title = %s',
                                                   $dbh->quote($filmname)));

    if (!defined($filmname))
    {
      return (undef);
    }

    $filmbase->{stars} =
 $dbh->selectall_arrayref(sprintf('select concat(first_name," ",last_name) ' .
                                  'from film_actor left join (actor) ' .
                                  'on (film_actor.actor_id = actor.actor_id) ' .
                                  ' where film_id=%s',
                                  $dbh->quote($filmbase->{film_id})));

    return($filmbase);
}
```

The example uses the Sakila database, obtaining film data from the database and writing a composite record of the film and actors to `memcached`. When calling it for a film does not exist, you get this result:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from database and cached
```

When accessing a film that has already been added to the cache:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from Memcached
```

15.3.3.5 Using MySQL and `memcached` with Python

The Python `memcache` module interfaces to `memcached` servers, and is written in pure Python (that is, without using one of the C APIs). You can download and install a copy from Python Memcached.

To install, download the package and then run the Python installer:

```
python setup.py install
running install
running bdist_egg
running egg_info
creating python_memcached.egg-info
...
removing 'build/bdist.linux-x86_64/egg' (and everything under it)
Processing python_memcached-1.43-py2.4.egg
creating /usr/lib64/python2.4/site-packages/python_memcached-1.43-py2.4.egg
Extracting python_memcached-1.43-py2.4.egg to /usr/lib64/python2.4/site-packages
Adding python-memcached 1.43 to easy-install.pth file

Installed /usr/lib64/python2.4/site-packages/python_memcached-1.43-py2.4.egg
Processing dependencies for python-memcached==1.43
Finished processing dependencies for python-memcached==1.43
```

Once installed, the `memcache` module provides a class-based interface to your `memcached` servers. When you store Python data structures as `memcached` items, they are automatically serialized (turned into string values) using the Python `cPickle` or `pickle` modules.

To create a new `memcache` interface, import the `memcache` module and create a new instance of the `memcache.Client` class. For example, if the `memcached` daemon is running on localhost using the default port:

```
import memcache
memc = memcache.Client(['127.0.0.1:11211'])
```

The first argument is an array of strings containing the server and port number for each `memcached` instance to use. To enable debugging, set the optional `debug` parameter to 1.

By default, the hashing mechanism used to divide the items among multiple servers is `crc32`. To change the function used, set the value of `memcache.serverHashFunction` to the alternate function to use. For example:

```
from zlib import adler32
memcache.serverHashFunction = adler32
```

Once you have defined the servers to use within the `memcache` instance, the core functions provide the same functionality as in the generic interface specification. The following table provides a summary of the supported functions:

Python `memcache` Function	Equivalent Generic Function
`get()`	Generic `get()`.
`get_multi(keys)`	Gets multiple values from the supplied array of `keys`. Returns a hash reference of key/value pairs.
`set()`	Generic `set()`.
`set_multi(dict [, expiry [, key_prefix]])`	Sets multiple key/value pairs from the supplied `dict`.
`add()`	Generic `add()`.

Python `memcache` Function	Equivalent Generic Function
`replace()`	Generic `replace()`.
`prepend(key, value [, expiry])`	Prepends the supplied `value` to the value of the existing `key`.
`append(key, value [, expiry[)`	Appends the supplied `value` to the value of the existing `key`.
`delete()`	Generic `delete()`.
`delete_multi(keys [, expiry [, key_prefix]] )`	Deletes all the keys from the hash matching each string in the array `keys`.
`incr()`	Generic `incr()`.
`decr()`	Generic `decr()`.

Note

Within the Python `memcache` module, all the `*_multi()` functions support an optional `key_prefix` parameter. If supplied, then the string is used as a prefix to all key lookups. For example, if you call:

```
memc.get_multi(['a','b'], key_prefix='users:')
```

The function retrieves the keys `users:a` and `users:b` from the servers.

Here is an example showing the storage and retrieval of information to a `memcache` instance, loading the raw data from MySQL:

```
import sys
import MySQLdb
import memcache

memc = memcache.Client(['127.0.0.1:11211'], debug=1);

try:
    conn = MySQLdb.connect (host = "localhost",
                            user = "sakila",
                            passwd = "password",
                            db = "sakila")
except MySQLdb.Error, e:
    print "Error %d: %s" % (e.args[0], e.args[1])
    sys.exit (1)

popularfilms = memc.get('top5films')

if not popularfilms:
    cursor = conn.cursor()
    cursor.execute('select film_id,title from film order by rental_rate desc limit 5')
    rows = cursor.fetchall()
    memc.set('top5films',rows,60)
    print "Updated memcached with MySQL data"
else:
    print "Loaded data from memcached"
    for row in popularfilms:
        print "%s, %s" % (row[0], row[1])
```

When executed for the first time, the data is loaded from the MySQL database and stored to the `memcached` server.

```
shell> python memc_python.py
Updated memcached with MySQL data
```

Because the data is automatically serialized using `cPickle`/`pickle`, when you load the data back from `memcached`, you can use the object directly. In the example above, the information stored to `memcached` is in the form of rows from a Python DB cursor. When accessing the information (within the 60 second expiry time), the data is loaded from `memcached` and dumped:

```
shell> python memc_python.py
Loaded data from memcached
2, ACE GOLDFINGER
7, AIRPLANE SIERRA
8, AIRPORT POLLOCK
10, ALADDIN CALENDAR
13, ALI FOREVER
```

The serialization and deserialization happens automatically. Because serialization of Python data may be incompatible with other interfaces and languages, you can change the serialization module used during initialization. For example, you might use JSON format when you store complex data structures using a script written in one language, and access them in a script written in a different language.

15.3.3.6 Using MySQL and `memcached` with PHP

PHP provides support for the Memcache functions through a PECL extension. To enable the PHP `memcache` extensions, build PHP using the `--enable-memcache` option to `configure` when building from source.

If you are installing on a Red Hat-based server, you can install the `php-pecl-memcache` RPM:

```
root-shell> yum --install php-pecl-memcache
```

On Debian-based distributions, use the `php-memcache` package.

To set global runtime configuration options, specify the configuration option values within your `php.ini` file. The following table provides the name, default value, and a description for each global runtime configuration option.

Configuration option	Default	Description
`memcache.allow_failover`	1	Specifies whether another server in the list should be queried if the first server selected fails.
`memcache.max_failover_attempts`	20	Specifies the number of servers to try before returning a failure.
`memcache.chunk_size`	8192	Defines the size of network chunks used to exchange data with the `memcached` server.
`memcache.default_port`	11211	Defines the default port to use when communicating with the `memcached` servers.
`memcache.hash_strategy`	standard	Specifies which hash strategy to use. Set to `consistent` to enable servers to be added or removed from the pool without causing the keys to be remapped to other servers. When set to `standard`, an older (modula) strategy is used that potentially uses different servers for storage.

Configuration option	Default	Description
`memcache.hash_function`	crc32	Specifies which function to use when mapping keys to servers. `crc32` uses the standard CRC32 hash. `fnv` uses the FNV-1a hashing algorithm.

To create a connection to a `memcached` server, create a new `Memcache` object and then specify the connection options. For example:

```
<?php

$cache = new Memcache;
$cache->connect('localhost',11211);
?>
```

This opens an immediate connection to the specified server.

To use multiple `memcached` servers, you need to add servers to the memcache object using `addServer()`:

```
bool Memcache::addServer ( string $host [, int $port [, bool $persistent
                 [, int $weight [, int $timeout [, int $retry_interval
                 [, bool $status [, callback $failure_callback
                 ]]]]]]] )
```

The server management mechanism within the `php-memcache` module is a critical part of the interface as it controls the main interface to the `memcached` instances and how the different instances are selected through the hashing mechanism.

To create a simple connection to two `memcached` instances:

```
<?php

$cache = new Memcache;
$cache->addServer('192.168.0.100',11211);
$cache->addServer('192.168.0.101',11211);
?>
```

In this scenario, the instance connection is not explicitly opened, but only opened when you try to store or retrieve a value. To enable persistent connections to `memcached` instances, set the `$persistent` argument to true. This is the default setting, and causes the connections to remain open.

To help control the distribution of keys to different instances, use the global `memcache.hash_strategy` setting. This sets the hashing mechanism used to select. You can also add another weight to each server, which effectively increases the number of times the instance entry appears in the instance list, therefore increasing the likelihood of the instance being chosen over other instances. To set the weight, set the value of the `$weight` argument to more than one.

The functions for setting and retrieving information are identical to the generic functional interface offered by `memcached`, as shown in this table:

PECL `memcache` Function	Generic Function
`get()`	Generic `get()`.
`set()`	Generic `set()`.
`add()`	Generic `add()`.
`replace()`	Generic `replace()`.

PECL `memcache` Function	Generic Function
`delete()`	Generic `delete()`.
`increment()`	Generic `incr()`.
`decrement()`	Generic `decr()`.

A full example of the PECL `memcache` interface is provided below. The code loads film data from the Sakila database when the user provides a film name. The data stored into the `memcached` instance is recorded as a `mysqli` result row, and the API automatically serializes the information for you.

```php
<?php

$memc = new Memcache;
$memc->addServer('localhost','11211');

if(empty($_POST['film'])) {
?>
  <html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en" lang="en">
    <head>
      <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
      <title>Simple Memcache Lookup</title>
    </head>
    <body>
      <form method="post">
        <p><b>Film</b>: <input type="text" size="20" name="film"></p>
        <input type="submit">
      </form>
      <hr/>
<?php

} else {

    echo "Loading data...\n";

    $film   = htmlspecialchars($_POST['film'], ENT_QUOTES, 'UTF-8');
    $mfilms = $memc->get($film);

    if ($mfilms) {

        printf("<p>Film data for %s loaded from memcache</p>", $mfilms['title']);

        foreach (array_keys($mfilms) as $key) {
            printf("<p><b>%s</b>: %s</p>", $key, $mfilms[$key]);
        }

    } else {

        $mysqli = mysqli('localhost','sakila','password','sakila');

        if (mysqli_connect_error()) {
            sprintf("Database error: (%d) %s", mysqli_connect_errno(), mysqli_connect_error());
            exit;
        }

        $sql = sprintf('SELECT * FROM film WHERE title="%s"', $mysqli->real_escape_string($film));

        $result = $mysqli->query($sql);

        if (!$result) {
            sprintf("Database error: (%d) %s", $mysqli->errno, $mysqli->error);
            exit;
        }
```

```
        $row = $result->fetch_assoc();

        $memc->set($row['title'], $row);

        printf("<p>Loaded (%s) from MySQL</p>", htmlspecialchars($row['title'], ENT_QUOTES, 'UTF-8');
    }
}
?>
  </body>
</html>
```

With PHP, the connections to the `memcached` instances are kept open as long as the PHP and associated Apache instance remain running. When adding or removing servers from the list in a running instance (for example, when starting another script that mentions additional servers), the connections are shared, but the script only selects among the instances explicitly configured within the script.

To ensure that changes to the server list within a script do not cause problems, make sure to use the consistent hashing mechanism.

15.3.3.7 Using MySQL and `memcached` with Ruby

There are a number of different modules for interfacing to `memcached` within Ruby. The `Ruby-MemCache` client library provides a native interface to `memcached` that does not require any external libraries, such as `libmemcached`. You can obtain the installer package from http://www.deveiate.org/projects/RMemCache.

To install, extract the package and then run `install.rb`:

```
shell> install.rb
```

If you have RubyGems, you can install the `Ruby-MemCache` gem:

```
shell> gem install Ruby-MemCache
Bulk updating Gem source index for: http://gems.rubyforge.org
Install required dependency io-reactor? [Yn]  y
Successfully installed Ruby-MemCache-0.0.1
Successfully installed io-reactor-0.05
Installing ri documentation for io-reactor-0.05...
Installing RDoc documentation for io-reactor-0.05...
```

To use a `memcached` instance from within Ruby, create a new instance of the `MemCache` object.

```
require 'memcache'
memc = MemCache::new '192.168.0.100:11211'
```

You can add a weight to each server to increase the likelihood of the server being selected during hashing by appending the weight count to the server host name/port string:

```
require 'memcache'
memc = MemCache::new '192.168.0.100:11211:3'
```

To add servers to an existing list, you can append them directly to the `MemCache` object:

```
memc += ["192.168.0.101:11211"]
```

To set data into the cache, you can just assign a value to a key within the new cache object, which works just like a standard Ruby hash object:

```
memc["key"] = "value"
```

Or to retrieve the value:

```
print memc["key"]
```

For more explicit actions, you can use the method interface, which mimics the main `memcached` API functions, as summarized in the following table:

Ruby `MemCache` Method	Equivalent `memcached` API Functions
`get()`	Generic `get()`.
`get_hash(keys)`	Get the values of multiple `keys`, returning the information as a hash of the keys and their values.
`set()`	Generic `set()`.
`set_many(pairs)`	Set the values of the keys and values in the hash `pairs`.
`add()`	Generic `add()`.
`replace()`	Generic `replace()`.
`delete()`	Generic `delete()`.
`incr()`	Generic `incr()`.
`decr()`	Generic `decr()`.

15.3.3.8 Using MySQL and `memcached` with Java

The `com.danga.MemCached` class within Java provides a native interface to `memcached` instances. You can obtain the client from https://github.com/gwhalin/Memcached-Java-Client/downloads. The Java class uses hashes that are compatible with `libmemcached`, so you can mix and match Java and `libmemcached` applications accessing the same `memcached` instances. The serialization between Java and other interfaces are not compatible. If this is a problem, use JSON or a similar nonbinary serialization format.

On most systems, you can download the package and use the `jar` directly.

To use the `com.danga.MemCached` interface, you create a `MemCachedClient` instance and then configure the list of servers by configuring the `SockIOPool`. Through the pool specification you set up the server list, weighting, and the connection parameters to optimized the connections between your client and the `memcached` instances that you configure.

Generally, you can configure the `memcached` interface once within a single class, then use this interface throughout the rest of your application.

For example, to create a basic interface, first configure the `MemCachedClient` and base `SockIOPool` settings:

```
public class MyClass {

    protected static MemCachedClient mcc = new MemCachedClient();

    static {

        String[] servers =
            {
                "localhost:11211",
            };

        Integer[] weights = { 1 };
```

```
    SockIOPool pool = SockIOPool.getInstance();

    pool.setServers( servers );
    pool.setWeights( weights );
```

In the above sample, the list of servers is configured by creating an array of the `memcached` instances to use. You can then configure individual weights for each server.

The remainder of the properties for the connection are optional, but you can set the connection numbers (initial connections, minimum connections, maximum connections, and the idle timeout) by setting the pool parameters:

```
pool.setInitConn( 5 );
pool.setMinConn( 5 );
pool.setMaxConn( 250 );
pool.setMaxIdle( 1000 * 60 * 60 * 6
```

Once the parameters have been configured, initialize the connection pool:

```
pool.initialize();
```

The pool, and the connection to your `memcached` instances should now be ready to use.

To set the hashing algorithm used to select the server used when storing a given key, use `pool.setHashingAlg()`:

```
pool.setHashingAlg( SockIOPool.NEW_COMPAT_HASH );
```

Valid values are `NEW_COMPAT_HASH`, `OLD_COMPAT_HASH` and `NATIVE_HASH` are also basic modula hashing algorithms. For a consistent hashing algorithm, use `CONSISTENT_HASH`. These constants are equivalent to the corresponding hash settings within `libmemcached`.

The following table outlines the Java `com.danga.MemCached` methods and the equivalent generic methods in the `memcached` interface specification.

Java `com.danga.MemCached` Method	Equivalent Generic Method
`get()`	Generic `get()`.
`getMulti(keys)`	Get the values of multiple `keys`, returning the information as Hash map using `java.lang.String` for the keys and `java.lang.Object` for the corresponding values.
`set()`	Generic `set()`.
`add()`	Generic `add()`.
`replace()`	Generic `replace()`.
`delete()`	Generic `delete()`.
`incr()`	Generic `incr()`.
`decr()`	Generic `decr()`.

15.3.3.9 Using the `memcached` TCP Text Protocol

Communicating with a `memcached` server can be achieved through either the TCP or UDP protocols. When using the TCP protocol, you can use a simple text based interface for the exchange of information.

When communicating with `memcached`, you can connect to the server using the port configured for the server. You can open a connection with the server without requiring authorization or login. As soon as you have connected, you can start to send commands to the server. When you have finished, you can terminate the connection without sending any specific disconnection command. Clients are encouraged to keep their connections open to decrease latency and improve performance.

Data is sent to the `memcached` server in two forms:

- Text lines, which are used to send commands to the server, and receive responses from the server.

- Unstructured data, which is used to receive or send the value information for a given key. Data is returned to the client in exactly the format it was provided.

Both text lines (commands and responses) and unstructured data are always terminated with the string `\r` `\n`. Because the data being stored may contain this sequence, the length of the data (returned by the client before the unstructured data is transmitted should be used to determine the end of the data.

Commands to the server are structured according to their operation:

- **Storage commands**: `set`, `add`, `replace`, `append`, `prepend`, `cas`

  Storage commands to the server take the form:

  ```
  command key [flags] [exptime] length [noreply]
  ```

  Or when using compare and swap (cas):

  ```
  cas key [flags] [exptime] length [casunique] [noreply]
  ```

  Where:

  - `command`: The command name.

    - `set`: Store value against key

    - `add`: Store this value against key if the key does not already exist

    - `replace`: Store this value against key if the key already exists

    - `append`: Append the supplied value to the end of the value for the specified key. The `flags` and `exptime` arguments should not be used.

    - `prepend`: Append value currently in the cache to the end of the supplied value for the specified key. The `flags` and `exptime` arguments should not be used.

    - `cas`: Set the specified key to the supplied value, only if the supplied `casunique` matches. This is effectively the equivalent of change the information if nobody has updated it since I last fetched it.

  - `key`: The key. All data is stored using a the specific key. The key cannot contain control characters or whitespace, and can be up to 250 characters in size.

  - `flags`: The flags for the operation (as an integer). Flags in `memcached` are transparent. The `memcached` server ignores the contents of the flags. They can be used by the client to indicate any type of information. In `memcached` 1.2.0 and lower the value is a 16-bit integer value. In `memcached` 1.2.1 and higher the value is a 32-bit integer.

  - `exptime`: The expiry time, or zero for no expiry.

- `length`: The length of the supplied value block in bytes, excluding the terminating `\r\n` characters.

- `casunique`: A unique 64-bit value of an existing entry. This is used to compare against the existing value. Use the value returned by the `gets` command when issuing `cas` updates.

- `noreply`: Tells the server not to reply to the command.

For example, to store the value `abcdef` into the key `xyzkey`, you would use:

```
set xyzkey 0 0 6\r\nabcdef\r\n
```

The return value from the server is one line, specifying the status or error information. For more information, see Table 15.3, "`memcached` Protocol Responses".

- **Retrieval commands**: `get`, `gets`

  Retrieval commands take the form:

  ```
  get key1 [key2 .... keyn]
  gets key1 [key2 ... keyn]
  ```

  You can supply multiple keys to the commands, with each requested key separated by whitespace.

  The server responds with an information line of the form:

  ```
  VALUE key flags bytes [casunique]
  ```

  Where:

  - `key`: The key name.

  - `flags`: The value of the flag integer supplied to the `memcached` server when the value was stored.

  - `bytes`: The size (excluding the terminating `\r\n` character sequence) of the stored value.

  - `casunique`: The unique 64-bit integer that identifies the item.

  The information line is immediately followed by the value data block. For example:

  ```
  get xyzkey\r\n
  VALUE xyzkey 0 6\r\n
  abcdef\r\n
  ```

  If you have requested multiple keys, an information line and data block is returned for each key found. If a requested key does not exist in the cache, no information is returned.

- **Delete commands**: `delete`

  Deletion commands take the form:

  ```
  delete key [time] [noreply]
  ```

  Where:

  - `key`: The key name.

- `time`: The time in seconds (or a specific Unix time) for which the client wishes the server to refuse `add` or `replace` commands on this key. All `add`, `replace`, `get`, and `gets` commands fail during this period. `set` operations succeed. After this period, the key is deleted permanently and all commands are accepted.

  If not supplied, the value is assumed to be zero (delete immediately).

- `noreply`: Tells the server not to reply to the command.

Responses to the command are either `DELETED` to indicate that the key was successfully removed, or `NOT_FOUND` to indicate that the specified key could not be found.

- **Increment/Decrement**: `incr`, `decr`

  The increment and decrement commands change the value of a key within the server without performing a separate get/set sequence. The operations assume that the currently stored value is a 64-bit integer. If the stored value is not a 64-bit integer, then the value is assumed to be zero before the increment or decrement operation is applied.

  Increment and decrement commands take the form:

  ```
  incr key value [noreply]
  decr key value [noreply]
  ```

  Where:

  - `key`: The key name.

  - `value`: An integer to be used as the increment or decrement value.

  - `noreply`: Tells the server not to reply to the command.

  The response is:

  - `NOT_FOUND`: The specified key could not be located.

  - `value`: The new value associated with the specified key.

  Values are assumed to be unsigned. For `decr` operations, the value is never decremented below 0. For `incr` operations, the value wraps around the 64-bit maximum.

- **Statistics commands**: `stats`

  The `stats` command provides detailed statistical information about the current status of the `memcached` instance and the data it is storing.

  Statistics commands take the form:

  ```
  STAT [name] [value]
  ```

  Where:

  - `name`: The optional name of the statistics to return. If not specified, the general statistics are returned.

  - `value`: A specific value to be used when performing certain statistics operations.

The return value is a list of statistics data, formatted as follows:

```
STAT name value
```

The statistics are terminated with a single line, END.

For more information, see Section 15.3.4, "Getting `memcached` Statistics".

For reference, a list of the different commands supported and their formats is provided below.

Table 15.2 `memcached` Command Reference

Command	Command Formats
set	set key flags exptime length, set key flags exptime length noreply
add	add key flags exptime length, add key flags exptime length noreply
replace	replace key flags exptime length, replace key flags exptime length noreply
append	append key length, append key length noreply
prepend	prepend key length, prepend key length noreply
cas	cas key flags exptime length casunique, cas key flags exptime length casunique noreply
get	get key1 [key2 ... keyn]
gets	
delete	delete key, delete key noreply, delete key expiry, delete key expiry noreply
incr	incr key, incr key noreply, incr key value, incr key value noreply
decr	decr key, decr key noreply, decr key value, decr key value noreply
stat	stat, stat name, stat name value

When sending a command to the server, the response from the server is one of the settings in the following table. All response values from the server are terminated by \r\n:

Table 15.3 `memcached` Protocol Responses

String	Description
STORED	Value has successfully been stored.
NOT_STORED	The value was not stored, but not because of an error. For commands where you are adding a or updating a value if it exists (such as add and replace), or where the item has already been set to be deleted.
EXISTS	When using a cas command, the item you are trying to store already exists and has been modified since you last checked it.
NOT_FOUND	The item you are trying to store, update or delete does not exist or has already been deleted.
ERROR	You submitted a nonexistent command name.

String	Description
`CLIENT_ERROR errorstring`	There was an error in the input line, the detail is contained in `errorstring`.
`SERVER_ERROR errorstring`	There was an error in the server that prevents it from returning the information. In extreme conditions, the server may disconnect the client after this error occurs.
`VALUE keys flags length`	The requested key has been found, and the stored `key`, `flags` and data block are returned, of the specified `length`.
`DELETED`	The requested key was deleted from the server.
`STAT name value`	A line of statistics data.
`END`	The end of the statistics data.

15.3.4 Getting `memcached` Statistics

The `memcached` system has a built-in statistics system that collects information about the data being stored into the cache, cache hit ratios, and detailed information on the memory usage and distribution of information through the slab allocation used to store individual items. Statistics are provided at both a basic level that provide the core statistics, and more specific statistics for specific areas of the `memcached` server.

This information can be useful to ensure that you are getting the correct level of cache and memory usage, and that your slab allocation and configuration properties are set at an optimal level.

The stats interface is available through the standard `memcached` protocol, so the reports can be accessed by using `telnet` to connect to the `memcached`. The supplied `memcached-tool` includes support for obtaining the Section 15.3.4.2, "`memcached` Slabs Statistics" and Section 15.3.4.1, "`memcached` General Statistics" information. For more information, see Section 15.3.4.6, "Using `memcached-tool`".

Alternatively, most of the language API interfaces provide a function for obtaining the statistics from the server.

For example, to get the basic stats using `telnet`:

```
shell> telnet localhost 11211
Trying ::1...
Connected to localhost.
Escape character is '^]'.
stats
STAT pid 23599
STAT uptime 675
STAT time 1211439587
STAT version 1.2.5
STAT pointer_size 32
STAT rusage_user 1.404992
STAT rusage_system 4.694685
STAT curr_items 32
STAT total_items 56361
STAT bytes 2642
STAT curr_connections 53
STAT total_connections 438
STAT connection_structures 55
STAT cmd_get 113482
STAT cmd_set 80519
STAT get_hits 78926
STAT get_misses 34556
STAT evictions 0
STAT bytes_read 6379783
```

```
STAT bytes_written 4860179
STAT limit_maxbytes 67108864
STAT threads 1
END
```

When using Perl and the `Cache::Memcached` module, the `stats()` function returns information about all the servers currently configured in the connection object, and total statistics for all the `memcached` servers as a whole.

For example, the following Perl script obtains the stats and dumps the hash reference that is returned:

```
use Cache::Memcached;
use Data::Dumper;

my $memc = new Cache::Memcached;
$memc->set_servers(\@ARGV);

print Dumper($memc->stats());
```

When executed on the same `memcached` as used in the `Telnet` example above we get a hash reference with the host by host and total statistics:

```
$VAR1 = {
    'hosts' => {
            'localhost:11211' => {
                        'misc' => {
                                'bytes' => '2421',
                                'curr_connections' => '3',
                                'connection_structures' => '56',
                                'pointer_size' => '32',
                                'time' => '1211440166',
                                'total_items' => '410956',
                                'cmd_set' => '588167',
                                'bytes_written' => '35715151',
                                'evictions' => '0',
                                'curr_items' => '31',
                                'pid' => '23599',
                                'limit_maxbytes' => '67108864',
                                'uptime' => '1254',
                                'rusage_user' => '9.857805',
                                'cmd_get' => '838451',
                                'rusage_system' => '34.096988',
                                'version' => '1.2.5',
                                'get_hits' => '581511',
                                'bytes_read' => '46665716',
                                'threads' => '1',
                                'total_connections' => '3104',
                                'get_misses' => '256940'
                            },
                        'sizes' => {
                                '128' => '16',
                                '64' => '15'
                            }
                        }
            },
    'self' => {},
    'total' => {
            'cmd_get' => 838451,
            'bytes' => 2421,
            'get_hits' => 581511,
            'connection_structures' => 56,
            'bytes_read' => 46665716,
            'total_items' => 410956,
            'total_connections' => 3104,
```

```
          'cmd_set' => 588167,
          'bytes_written' => 35715151,
          'curr_items' => 31,
          'get_misses' => 256940
        }
      };
```

The statistics are divided up into a number of distinct sections, and then can be requested by adding the type to the `stats` command. Each statistics output is covered in more detail in the following sections.

- General statistics, see Section 15.3.4.1, "`memcached` General Statistics".

- Slab statistics (`slabs`), see Section 15.3.4.2, "`memcached` Slabs Statistics".

- Item statistics (`items`), see Section 15.3.4.3, "`memcached` Item Statistics".

- Size statistics (`sizes`), see Section 15.3.4.4, "`memcached` Size Statistics".

- Detailed status (`detail`), see Section 15.3.4.5, "`memcached` Detail Statistics".

15.3.4.1 `memcached` General Statistics

The output of the general statistics provides an overview of the performance and use of the `memcached` instance. The statistics returned by the command and their meaning is shown in the following table.

The following terms are used to define the value type for each statistics value:

- `32u`: 32-bit unsigned integer

- `64u`: 64-bit unsigned integer

- `32u:32u`: Two 32-bit unsigned integers separated by a colon

- `String`: Character string

Statistic	Data type	Description	Version
`pid`	32u	Process ID of the `memcached` instance.	
`uptime`	32u	Uptime (in seconds) for this `memcached` instance.	
`time`	32u	Current time (as epoch).	
`version`	string	Version string of this instance.	
`pointer_size`	string	Size of pointers for this host specified in bits (32 or 64).	
`rusage_user`	32u:32u	Total user time for this instance (seconds:microseconds).	
`rusage_system`	32u:32u	Total system time for this instance (seconds:microseconds).	
`curr_items`	32u	Current number of items stored by this instance.	
`total_items`	32u	Total number of items stored during the life of this instance.	
`bytes`	64u	Current number of bytes used by this server to store items.	
`curr_connections`	32u	Current number of open connections.	
`total_connections`	32u	Total number of connections opened since the server started running.	
`connection_structures`	32u	Number of connection structures allocated by the server.	

Statistic	Data type	Description	Version
`cmd_get`	64u	Total number of retrieval requests (`get` operations).	
`cmd_set`	64u	Total number of storage requests (`set` operations).	
`get_hits`	64u	Number of keys that have been requested and found present.	
`get_misses`	64u	Number of items that have been requested and not found.	
`delete_hits`	64u	Number of keys that have been deleted and found present.	1.3.x
`delete_misses`	64u	Number of items that have been delete and not found.	1.3.x
`incr_hits`	64u	Number of keys that have been incremented and found present.	1.3.x
`incr_misses`	64u	Number of items that have been incremented and not found.	1.3.x
`decr_hits`	64u	Number of keys that have been decremented and found present.	1.3.x
`decr_misses`	64u	Number of items that have been decremented and not found.	1.3.x
`cas_hits`	64u	Number of keys that have been compared and swapped and found present.	1.3.x
`cas_misses`	64u	Number of items that have been compared and swapped and not found.	1.3.x
`cas_badvalue`	64u	Number of keys that have been compared and swapped, but the comparison (original) value did not match the supplied value.	1.3.x
`evictions`	64u	Number of valid items removed from cache to free memory for new items.	
`bytes_read`	64u	Total number of bytes read by this server from network.	
`bytes_written`	64u	Total number of bytes sent by this server to network.	
`limit_maxbytes`	32u	Number of bytes this server is permitted to use for storage.	
`threads`	32u	Number of worker threads requested.	
`conn_yields`	64u	Number of yields for connections (related to the `-R` option).	1.4.0

The most useful statistics from those given here are the number of cache hits, misses, and evictions.

A large number of `get_misses` may just be an indication that the cache is still being populated with information. The number should, over time, decrease in comparison to the number of cache `get_hits`. If, however, you have a large number of cache misses compared to cache hits after an extended period of execution, it may be an indication that the size of the cache is too small and you either need to increase the total memory size, or increase the number of the `memcached` instances to improve the hit ratio.

A large number of `evictions` from the cache, particularly in comparison to the number of items stored is a sign that your cache is too small to hold the amount of information that you regularly want to keep cached. Instead of items being retained in the cache, items are being evicted to make way for new items keeping the turnover of items in the cache high, reducing the efficiency of the cache.

15.3.4.2 `memcached` Slabs Statistics

To get the `slabs` statistics, use the `stats slabs` command, or the API equivalent.

The slab statistics provide you with information about the slabs that have created and allocated for storing information within the cache. You get information both on each individual slab-class and total statistics for the whole slab.

```
STAT 1:chunk_size 104
STAT 1:chunks_per_page 10082
STAT 1:total_pages 1
STAT 1:total_chunks 10082
STAT 1:used_chunks 10081
STAT 1:free_chunks 1
STAT 1:free_chunks_end 10079
STAT 9:chunk_size 696
STAT 9:chunks_per_page 1506
STAT 9:total_pages 63
STAT 9:total_chunks 94878
STAT 9:used_chunks 94878
STAT 9:free_chunks 0
STAT 9:free_chunks_end 0
STAT active_slabs 2
STAT total_malloced 67083616
END
```

Individual stats for each slab class are prefixed with the slab ID. A unique ID is given to each allocated slab from the smallest size up to the largest. The prefix number indicates the slab class number in relation to the calculated chunk from the specified growth factor. Hence in the example, 1 is the first chunk size and 9 is the 9th chunk allocated size.

The parameters returned for each chunk size and a description of each parameter are provided in the following table.

Statistic	Description	Version
chunk_size	Space allocated to each chunk within this slab class.	
chunks_per_page	Number of chunks within a single page for this slab class.	
total_pages	Number of pages allocated to this slab class.	
total_chunks	Number of chunks allocated to the slab class.	
used_chunks	Number of chunks allocated to an item..	
free_chunks	Number of chunks not yet allocated to items.	
free_chunks_end	Number of free chunks at the end of the last allocated page.	
get_hits	Number of get hits to this chunk	1.3.x
cmd_set	Number of set commands on this chunk	1.3.x
delete_hits	Number of delete hits to this chunk	1.3.x
incr_hits	Number of increment hits to this chunk	1.3.x
decr_hits	Number of decrement hits to this chunk	1.3.x
cas_hits	Number of CAS hits to this chunk	1.3.x
cas_badval	Number of CAS hits on this chunk where the existing value did not match	1.3.x
mem_requested	The true amount of memory of memory requested within this chunk	1.4.1

The following additional statistics cover the information for the entire server, rather than on a chunk by chunk basis:

Statistic	Description	Version
`active_slabs`	Total number of slab classes allocated.	
`total_malloced`	Total amount of memory allocated to slab pages.	

The key values in the slab statistics are the `chunk_size`, and the corresponding `total_chunks` and `used_chunks` parameters. These given an indication of the size usage of the chunks within the system. Remember that one key/value pair is placed into a chunk of a suitable size.

From these stats, you can get an idea of your size and chunk allocation and distribution. If you store many items with a number of largely different sizes, consider adjusting the chunk size growth factor to increase in larger steps to prevent chunk and memory wastage. A good indication of a bad growth factor is a high number of different slab classes, but with relatively few chunks actually in use within each slab. Increasing the growth factor creates fewer slab classes and therefore makes better use of the allocated pages.

15.3.4.3 `memcached` Item Statistics

To get the `items` statistics, use the `stats items` command, or the API equivalent.

The `items` statistics give information about the individual items allocated within a given slab class.

```
STAT items:2:number 1
STAT items:2:age 452
STAT items:2:evicted 0
STAT items:2:evicted_nonzero 0
STAT items:2:evicted_time 2
STAT items:2:outofmemory 0
STAT items:2:tailrepairs 0
...
STAT items:27:number 1
STAT items:27:age 452
STAT items:27:evicted 0
STAT items:27:evicted_nonzero 0
STAT items:27:evicted_time 2
STAT items:27:outofmemory 0
STAT items:27:tailrepairs 0
```

The prefix number against each statistics relates to the corresponding chunk size, as returned by the `stats slabs` statistics. The result is a display of the number of items stored within each chunk within each slab size, and specific statistics about their age, eviction counts, and out of memory counts. A summary of the statistics is given in the following table.

Statistic	Description	
`number`	The number of items currently stored in this slab class.	
`age`	The age of the oldest item within the slab class, in seconds.	
`evicted`	The number of items evicted to make way for new entries.	
`evicted_time`	The time of the last evicted entry	
`evicted_nonzero`	The time of the last evicted non-zero entry	1.4.0
`outofmemory`	The number of items for this slab class that have triggered an out of memory error (only value when the `-M` command line option is in effect).	

Statistic	Description	
`tailrepairs`	Number of times the entries for a particular ID need repairing	

Item level statistics can be used to determine how many items are stored within a given slab and their freshness and recycle rate. You can use this to help identify whether there are certain slab classes that are triggering a much larger number of evictions that others.

15.3.4.4 `memcached` Size Statistics

To get size statistics, use the `stats sizes` command, or the API equivalent.

The size statistics provide information about the sizes and number of items of each size within the cache. The information is returned as two columns, the first column is the size of the item (rounded up to the nearest 32 byte boundary), and the second column is the count of the number of items of that size within the cache:

```
96 35
128 38
160 807
192 804
224 410
256 222
288 83
320 39
352 53
384 33
416 64
448 51
480 30
512 54
544 39
576 10065
```

Caution

Running this statistic locks up your cache as each item is read from the cache and its size calculated. On a large cache, this may take some time and prevent any set or get operations until the process completes.

The item size statistics are useful only to determine the sizes of the objects you are storing. Since the actual memory allocation is relevant only in terms of the chunk size and page size, the information is only useful during a careful debugging or diagnostic session.

15.3.4.5 `memcached` Detail Statistics

For `memcached` 1.3.x and higher, you can enable and obtain detailed statistics about the get, set, and del operations on theindividual keys stored in the cache, and determine whether the attempts hit (found) a particular key. These operations are only recorded while the detailed stats analysis is turned on.

To enable detailed statistics, you must send the `stats detail on` command to the `memcached` server:

```
$ telnet localhost 11211
Trying 127.0.0.1...
Connected to tiger.
Escape character is '^]'.
stats detail on
OK
```

Individual statistics are recorded for every `get`, `set` and `del` operation on a key, including keys that are not currently stored in the server. For example, if an attempt is made to obtain the value of key `abckey` and it does not exist, the `get` operating on the specified key are recorded while detailed statistics are in effect, even if the key is not currently stored. The `hits`, that is, the number of `get` or `del` operations for a key that exists in the server are also counted.

To turn detailed statistics off, send the `stats detail off` command to the `memcached` server:

```
$ telnet localhost 11211
Trying 127.0.0.1...
Connected to tiger.
Escape character is '^]'.
stats detail on
OK
```

To obtain the detailed statistics recorded during the process, send the `stats detail dump` command to the `memcached` server:

```
stats detail dump
PREFIX hykkey get 0 hit 0 set 1 del 0
PREFIX xyzkey get 0 hit 0 set 1 del 0
PREFIX yukkey get 1 hit 0 set 0 del 0
PREFIX abckey get 3 hit 3 set 1 del 0
END
```

You can use the detailed statistics information to determine whether your `memcached` clients are using a large number of keys that do not exist in the server by comparing the `hit` and `get` or `del` counts. Because the information is recorded by key, you can also determine whether the failures or operations are clustered around specific keys.

15.3.4.6 Using `memcached-tool`

The `memcached-tool`, located within the `scripts` directory within the `memcached` source directory. The tool provides convenient access to some reports and statistics from any `memcached` instance.

The basic format of the command is:

```
shell> ./memcached-tool hostname:port [command]
```

The default output produces a list of the slab allocations and usage. For example:

```
shell> memcached-tool localhost:11211 display
  #  Item_Size  Max_age   Pages   Count   Full?  Evicted Evict_Time OOM
  1       80B      93s        1      20      no        0          0   0
  2      104B      93s        1      16      no        0          0   0
  3      136B     1335s       1      28      no        0          0   0
  4      176B     1335s       1      24      no        0          0   0
  5      224B     1335s       1      32      no        0          0   0
  6      280B     1335s       1      34      no        0          0   0
  7      352B     1335s       1      36      no        0          0   0
  8      440B     1335s       1      46      no        0          0   0
  9      552B     1335s       1      58      no        0          0   0
 10      696B     1335s       1      66      no        0          0   0
 11      872B     1335s       1      89      no        0          0   0
 12      1.1K     1335s       1     112      no        0          0   0
 13      1.3K     1335s       1     145      no        0          0   0
 14      1.7K     1335s       1     123      no        0          0   0
 15      2.1K     1335s       1     198      no        0          0   0
 16      2.6K     1335s       1     199      no        0          0   0
```

```
17     3.3K      1335s      1      229       no        0          0      0
18     4.1K      1335s      1      248       yes       36         2      0
19     5.2K      1335s      2      328       no        0          0      0
20     6.4K      1335s      2      316       yes       387        1      0
21     8.1K      1335s      3      381       yes       492        1      0
22    10.1K      1335s      3      303       yes       598        2      0
23    12.6K      1335s      5      405       yes       605        1      0
24    15.8K      1335s      6      384       yes       766        2      0
25    19.7K      1335s      7      357       yes       908      170      0
26    24.6K      1336s      7      287       yes      1012        1      0
27    30.8K      1336s      7      231       yes      1193      169      0
28    38.5K      1336s      4      104       yes      1323      169      0
29    48.1K      1336s      1       21       yes      1287        1      0
30    60.2K      1336s      1       17       yes      1093      169      0
31    75.2K      1337s      1       13       yes       713      168      0
32    94.0K      1337s      1       10       yes       278      168      0
33   117.5K      1336s      1        3       no        0          0      0
```

This output is the same if you specify the command as display:

```
shell> memcached-tool localhost:11211 display
  #   Item_Size   Max_age   Pages    Count    Full?   Evicted  Evict_Time  OOM
  1       80B        93s      1        20       no       0          0      0
  2      104B        93s      1        16       no       0          0      0
...
```

The output shows a summarized version of the output from the slabs statistics. The columns provided in the output are shown below:

- #: The slab number

- Item_Size: The size of the slab

- Max_age: The age of the oldest item in the slab

- Pages: The number of pages allocated to the slab

- Count: The number of items in this slab

- Full?: Whether the slab is fully populated

- Evicted: The number of objects evicted from this slab

- Evict_Time: The time (in seconds) since the last eviction

- OOM: The number of items that have triggered an out of memory error

You can also obtain a dump of the general statistics for the server using the stats command:

```
shell> memcached-tool localhost:11211 stats
#localhost:11211    Field       Value
        accepting_conns         1
                bytes         162
           bytes_read         485
        bytes_written        6820
           cas_badval           0
             cas_hits           0
           cas_misses           0
            cmd_flush           0
              cmd_get           4
              cmd_set           2
```

```
           conn_yields              0
 connection_structures             11
      curr_connections             10
            curr_items              2
             decr_hits              0
           decr_misses              1
           delete_hits              0
         delete_misses              0
             evictions              0
              get_hits              4
            get_misses              0
             incr_hits              0
           incr_misses              2
        limit_maxbytes       67108864
    listen_disabled_num              0
                   pid          12981
          pointer_size             32
         rusage_system       0.013911
           rusage_user       0.011876
               threads              4
                  time     1255518565
     total_connections             20
           total_items              2
                uptime            880
               version          1.4.2
```

15.3.5 memcached FAQ

15.3.5.1 Can memcached be run on a Windows environment?

No. Currently memcached is available only on the Unix/Linux platform. There is an unofficial port available, see http://www.codeplex.com/memcachedproviders.

15.3.5.2 What is the maximum size of an object you can store in memcached? Is that configurable?

The default maximum object size is 1MB. In memcached 1.4.2 and later, you can change the maximum size of an object using the -I command line option.

For versions before this, to increase this size, you have to re-compile `memcached`. You can modify the value of the `POWER_BLOCK` within the `slabs.c` file within the source.

In `memcached` 1.4.2 and higher, you can configure the maximum supported object size by using the `-I` command-line option. For example, to increase the maximum object size to 5MB:

```
$ memcached -I 5m
```

If an object is larger than the maximum object size, you must manually split it. `memcached` is very simple: you give it a key and some data, it tries to cache it in RAM. If you try to store more than the default maximum size, the value is just truncated for speed reasons.

15.3.5.3. Is it true `memcached` will be much more effective with db-read-intensive applications than with db-write-intensive applications?

Yes. `memcached` plays no role in database writes, it is a method of caching data already read from the database in RAM.

15.3.5.4. Is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (for example, locking up)?

If you don't use persistent connections when communicating with `memcached`, there will be a small increase in the latency of opening the connection each time. The effect is comparable to use nonpersistent connections with MySQL.

In general, the chance of locking or other issues with persistent connections is minimal, because there is very little locking within `memcached`. If there is a problem, eventually your request will time out and return no result, so your application will need to load from MySQL again.

15.3.5.5. How is an event such as a crash of one of the `memcached` servers handled by the `memcached` client?

There is no automatic handling of this. If your client fails to get a response from a server, code a fallback mechanism to load the data from the MySQL database.

The client APIs all provide the ability to add and remove `memcached` instances on the fly. If within your application you notice that `memcached` server is no longer responding, you can remove the server from the list of servers, and keys will automatically be redistributed to another `memcached` server in the list. If retaining the cache content on all your servers is important, make sure you use an API that supports a consistent hashing algorithm. For more information, see Section 15.3.2.5, "memcached Hashing/Distribution Types".

15.3.5.6. What is a recommended hardware configuration for a memcached server?

`memcached` has a very low processing overhead. All that is required is spare physical RAM capacity. A `memcached` server does not require a dedicated machine. If you have web, application, or database servers that have spare RAM capacity, then use them with `memcached`.

To build and deploy a dedicated `memcached` server, use a relatively low-power CPU, lots of RAM, and one or more Gigabit Ethernet interfaces.

15.3.5.7. Is memcached more effective for video and audio as opposed to textual read/writes?

`memcached` works equally well for all kinds of data. To `memcached`, any value you store is just a stream of data. Remember, though, that the maximum size of an object you can store in `memcached` is 1MB, but can be configured to be larger by using the `-I` option in `memcached` 1.4.2

and later, or by modifying the source in versions before 1.4.2. If you plan on using `memcached` with audio and video content, you will probably want to increase the maximum object size. Also remember that `memcached` is a solution for caching information for reading. It shouldn't be used for writes, except when updating the information in the cache.

15.3.5.8. Can `memcached` work with ASPX?

There are ports and interfaces for many languages and environments. ASPX relies on an underlying language such as C# or VisualBasic, and if you are using ASP.NET then there is a C# `memcached` library. For more information, see https://sourceforge.net/projects/memcacheddotnet/.

15.3.5.9. How expensive is it to establish a memcache connection? Should those connections be pooled?

Opening the connection is relatively inexpensive, because there is no security, authentication or other handshake taking place before you can start sending requests and getting results. Most APIs support a persistent connection to a `memcached` instance to reduce the latency. Connection pooling would depend on the API you are using, but if you are communicating directly over TCP/IP, then connection pooling would provide some small performance benefit.

15.3.5.10. How is the data handled when the `memcached` server is down?

The behavior is entirely application dependent. Most applications fall back to loading the data from the database (just as if they were updating the `memcached` information). If you are using multiple `memcached` servers, you might also remove a downed server from the list to prevent it from affecting performance. Otherwise, the client will still attempt to communicate with the `memcached` server that corresponds to the key you are trying to load.

15.3.5.11. How are auto-increment columns in the MySQL database coordinated across multiple instances of memcached?

They aren't. There is no relationship between MySQL and `memcached` unless your application (or, if you are using the MySQL UDFs for `memcached`, your database definition) creates one.

If you are storing information based on an auto-increment key into multiple instances of `memcached`, the information is only stored on one of the `memcached` instances anyway. The client uses the key value to determine which `memcached` instance to store the information. It doesn't store the same information across all the instances, as that would be a waste of cache memory.

15.3.5.12. Is compression available?

Yes. Most of the client APIs support some sort of compression, and some even allow you to specify the threshold at which a value is deemed appropriate for compression during storage.

15.3.5.13. Can we implement different types of `memcached` as different nodes in the same server, so can there be deterministic and non-deterministic in the same server?

Yes. You can run multiple instances of `memcached` on a single server, and in your client configuration you choose the list of servers you want to use.

15.3.5.14. What are best practices for testing an implementation, to ensure that it improves performance, and to measure the impact of `memcached` configuration changes? And would you recommend keeping the configuration very simple to start?

The best way to test the performance is to start up a `memcached` instance. First, modify your application so that it stores the data just before the data is about to be used or displayed into `memcached`. Since the APIs handle the serialization of the data, it should just be a one-line modification to your code. Then, modify the start of the process that would normally load that

information from MySQL with the code that requests the data from `memcached`. If the data cannot be loaded from `memcached`, default to the MySQL process.

All of the changes required will probably amount to just a few lines of code. To get the best benefit, make sure you cache entire objects (for example, all the components of a web page, blog post, discussion thread, and so on), rather than using `memcached` as a simple cache of individual rows of MySQL tables.

Keeping the configuration simple at the start, or even over the long term, is easy with `memcached`. Once you have the basic structure up and running, often the only ongoing change is to add more servers into the list of servers used by your applications. You don't need to manage the `memcached` servers, and there is no complex configuration; just add more servers to the list and let the client API and the `memcached` servers make the decisions.

Chapter 16 Replication

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Replication enables data from one MySQL database server (the master) to be replicated to one or more MySQL database servers (the slaves). Replication is asynchronous - slaves need not be connected permanently to receive updates from the master. This means that updates can occur over long-distance connections and even over temporary or intermittent connections such as a dial-up service. Depending on the configuration, you can replicate all databases, selected databases, or even selected tables within a database.

For answers to some questions often asked by those who are new to MySQL Replication, see Section A.13, "MySQL 5.1 FAQ: Replication".

The target uses for replication in MySQL include:

- Scale-out solutions - spreading the load among multiple slaves to improve performance. In this environment, all writes and updates must take place on the master server. Reads, however, may take place on one or more slaves. This model can improve the performance of writes (since the master is dedicated to updates), while dramatically increasing read speed across an increasing number of slaves.

- Data security - because data is replicated to the slave, and the slave can pause the replication process, it is possible to run backup services on the slave without corrupting the corresponding master data.

- Analytics - live data can be created on the master, while the analysis of the information can take place on the slave without affecting the performance of the master.

- Long-distance data distribution - if a branch office would like to work with a copy of your main data, you can use replication to create a local copy of the data for their use without requiring permanent access to the master.

Replication in MySQL features support for one-way, asynchronous replication, in which one server acts as the master, while one or more other servers act as slaves. This is in contrast to the *synchronous* replication which is a characteristic of MySQL Cluster (see Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*).

There are a number of solutions available for setting up replication between two servers, but the best method to use depends on the presence of data and the engine types you are using. For more information on the available options, see Section 16.1.1, "How to Set Up Replication".

There are two core types of replication format, Statement Based Replication (SBR), which replicates entire SQL statements, and Row Based Replication (RBR), which replicates only the changed rows. You may also use a third variety, Mixed Based Replication (MBR). For more information on the different replication formats, see Section 16.1.2, "Replication Formats". From MySQL 5.1.12 to MySQL 5.1.28, mixed format is the default. Beginning with MySQL 5.1.29, statement-based format is the default.

Replication is controlled through a number of different options and variables. These control the core operation of the replication, timeouts, and the databases and filters that can be applied on databases and tables. For more information on the available options, see Section 16.1.3, "Replication and Binary Logging Options and Variables".

You can use replication to solve a number of different problems, including problems with performance, supporting the backup of different databases, and as part of a larger solution to alleviate system failures. For information on how to address these issues, see Section 16.3, "Replication Solutions".

For notes and tips on how different data types and statements are treated during replication, including details of replication features, version compatibility, upgrades, and problems and their resolution, including an FAQ, see Section 16.4, "Replication Notes and Tips".

For detailed information on the implementation of replication, how replication works, the process and contents of the binary log, background threads and the rules used to decide how statements are recorded and replication, see Section 16.2, "Replication Implementation".

16.1 Replication Configuration

Replication between servers in MySQL is based on the binary logging mechanism. The MySQL instance operating as the master (the source of the database changes) writes updates and changes as "events" to the binary log. The information in the binary log is stored in different logging formats according to the database changes being recorded. Slaves are configured to read the binary log from the master and to execute the events in the binary log on the slave's local database.

The master is "dumb" in this scenario. Once binary logging has been enabled, all statements are recorded in the binary log. Each slave receives a copy of the entire contents of the binary log. It is the responsibility of the slave to decide which statements in the binary log should be executed; you cannot configure the master to log only certain events. If you do not specify otherwise, all events in the master binary log are executed on the slave. If required, you can configure the slave to process only events that apply to particular databases or tables.

Each slave keeps a record of the binary log coordinates: The file name and position within the file that it has read and processed from the master. This means that multiple slaves can be connected to the master and executing different parts of the same binary log. Because the slaves control this process, individual slaves can be connected and disconnected from the server without affecting the master's operation. Also, because each slave remembers the position within the binary log, it is possible for slaves to be disconnected, reconnect and then "catch up" by continuing from the recorded position.

Both the master and each slave must be configured with a unique ID (using the `server-id` option). In addition, each slave must be configured with information about the master host name, log file name, and

position within that file. These details can be controlled from within a MySQL session using the `CHANGE MASTER TO` statement on the slave. The details are stored within the slave's `master.info` file.

This section describes the setup and configuration required for a replication environment, including step-by-step instructions for creating a new replication environment. The major components of this section are:

- For a guide to setting up two or more servers for replication, Section 16.1.1, "How to Set Up Replication", deals with the configuration of the systems and provides methods for copying data between the master and slaves.

- Events in the binary log are recorded using a number of formats. These are referred to as statement-based replication (SBR) or row-based replication (RBR). A third type, mixed-format replication (MIXED), uses SBR or RBR replication automatically to take advantage of the benefits of both SBR and RBR formats when appropriate. The different formats are discussed in Section 16.1.2, "Replication Formats".

- Detailed information on the different configuration options and variables that apply to replication is provided in Section 16.1.3, "Replication and Binary Logging Options and Variables".

- Once started, the replication process should require little administration or monitoring. However, for advice on common tasks that you may want to execute, see Section 16.1.4, "Common Replication Administration Tasks".

16.1.1 How to Set Up Replication

This section describes how to set up complete replication of a MySQL server. There are a number of different methods for setting up replication, and the exact method to use depends on how you are setting up replication, and whether you already have data within your master database.

There are some generic tasks that are common to all replication setups:

- On the master, you must enable binary logging and configure a unique server ID. This might require a server restart. See Section 16.1.1.1, "Setting the Replication Master Configuration".

- On each slave that you want to connect to the master, you must configure a unique server ID. This might require a server restart. See Section 16.1.1.2, "Setting the Replication Slave Configuration".

- You may want to create a separate user that will be used by your slaves to authenticate with the master to read the binary log for replication. The step is optional. See Section 16.1.1.3, "Creating a User for Replication".

- Before creating a data snapshot or starting the replication process, you should record the position of the binary log on the master. You will need this information when configuring the slave so that the slave knows where within the binary log to start executing events. See Section 16.1.1.4, "Obtaining the Replication Master Binary Log Coordinates".

- If you already have data on your master and you want to use it to synchronize your slave, you will need to create a data snapshot. You can create a snapshot using `mysqldump` (see Section 16.1.1.5, "Creating a Data Snapshot Using mysqldump") or by copying the data files directly (see Section 16.1.1.6, "Creating a Data Snapshot Using Raw Data Files").

- You will need to configure the slave with settings for connecting to the master, such as the host name, login credentials, and binary log file name and position. See Section 16.1.1.10, "Setting the Master Configuration on the Slave".

Once you have configured the basic options, you will need to follow the instructions for your replication setup. A number of alternatives are provided:

- If you are establishing a new MySQL master and one or more slaves, you need only set up the configuration, as you have no data to exchange. For guidance on setting up replication in this situation, see Section 16.1.1.7, "Setting Up Replication with New Master and Slaves".

- If you are already running a MySQL server, and therefore already have data that must be transferred to your slaves before replication starts, have not previously configured the binary log and are able to shut down your MySQL server for a short period during the process, see Section 16.1.1.8, "Setting Up Replication with Existing Data".

- If you are adding slaves to an existing replication environment, you can set up the slaves without affecting the master. See Section 16.1.1.9, "Introducing Additional Slaves to an Existing Replication Environment".

If you will be administering MySQL replication servers, we suggest that you read this entire chapter through and try all statements mentioned in Section 13.4.1, "SQL Statements for Controlling Master Servers", and Section 13.4.2, "SQL Statements for Controlling Slave Servers". You should also familiarize yourself with the replication startup options described in Section 16.1.3, "Replication and Binary Logging Options and Variables".

> **Note**
>
> Note that certain steps within the setup process require the `SUPER` privilege. If you do not have this privilege, it might not be possible to enable replication.

16.1.1.1 Setting the Replication Master Configuration

On a replication master, you must enable binary logging and establish a unique server ID. If this has not already been done, this part of master setup requires a server restart.

Binary logging *must* be enabled on the master because the binary log is the basis for sending data changes from the master to its slaves. If binary logging is not enabled, replication will not be possible.

Each server within a replication group must be configured with a unique server ID. This ID is used to identify individual servers within the group, and must be a positive integer between 1 and $(2^{32})-1$. How you organize and select the numbers is entirely up to you.

To configure the binary log and server ID options, you will need to shut down your MySQL server and edit the `my.cnf` or `my.ini` file. Add the following options to the configuration file within the `[mysqld]` section. If these options already exist, but are commented out, uncomment the options and alter them according to your needs. For example, to enable binary logging using a log file name prefix of `mysql-bin`, and configure a server ID of 1, use these lines:

```
[mysqld]
log-bin=mysql-bin
server-id=1
```

After making the changes, restart the server.

> **Note**
>
> If you omit `server-id` (or set it explicitly to its default value of 0), a master refuses connections from all slaves.

> **Note**
>
> For the greatest possible durability and consistency in a replication setup using `InnoDB` with transactions, you should use

> `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in the master `my.cnf` file.

> **Note**
>
> Ensure that the `skip-networking` option is not enabled on your replication master. If networking has been disabled, your slave will not able to communicate with the master and replication will fail.

16.1.1.2 Setting the Replication Slave Configuration

On a replication slave, you must establish a unique server ID. If this has not already been done, this part of slave setup requires a server restart.

If the slave server ID is not already set, or the current value conflicts with the value that you have chosen for the master server, you should shut down your slave server and edit the configuration to specify a unique server ID. For example:

```
[mysqld]
server-id=2
```

After making the changes, restart the server.

If you are setting up multiple slaves, each one must have a unique `server-id` value that differs from that of the master and from each of the other slaves. Think of `server-id` values as something similar to IP addresses: These IDs uniquely identify each server instance in the community of replication partners.

> **Note**
>
> If you omit `server-id` (or set it explicitly to its default value of 0), a slave refuses to connect to a master.

You do not have to enable binary logging on the slave for replication to be enabled. However, if you enable binary logging on the slave, you can use the binary log for data backups and crash recovery on the slave, and also use the slave as part of a more complex replication topology (for example, where the slave acts as a master to other slaves).

16.1.1.3 Creating a User for Replication

Each slave must connect to the master using a MySQL user name and password, so there must be a user account on the master that the slave can use to connect. Any account can be used for this operation, providing it has been granted the `REPLICATION SLAVE` privilege. You may wish to create a different account for each slave, or connect to the master using the same account for each slave.

You need not create an account specifically for replication. However, you should be aware that the user name and password will be stored in plain text within the `master.info` file (see Section 16.2.2.2, "Slave Status Logs"). Therefore, you may want to create a separate account that has privileges only for the replication process, to minimize the possibility of compromise to other accounts.

To create a new account, use `CREATE USER`. To grant this account the privileges required for replication, use the `GRANT` statement. If you create an account solely for the purposes of replication, that account needs only the `REPLICATION SLAVE` privilege. For example, to set up a new user, `repl`, that can connect for replication from any host within the `mydomain.com` domain, issue these statements on the master:

```
mysql> CREATE USER 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass';
mysql> GRANT REPLICATION SLAVE ON *.* TO 'repl'@'%.mydomain.com';
```

See Section 13.7.1, "Account Management Statements", for more information on statements for manipulation of user accounts.

16.1.1.4 Obtaining the Replication Master Binary Log Coordinates

To configure replication on the slave you must determine the master's current coordinates within its binary log. You will need this information so that when the slave starts the replication process, it is able to start processing events from the binary log at the correct point.

If you have existing data on your master that you want to synchronize on your slaves before starting the replication process, you must stop processing statements on the master, and then obtain its current binary log coordinates and dump its data, before permitting the master to continue executing statements. If you do not stop the execution of statements, the data dump and the master status information that you use will not match and you will end up with inconsistent or corrupted databases on the slaves.

To obtain the master binary log coordinates, follow these steps:

1. Start a session on the master by connecting to it with the command-line client, and flush all tables and block write statements by executing the FLUSH TABLES WITH READ LOCK statement:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   ```

   For InnoDB tables, note that FLUSH TABLES WITH READ LOCK also blocks COMMIT operations.

   > **Warning**
   >
   > Leave the client from which you issued the FLUSH TABLES statement running so that the read lock remains in effect. If you exit the client, the lock is released.

2. In a different session on the master, use the SHOW MASTER STATUS statement to determine the current binary log file name and position:

   ```
   mysql > SHOW MASTER STATUS;
   +------------------+----------+--------------+------------------+
   | File             | Position | Binlog_Do_DB | Binlog_Ignore_DB |
   +------------------+----------+--------------+------------------+
   | mysql-bin.000003 | 73       | test         | manual,mysql     |
   +------------------+----------+--------------+------------------+
   ```

   The File column shows the name of the log file and Position shows the position within the file. In this example, the binary log file is mysql-bin.000003 and the position is 73. Record these values. You need them later when you are setting up the slave. They represent the replication coordinates at which the slave should begin processing new updates from the master.

   If the master has been running previously without binary logging enabled, the log file name and position values displayed by SHOW MASTER STATUS or mysqldump --master-data will be empty. In that case, the values that you need to use later when specifying the slave's log file and position are the empty string ('') and 4.

You now have the information you need to enable the slave to start reading from the binary log in the correct place to start replication.

If you have existing data that needs be to synchronized with the slave before you start replication, leave the client running so that the lock remains in place and then proceed to Section 16.1.1.5, "Creating a Data

Snapshot Using mysqldump", or Section 16.1.1.6, "Creating a Data Snapshot Using Raw Data Files". The idea here is to prevent any further changes so that the data copied to the slaves is in synchrony with the master.

If you are setting up a brand new master and slave replication group, you can exit the first session to release the read lock.

16.1.1.5 Creating a Data Snapshot Using mysqldump

One way to create a snapshot of the data in an existing master database is to use the `mysqldump` tool to create a dump of all the databases you want to replicate. Once the data dump has been completed, you then import this data into the slave before starting the replication process.

The example shown here dumps all databases to a file named `dbdump.db`, and includes the `--master-data` option which automatically appends the `CHANGE MASTER TO` statement required on the slave to start the replication process:

```
shell> mysqldump --all-databases --master-data > dbdump.db
```

If you do not use `--master-data`, then it is necessary to lock all tables in a separate session manually (using `FLUSH TABLES WITH READ LOCK`) prior to running `mysqldump`, then exiting or running UNLOCK TABLES from the second session to release the locks. You must also obtain binary log position information matching the snapshot, using `SHOW MASTER STATUS`, and use this to issue the appropriate `CHANGE MASTER TO` statement when starting the slave.

When choosing databases to include in the dump, remember that you need to filter out databases on each slave that you do not want to include in the replication process.

To import the data, either copy the dump file to the slave, or access the file from the master when connecting remotely to the slave.

16.1.1.6 Creating a Data Snapshot Using Raw Data Files

If your database is large, copying the raw data files can be more efficient than using `mysqldump` and importing the file on each slave. This technique skips the overhead of updating indexes as the `INSERT` statements are replayed.

Using this method with tables in storage engines with complex caching or logging algorithms requires extra steps to produce a perfect "point in time" snapshot: the initial copy command might leave out cache information and logging updates, even if you have acquired a global read lock. How the storage engine responds to this depends on its crash recovery abilities.

This method also does not work reliably if the master and slave have different values for `ft_stopword_file`, `ft_min_word_len`, or `ft_max_word_len` and you are copying tables having full-text indexes.

If you use `InnoDB` tables, you can use the `mysqlbackup` command from the MySQL Enterprise Backup component to produce a consistent snapshot. This command records the log name and offset corresponding to the snapshot to be later used on the slave. MySQL Enterprise Backup is a commercial product that is included as part of a MySQL Enterprise subscription. See Section 23.2, "MySQL Enterprise Backup Overview" for detailed information.

Otherwise, use the cold backup technique to obtain a reliable binary snapshot of `InnoDB` tables: copy all data files after doing a slow shutdown of the MySQL Server.

To create a raw data snapshot of `MyISAM` tables, you can use standard copy tools such as `cp` or `copy`, a remote copy tool such as `scp` or `rsync`, an archiving tool such as `zip` or `tar`, or a file system snapshot tool such as `dump`, providing that your MySQL data files exist on a single file system. If you are replicating only certain databases, copy only those files that relate to those tables. (For `InnoDB`, all tables in all databases are stored in the system tablespace files, unless you have the `innodb_file_per_table` option enabled.)

You might want to specifically exclude the following files from your archive:

- Files relating to the `mysql` database.

- The `master.info` file.

- The master's binary log files.

- Any relay log files.

To get the most consistent results with a raw data snapshot, shut down the master server during the process, as follows:

1. Acquire a read lock and get the master's status. See Section 16.1.1.4, "Obtaining the Replication Master Binary Log Coordinates".

2. In a separate session, shut down the master server:

   ```
   shell> mysqladmin shutdown
   ```

3. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

   ```
   shell> tar cf /tmp/db.tar ./data
   shell> zip -r /tmp/db.zip ./data
   shell> rsync --recursive ./data /tmp/dbdata
   ```

4. Restart the master server.

If you are not using `InnoDB` tables, you can get a snapshot of the system from a master without shutting down the server as described in the following steps:

1. Acquire a read lock and get the master's status. See Section 16.1.1.4, "Obtaining the Replication Master Binary Log Coordinates".

2. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

   ```
   shell> tar cf /tmp/db.tar ./data
   shell> zip -r /tmp/db.zip ./data
   shell> rsync --recursive ./data /tmp/dbdata
   ```

3. In the client where you acquired the read lock, release the lock:

   ```
   mysql> UNLOCK TABLES;
   ```

Once you have created the archive or copy of the database, copy the files to each slave before starting the slave replication process.

16.1.1.7 Setting Up Replication with New Master and Slaves

The easiest and most straightforward method for setting up replication is to use new master and slave servers.

You can also use this method if you are setting up new servers but have an existing dump of the databases from a different server that you want to load into your replication configuration. By loading the data into a new master, the data will be automatically replicated to the slaves.

To set up replication between a new master and slave:

1. Configure the MySQL master with the necessary configuration properties. See Section 16.1.1.1, "Setting the Replication Master Configuration".

2. Start up the MySQL master.

3. Set up a user. See Section 16.1.1.3, "Creating a User for Replication".

4. Obtain the master status information. See Section 16.1.1.4, "Obtaining the Replication Master Binary Log Coordinates".

5. On the master, release the read lock:

   ```
   mysql> UNLOCK TABLES;
   ```

6. On the slave, edit the MySQL configuration. See Section 16.1.1.2, "Setting the Replication Slave Configuration".

7. Start up the MySQL slave.

8. Execute a `CHANGE MASTER TO` statement to set the master replication server configuration. See Section 16.1.1.10, "Setting the Master Configuration on the Slave".

Perform the slave setup steps on each slave.

Because there is no data to load or exchange on a new server configuration you do not need to copy or import any information.

If you are setting up a new replication environment using the data from a different existing database server, you will now need to run the dump file generated from that server on the new master. The database updates will automatically be propagated to the slaves:

```
shell> mysql -h master < fulldb.dump
```

16.1.1.8 Setting Up Replication with Existing Data

When setting up replication with existing data, you will need to decide how best to get the data from the master to the slave before starting the replication service.

The basic process for setting up replication with existing data is as follows:

1. With the MySQL master running, create a user to be used by the slave when connecting to the master during replication. See Section 16.1.1.3, "Creating a User for Replication".

2. If you have not already configured the `server-id` and enabled binary logging on the master server, you will need to shut it down to configure these options. See Section 16.1.1.1, "Setting the Replication Master Configuration".

If you have to shut down your master server, this is a good opportunity to take a snapshot of its databases. You should obtain the master status (see Section 16.1.1.4, "Obtaining the Replication Master Binary Log Coordinates") before taking down the master, updating the configuration and taking a snapshot. For information on how to create a snapshot using raw data files, see Section 16.1.1.6, "Creating a Data Snapshot Using Raw Data Files".

3. If your master server is already correctly configured, obtain its status (see Section 16.1.1.4, "Obtaining the Replication Master Binary Log Coordinates") and then use `mysqldump` to take a snapshot (see Section 16.1.1.5, "Creating a Data Snapshot Using mysqldump") or take a raw snapshot of the live server using the guide in Section 16.1.1.6, "Creating a Data Snapshot Using Raw Data Files".

4. Update the configuration of the slave. See Section 16.1.1.2, "Setting the Replication Slave Configuration".

5. The next step depends on how you created the snapshot of data on the master.

   If you used `mysqldump`:

   a. Start the slave, using the `--skip-slave-start` option so that replication does not start.

   b. Import the dump file:

   ```
   shell> mysql < fulldb.dump
   ```

   If you created a snapshot using the raw data files:

   a. Extract the data files into your slave data directory. For example:

   ```
   shell> tar xvf dbdump.tar
   ```

   You may need to set permissions and ownership on the files so that the slave server can access and modify them.

   b. Start the slave, using the `--skip-slave-start` option so that replication does not start.

6. Configure the slave with the replication coordinates from the master. This tells the slave the binary log file and position within the file where replication needs to start. Also, configure the slave with the login credentials and host name of the master. For more information on the `CHANGE MASTER TO` statement required, see Section 16.1.1.10, "Setting the Master Configuration on the Slave".

7. Start the slave threads:

   ```
   mysql> START SLAVE;
   ```

After you have performed this procedure, the slave should connect to the master and catch up on any updates that have occurred since the snapshot was taken.

If you have forgotten to set the `server-id` option for the master, slaves cannot connect to it.

If you have forgotten to set the `server-id` option for the slave, you get the following error in the slave's error log:

```
Warning: You should set server-id to a non-0 value if master_host
is set; we will force server id to 2, but this MySQL server will
not act as a slave.
```

You also find error messages in the slave's error log if it is not able to replicate for any other reason.

Once a slave is replicating, you can find in its data directory one file named `master.info` and another named `relay-log.info`. The slave uses these two files to keep track of how much of the master's binary log it has processed. Do *not* remove or edit these files unless you know exactly what you are doing and fully understand the implications. Even in that case, it is preferred that you use the `CHANGE MASTER TO` statement to change replication parameters. The slave will use the values specified in the statement to update the status files automatically.

> **Note**
>
> The content of `master.info` overrides some of the server options specified on the command line or in `my.cnf`. See Section 16.1.3, "Replication and Binary Logging Options and Variables", for more details.

A single snapshot of the master suffices for multiple slaves. To set up additional slaves, use the same master snapshot and follow the slave portion of the procedure just described.

16.1.1.9 Introducing Additional Slaves to an Existing Replication Environment

To add another slave to an existing replication configuration, you can do so without stopping the master. Instead, set up the new slave by making a copy of an existing slave, except that you configure the new slave with a different `server-id` value.

To duplicate an existing slave:

1. Shut down the existing slave:

   ```
   shell> mysqladmin shutdown
   ```

2. Copy the data directory from the existing slave to the new slave. You can do this by creating an archive using `tar` or `WinZip`, or by performing a direct copy using a tool such as `cp` or `rsync`. Ensure that you also copy the log files and relay log files.

   A common problem that is encountered when adding new replication slaves is that the new slave fails with a series of warning and error messages like these:

   ```
   071118 16:44:10 [Warning] Neither --relay-log nor --relay-log-index were used; so
   replication may break when this MySQL server acts as a slave and has his hostname
   changed!! Please use '--relay-log=new_slave_hostname-relay-bin' to avoid this problem.
   071118 16:44:10 [ERROR] Failed to open the relay log './old_slave_hostname-relay-bin.003525'
   (relay_log_pos 22940879)
   071118 16:44:10 [ERROR] Could not find target log during relay log initialization
   071118 16:44:10 [ERROR] Failed to initialize the master info structure
   ```

   This is due to the fact that, if the `--relay-log` option is not specified, the relay log files contain the host name as part of their file names. (This is also true of the relay log index file if the `--relay-log-index` option is not used. See Section 16.1.3, "Replication and Binary Logging Options and Variables", for more information about these options.)

   To avoid this problem, use the same value for `--relay-log` on the new slave that was used on the existing slave. (If this option was not set explicitly on the existing slave, use `existing_slave_hostname-relay-bin`.) If this is not feasible, copy the existing slave's relay log index file to the new slave and set the `--relay-log-index` option on the new slave to match what was used on the existing slave. (If this option was not set explicitly on the existing slave, use `existing_slave_hostname-relay-bin.index`.) Alternatively—if you have already tried to start

the new slave (after following the remaining steps in this section) and have encountered errors like those described previously—then perform the following steps:

a. If you have not already done so, issue a `STOP SLAVE` on the new slave.

   If you have already started the existing slave again, issue a `STOP SLAVE` on the existing slave as well.

b. Copy the contents of the existing slave's relay log index file into the new slave's relay log index file, making sure to overwrite any content already in the file.

c. Proceed with the remaining steps in this section.

3. Copy the `master.info` and `relay-log.info` files from the existing slave to the new slave if they were not located in the data directory. These files hold the current log coordinates for the master's binary log and the slave's relay log.

4. Start the existing slave.

5. On the new slave, edit the configuration and give the new slave a unique `server-id` not used by the master or any of the existing slaves.

6. Start the new slave. The slave will use the information in its `master.info` file to start the replication process.

16.1.1.10 Setting the Master Configuration on the Slave

To set up the slave to communicate with the master for replication, you must tell the slave the necessary connection information. To do this, execute the following statement on the slave, replacing the option values with the actual values relevant to your system:

```
mysql> CHANGE MASTER TO
    ->     MASTER_HOST='master_host_name',
    ->     MASTER_USER='replication_user_name',
    ->     MASTER_PASSWORD='replication_password',
    ->     MASTER_LOG_FILE='recorded_log_file_name',
    ->     MASTER_LOG_POS=recorded_log_position;
```

> **Note**
>
> Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

The `CHANGE MASTER TO` statement has other options as well. For example, it is possible to set up secure replication using SSL. For a full list of options, and information about the maximum permissible length for the string-valued options, see Section 13.4.2.1, "CHANGE MASTER TO Syntax".

16.1.2 Replication Formats

Replication works because events written to the binary log are read from the master and then processed on the slave. The events are recorded within the binary log in different formats according to the type of event. The different replication formats used correspond to the binary logging format used when the events were recorded in the master's binary log. The correlation between binary logging formats and the terms used during replication are:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called *statement-based replication* (often abbreviated as *SBR*), which corresponds to

the standard statement-based binary logging format. In MySQL 5.1.4 and earlier, binary logging and replication used this format exclusively.

- Row-based binary logging logs changes in individual table rows. When used with MySQL replication, this is known as *row-based replication* (often abbreviated as *RBR*). In row-based replication, the master writes *events* to the binary log that indicate how individual table rows are changed.

- As of MySQL 5.1.8, the server can change the binary logging format in real time according to the type of event using *mixed-format logging*.

  When the mixed format is in effect, statement-based logging is used by default, but automatically switches to row-based logging in particular cases as described later. Replication using the mixed format is often referred to as *mixed-based replication* or *mixed-format replication*. For more information, see Section 5.4.4.3, "Mixed Binary Logging Format".

From MySQL 5.1.12 to MySQL 5.1.28, mixed format is the default. Beginning with MySQL 5.1.29, statement-based format is the default.

MySQL Cluster.   The default binary logging format in all MySQL Cluster NDB 6.x and 7.x releases is `ROW`. MySQL Cluster Replication always uses row-based replication, and the `NDBCLUSTER` storage engine is incompatible with statement-based replication. Using `NDBCLUSTER` sets row-based logging format automatically. See Section 17.6.2, "General Requirements for MySQL Cluster Replication", for more information.

Starting with MySQL 5.1.20, when using `MIXED` format, the binary logging format is determined in part by the storage engine being used and the statement being executed. For more information on mixed-format logging and the rules governing the support of different logging formats, see Section 5.4.4.3, "Mixed Binary Logging Format".

The logging format in a running MySQL server is controlled by setting the `binlog_format` server system variable. This variable can be set with session or global scope. The rules governing when and how the new setting takes effect are the same as for other MySQL server system variables—setting the variable for the current session lasts only until the end of that session, and the change is not visible to other sessions; setting the variable globally requires a restart of the server to take effect. For more information, see Section 13.7.4.1, "SET Syntax for Variable Assignment".

There are conditions under which you cannot change the binary logging format at runtime or doing so causes replication to fail. See Section 5.4.4.2, "Setting The Binary Log Format".

You must have the `SUPER` privilege to set the global `binlog_format` value. Starting with MySQL 5.1.29, you must have the `SUPER` privilege to set either the global or session `binlog_format` value. (Bug #39106)

The statement-based and row-based replication formats have different issues and limitations. For a comparison of their relative advantages and disadvantages, see Section 16.1.2.1, "Advantages and Disadvantages of Statement-Based and Row-Based Replication".

With statement-based replication, you may encounter issues with replicating stored routines or triggers. You can avoid these issues by using row-based replication instead. For more information, see Section 19.7, "Binary Logging of Stored Programs".

16.1.2.1 Advantages and Disadvantages of Statement-Based and Row-Based Replication

Each binary logging format has advantages and disadvantages. For most users, the mixed replication format should provide the best combination of data integrity and performance. If, however, you want to take advantage of the features specific to the statement-based or row-based replication format when

performing certain tasks, you can use the information in this section, which provides a summary of their relative advantages and disadvantages, to determine which is best for your needs.

- Advantages of statement-based replication

- Disadvantages of statement-based replication

- Advantages of row-based replication

- Disadvantages of row-based replication

Advantages of statement-based replication

- Proven technology that has existed in MySQL since 3.23.

- Less data written to log files. When updates or deletes affect many rows, this results in *much* less storage space required for log files. This also means that taking and restoring from backups can be accomplished more quickly.

- Log files contain all statements that made any changes, so they can be used to audit the database.

Disadvantages of statement-based replication

- **Statements that are unsafe for SBR.**
  Not all statements which modify data (such as `INSERT DELETE`, `UPDATE`, and `REPLACE` statements) can be replicated using statement-based replication. Any nondeterministic behavior is difficult to replicate when using statement-based replication. Examples of such DML (Data Modification Language) statements include the following:

  - A statement that depends on a UDF or stored program that is nondeterministic, since the value returned by such a UDF or stored program or depends on factors other than the parameters supplied to it. (Row-based replication, however, simply replicates the value returned by the UDF or stored program, so its effect on table rows and data is the same on both the master and slave.) See Section 16.4.1.12, "Replication of Invoked Features", for more information.

  - `DELETE` and `UPDATE` statements that use a `LIMIT` clause without an `ORDER BY` are nondeterministic. See Section 16.4.1.16, "Replication and LIMIT".

  - Statements using any of the following functions cannot be replicated properly using statement-based replication:

    - `LOAD_FILE()`

    - `UUID()`, `UUID_SHORT()`

    - `USER()`

    - `FOUND_ROWS()`

    - `SYSDATE()` (unless both the master and the slave are started with the `--sysdate-is-now` option)

    - `GET_LOCK()`

    - `IS_FREE_LOCK()`

    - `IS_USED_LOCK()`

    - `MASTER_POS_WAIT()`

- `RAND()`

- `RELEASE_LOCK()`

- `SLEEP()`

- `VERSION()`

However, all other functions are replicated correctly using statement-based replication, including `NOW()` and so forth.

For more information, see Section 16.4.1.15, "Replication and System Functions".

Statements that cannot be replicated correctly using statement-based replication are logged with a warning like the one shown here:

```
[Warning] Statement is not safe to log in statement format.
```

A similar warning is also issued to the client in such cases. The client can display it using `SHOW WARNINGS`.

- `INSERT ... SELECT` requires a greater number of row-level locks than with row-based replication.

- `UPDATE` statements that require a table scan (because no index is used in the `WHERE` clause) must lock a greater number of rows than with row-based replication.

- For `InnoDB`: An `INSERT` statement that uses `AUTO_INCREMENT` blocks other nonconflicting `INSERT` statements.

- For complex statements, the statement must be evaluated and executed on the slave before the rows are updated or inserted. With row-based replication, the slave only has to modify the affected rows, not execute the full statement.

- If there is an error in evaluation on the slave, particularly when executing complex statements, statement-based replication may slowly increase the margin of error across the affected rows over time. See Section 16.4.1.29, "Slave Errors During Replication".

- Stored functions execute with the same `NOW()` value as the calling statement. However, this is not true of stored procedures.

- Deterministic UDFs must be applied on the slaves.

- Table definitions must be (nearly) identical on master and slave. See Section 16.4.1.10, "Replication with Differing Table Definitions on Master and Slave", for more information.

Advantages of Row-Based Replication

- All changes can be replicated. This is the safest form of replication.

  For MySQL versions earlier than 5.1.14, DDL (Data Definition Language) statements such as `CREATE TABLE` are replicated using statement-based replication, while DML statements, as well as `GRANT` and `REVOKE` statements, are replicated using row-based replication.

  In MySQL 5.1.14 and later, the `mysql` database is not replicated. The `mysql` database is instead seen as a node-specific database. Row-based replication is not supported on tables in this database. Instead, statements that would normally update this information—such as `GRANT`, `REVOKE` and the manipulation

of triggers, stored routines (including stored procedures), and views—are all replicated to slaves using statement-based replication.

For statements such as `CREATE TABLE ... SELECT`, a `CREATE` statement is generated from the table definition and replicated using statement-based format, while the row insertions are replicated using row-based format.

- The technology is the same as in most other database management systems; knowledge about other systems transfers to MySQL.

- Fewer row locks are required on the master, which thus achieves higher concurrency, for the following types of statements:

  - `INSERT ... SELECT`

  - `INSERT` statements with `AUTO_INCREMENT`

  - `UPDATE` or `DELETE` statements with `WHERE` clauses that do not use keys or do not change most of the examined rows.

- Fewer row locks are required on the slave for any `INSERT`, `UPDATE`, or `DELETE` statement.

Disadvantages of Row-Based Replication

- RBR tends to generate more data that must be logged. To replicate a DML statement (such as an `UPDATE` or `DELETE` statement), statement-based replication writes only the statement to the binary log. By contrast, row-based replication writes each changed row to the binary log. If the statement changes many rows, row-based replication may write significantly more data to the binary log; this is true even for statements that are rolled back. This also means that taking and restoring from backup can require more time. In addition, the binary log is locked for a longer time to write the data, which may cause concurrency problems.

- Deterministic UDFs that generate large `BLOB` values take longer to replicate with row-based replication than with statement-based replication. This is because the `BLOB` column value is logged, rather than the statement generating the data.

- You cannot examine the logs to see what statements were executed, nor can you see on the slave what statements were received from the master and executed.

  However, beginning with MySQL 5.1.29, you can see what data was changed using `mysqlbinlog` with the options `--base64-output=DECODE-ROWS` and `--verbose`.

- For tables using the `MyISAM` storage engine, a stronger lock is required on the slave for `INSERT` statements when applying them as row-based events to the binary log than when applying them as statements. This means that concurrent inserts on `MyISAM` tables are not supported when using row-based replication.

- Formerly, when performing a bulk operation that includes nontransactional storage engines, changes were applied as the statement executed. With row-based logging, this meant that the binary log was written while the statement was running. On the master, this does not cause problems with concurrency, because tables are locked until the bulk operation terminates. On the slave server, tables were not locked while the slave applied changes, because the slave did not know that those changes were part of a bulk operation.

  In such cases, if you retrieved data from a table on the master (for example, using `SELECT * FROM table_name`), the server waited for the bulk operation to complete before executing the `SELECT` statement, because the table was read-locked. On the slave, the server did not wait (because there was

no lock). This meant that, until the bulk operation on the slave completed, different results were obtained for the same `SELECT` query on the master and on the slave.

This issue was resolved in MySQL 5.1.24. (Bug #29020)

16.1.2.2 Usage of Row-Based Logging and Replication

Major changes in the replication environment and in the behavior of applications can result from using row-based logging (RBL) or row-based replication (RBR) rather than statement-based logging or replication. This section describes a number of issues known to exist when using row-based logging or replication, and discusses some best practices for taking advantage of row-based logging and replication.

For additional information, see Section 16.1.2, "Replication Formats", and Section 16.1.2.1, "Advantages and Disadvantages of Statement-Based and Row-Based Replication".

For information about issues specific to MySQL Cluster Replication (which depends on row-based replication), see Section 17.6.3, "Known Issues in MySQL Cluster Replication".

- **RBL, RBR, and temporary tables.**   As noted in Section 16.4.1.23, "Replication and Temporary Tables", temporary tables are not replicated when using row-based format. When mixed format is in effect, "safe" statements involving temporary tables are logged using statement-based format. For more information, see Section 16.1.2.1, "Advantages and Disadvantages of Statement-Based and Row-Based Replication".

  Temporary tables are not replicated when using row-based format because there is no need. In addition, because temporary tables can be read only from the thread which created them, there is seldom if ever any benefit obtained from replicating them, even when using statement-based format.

- **RBL and the BLACKHOLE storage engine.**   Prior to MySQL 5.1.29, `DELETE` and `UPDATE` statements for `BLACKHOLE` tables did not work with RBL. (Bug #38360)

- **RBL and synchronization of nontransactional tables.**   When many rows are affected, the set of changes is split into several events; when the statement commits, all of these events are written to the binary log if the statement is an initial nontransactional statement (occurring in the transaction before any transactional statements). When executing on the slave, a table lock is taken on all tables involved, and then the rows are applied in batch mode. (This may or may not be effective, depending on the engine used for the slave's copy of the table.)

- **Latency and binary log size.**   Because RBL writes changes for each row to the binary log, its size can increase quite rapidly. In a replication environment, this can significantly increase the time required to make changes on the slave that match those on the master. You should be aware of the potential for this delay in your applications.

- **Reading the binary log.**   `mysqlbinlog` displays row-based events in the binary log using the `BINLOG` statement (see Section 13.7.6.1, "BINLOG Syntax"). This statement displays an event in printable form, but as a base 64-encoded string the meaning of which is not evident. As of MySQL 5.1.28, when invoked with the `--base64-output=DECODE-ROWS` and `--verbose` options, `mysqlbinlog` formats the contents of the binary log in a manner that is easily human readable. This is helpful when binary log events were written in row-based format if you want to read or recover from a replication or database failure using the contents of the binary log. For more information, see Section 4.6.7.2, "mysqlbinlog Row Event Display".

- **Binary log execution errors and slave_exec_mode.**   If `slave_exec_mode` is `IDEMPOTENT`, a failure to apply changes from RBL because the original row cannot be found does not trigger an error or cause replication to fail. This means that it is possible that updates are not applied on the slave, so that the master and slave are no longer synchronized. Latency issues and use of nontransactional tables with

RBR when `slave_exec_mode` is `IDEMPOTENT` can cause the master and slave to diverge even further. For more information about `slave_exec_mode`, see Section 5.1.4, "Server System Variables".

> **Note**
>
> `slave_exec_mode=IDEMPOTENT` is generally useful only for circular replication or multi-master replication with MySQL Cluster, for which `IDEMPOTENT` is the default value (see Section 17.6, "MySQL Cluster Replication").
>
> For other scenarios, setting `slave_exec_mode` to `STRICT` is normally sufficient; this is the default value for storage engines other than `NDB`.

- **Lack of binary log checksums.**   RBL uses no checksums. This means that network, disk, and other errors may not be identified when processing the binary log. To ensure that data is transmitted without network corruption, you may want to consider using SSL, which adds another layer of checksumming, for replication connections. The `CHANGE MASTER TO` statement has options to enable replication over SSL. See also Section 13.4.2.1, "CHANGE MASTER TO Syntax", for general information about setting up MySQL with SSL.

- **Filtering based on server ID not supported.**   A common practice is to filter out changes on some slaves by using a `WHERE` clause that includes the relation `@@server_id <> id_value` clause with `UPDATE` and `DELETE` statements, a simple example of such a clause being `WHERE @@server_id <> 1`. However, this does not work correctly with row-based logging. If you must use the `server_id` system variable for statement filtering, you must also use `--binlog_format=STATEMENT`.

- **Database-level replication options.**   The effects of the `--replicate-do-db`, `--replicate-ignore-db`, and `--replicate-rewrite-db` options differ considerably depending on whether row-based or statement-based logging is used. Because of this, it is recommended to avoid database-level options and instead use table-level options such as `--replicate-do-table` and `--replicate-ignore-table`. For more information about these options and the impact that your choice of replication format has on how they operate, see Section 16.1.3, "Replication and Binary Logging Options and Variables".

- **RBL, nontransactional tables, and stopped slaves.**   When using row-based logging, if the slave server is stopped while a slave thread is updating a nontransactional table, the slave database may reaches an inconsistent state. For this reason, it is recommended that you use a transactional storage engine such as `InnoDB` for all tables replicated using the row-based format.

  Use of `STOP SLAVE` (or `STOP SLAVE SQL_THREAD` in MySQL 5.1.55 and later) prior to shutting down the slave MySQL server helps prevent such issues from occurring, and is always recommended regardless of the logging format or storage engines employed.

16.1.2.3 Determination of Safe and Unsafe Statements in Binary Logging

When speaking of the "safeness" of a statement in MySQL Replication, we are referring to whether a statement and its effects can be replicated correctly using statement-based format. If this is true of the statement, we refer to the statement as *safe*; otherwise, we refer to it as *unsafe*.

In general, a statement is safe if it deterministic, and unsafe if it is not. However, certain nondeterministic functions are *not* considered unsafe (see Nondeterministic functions not considered unsafe, later in this section). In addition, statements using results from floating-point math functions—which are hardware-dependent—are always considered unsafe (see Section 16.4.1.13, "Replication and Floating-Point Values").

Handling of safe and unsafe statements.   A statement is treated differently depending on whether the statement is considered safe, and with respect to the binary logging format (that is, the current value of `binlog_format`).

- No distinction is made in the treatment of safe and unsafe statements when the binary logging mode is `ROW`.

- If the binary logging format is `MIXED`, statements flagged as unsafe are logged using the row-based format; statements regarded as safe are logged using the statement-based format.

- If the binary logging format is `STATEMENT`, statements flagged as being unsafe generate a warning to this effect. (Safe statements are logged normally.)

For more information, see Section 16.1.2, "Replication Formats".

Statements considered unsafe.
Statements having the following characteristics are considered unsafe:

- **Statements containing system functions that may return a different value on slave.**
  These functions include `FOUND_ROWS()`, `GET_LOCK()`, `IS_FREE_LOCK()`, `IS_USED_LOCK()`, `LOAD_FILE()`, `MASTER_POS_WAIT()`, `RELEASE_LOCK()`, `ROW_COUNT()`, `SESSION_USER()`, `SLEEP()`, `SYSDATE()`, `SYSTEM_USER()`, `USER()`, `UUID()`, and `UUID_SHORT()`.

  In MySQL 5.1.43 and later, `RAND()` is also treated as unsafe. (Bug #11757207, Bug #49222)

  Nondeterministic functions not considered unsafe.   Although these functions are not deterministic, they are treated as safe for purposes of logging and replication: `CONNECTION_ID()`, `CURDATE()`, `CURRENT_DATE()`, `CURRENT_TIME()`, `CURRENT_TIMESTAMP()`, `CURTIME()`, `LOCALTIME()`, `LOCALTIMESTAMP()`, `NOW()`, `UNIX_TIMESTAMP()`, `UTC_DATE()`, `UTC_TIME()`, `UTC_TIMESTAMP()`, and `LAST_INSERT_ID()`

  For more information, see Section 16.4.1.15, "Replication and System Functions".

- **References to system variables.**   Most system variables are not replicated correctly using the statement-based format. For exceptions, see Section 5.4.4.3, "Mixed Binary Logging Format".

  See Section 16.4.1.38, "Replication and Variables".

- **UDFs.**   Since we have no control over what a UDF does, we must assume that it is executing unsafe statements.

- **Updates a table having an AUTO_INCREMENT column.**   This is unsafe because the order in which the rows are updated may differ on the master and the slave.

  In addition, an `INSERT` into a table that has a composite primary key containing an `AUTO_INCREMENT` column that is not the first column of this composite key is unsafe.

  For more information, see Section 16.4.1.1, "Replication and AUTO_INCREMENT".

- **INSERT DELAYED statement.**   This statement is considered unsafe because the insertion of the rows may interleave with concurrently executing statements.

- **INSERT ... ON DUPLICATE KEY UPDATE statements on tables with multiple primary or unique keys.**   When executed against a table that contains more than one primary or unique key, this statement is considered unsafe, being sensitive to the order in which the storage engine checks the keys, which is not deterministic, and on which the choice of rows updated by the MySQL Server depends.

  Thus, such statements are considered unsafe.

- **Updates using LIMIT.**   The order in which rows are retrieved is not specified.

  See Section 16.4.1.16, "Replication and LIMIT".

- **Accesses or references log tables.**   The contents of the system log table may differ between master and slave.

- **Nontransactional operations after transactional operations.**   Within a transaction, allowing any nontransactional reads or writes to execute after any transactional reads or writes is considered unsafe.

  For more information, see Section 16.4.1.35, "Replication and Transactions".

- **Accesses or references self-logging tables.**   All reads and writes to self-logging tables are considered unsafe. Within a transaction, any statement following a read or write to self-logging tables is also considered unsafe.

- **LOAD DATA INFILE statements.**   Beginning with MySQL 5.1.50, `LOAD DATA INFILE` is considered unsafe, it causes a warning in statement-based mode, and a switch to row-based format when using mixed-format logging. See Section 16.4.1.17, "Replication and LOAD DATA INFILE".

For additional information, see Section 16.4.1, "Replication Features and Issues".

16.1.3 Replication and Binary Logging Options and Variables

The next few sections contain information about `mysqld` options and server variables that are used in replication and for controlling the binary log. Options and variables for use on replication masters and replication slaves are covered separately, as are options and variables relating to binary logging. A set of quick-reference tables providing basic information about these options and variables is also included (in the next section following this one).

Of particular importance is the `--server-id` option.

Command-Line Format	`--server-id=#`	
System Variable	**Name**	`server_id`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`

This option is common to both master and slave replication servers, and is used in replication to enable master and slave servers to identify themselves uniquely. For additional information, see Section 16.1.3.2, "Replication Master Options and Variables", and Section 16.1.3.3, "Replication Slave Options and Variables".

On the master and each slave, you *must* use the `--server-id` option to establish a unique replication ID in the range from 1 to $2^{32} - 1$. "Unique", means that each ID must be different from every other ID in use by any other replication master or slave. Example: `server-id=3`.

If you omit `--server-id`, the default ID is 0, in which case the master refuses connections from all slaves, and slaves refuse to connect to the master. In MySQL 5.1, whether the server ID is set to 0 explicitly or the default is allowed to be used, the server sets the `server_id` system variable to 1; this is a known issue that is fixed in MySQL 5.7.

For more information, see Section 16.1.1.2, "Setting the Replication Slave Configuration".

16.1.3.1 Replication and Binary Logging Option and Variable Reference

The following tables list basic information about the MySQL command-line options and system variables applicable to replication and the binary log.

Table 16.1 Summary of Replication options and variables in MySQL 5.1

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`abort-slave-event-count`		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
`Com_change_master`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of CHANGE MASTER TO statements		
`Com_show_master_status`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW MASTER STATUS statements		
`Com_show_new_master`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW NEW MASTER statements		
`Com_show_slave_hosts`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW SLAVE HOSTS statements		
`Com_show_slave_status`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW SLAVE STATUS statements		
`Com_slave_start`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of START SLAVE statements		
`Com_slave_stop`		
No	No	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Both	No
DESCRIPTION: Count of STOP SLAVE statements		
	disconnect-slave-event-count	
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
	have_row_based_replication	
No	Yes	No
No	Global	No
DESCRIPTION: Shows whether row-based replication is supported		
	init_slave	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Statements that are executed when a slave connects to a master		
	log-slave-updates	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Tells the slave to log the updates performed by its SQL thread to its own binary log		
	log_slave_updates	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Whether the slave should log the updates performed by its SQL thread to its own binary log. Read-only; set using the --log-slave-updates server option.		
	master-connect-retry	
Yes	No	No
Yes		No
DESCRIPTION: Number of seconds the slave thread will sleep before retrying to connect to the master in case the master goes down or the connection is lost		
	master-host	
Yes	No	No
Yes		No
DESCRIPTION: Master host name or IP address for replication		
	master-info-file	
Yes	No	No
Yes		No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: The location and name of the file that remembers the master and where the I/O replication thread is in the master's binary logs		
master-password		
Yes	No	No
Yes		No
DESCRIPTION: The password the slave thread will authenticate with when connecting to master		
master-port		
Yes	No	No
Yes		No
DESCRIPTION: The port the master is listening on		
master-retry-count		
Yes	No	No
Yes		No
DESCRIPTION: Number of tries the slave makes to connect to the master before giving up		
master-ssl		
Yes	No	No
Yes		No
DESCRIPTION: Enable the slave to connect to the master using SSL		
master-ssl-ca		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL CA file; applies only if master-ssl is enabled		
master-ssl-capath		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL CA path; applies only if master-ssl is enabled		
master-ssl-cert		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL certificate file name; applies only if master-ssl is enabled		
master-ssl-cipher		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL cipher; applies only if master-ssl is enabled		
master-ssl-key		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL key file name; applies only if master-ssl is enabled		
	master-user	
Yes	No	No
Yes		No
DESCRIPTION: The user name the slave thread will use for authentication when connecting to master. The user must have FILE privilege. If the master user is not set, user test is assumed. The value in master.info will take precedence if it can be read		
	relay-log	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location and base name to use for relay logs		
	relay-log-index	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location and name to use for the file that keeps a list of the last relay logs		
	relay-log-info-file	
Yes	No	No
Yes		No
DESCRIPTION: The location and name of the file that remembers where the SQL replication thread is in the relay logs		
	relay_log_index	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The name of the relay log index file		
	relay_log_info_file	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The name of the file in which the slave records information about the relay logs		
	relay_log_purge	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Determines whether relay logs are purged		
	relay_log_space_limit	
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	No
DESCRIPTION: Maximum space to use for all relay logs		
`replicate-do-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread to restrict replication to the specified database		
`replicate-do-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread to restrict replication to the specified table		
`replicate-ignore-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread not to replicate to the specified database		
`replicate-ignore-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread not to replicate to the specified table		
`replicate-rewrite-db`		
Yes	No	No
Yes		No
DESCRIPTION: Updates to a database with a different name than the original		
`replicate-same-server-id`		
Yes	No	No
Yes		No
DESCRIPTION: In replication, if set to 1, do not skip events having our server id		
`replicate-wild-do-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave thread to restrict replication to the tables that match the specified wildcard pattern		
`replicate-wild-ignore-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave thread not to replicate to the tables that match the given wildcard pattern		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
	report-host	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Host name or IP of the slave to be reported to the master during slave registration		
	report-password	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: An arbitrary password that the slave server should report to the master. Not the same as the password for the MySQL replication user account.		
	report-port	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Port for connecting to slave reported to the master during slave registration		
	report-user	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: An arbitrary user name that a slave server should report to the master. Not the same as the name used with the MySQL replication user account.		
	rpl_recovery_rank	
No	Yes	No
No	Global	Yes
DESCRIPTION: Not used; removed in later versions		
	Rpl_status	
No	No	Yes
No	Global	No
DESCRIPTION: The status of fail-safe replication (not implemented)		
	show-slave-auth-info	
Yes	No	No
Yes		No
DESCRIPTION: Show user name and password in SHOW SLAVE HOSTS on this master		
	skip-slave-start	
Yes	No	No
Yes		No
DESCRIPTION: If set, slave is not autostarted		
	slave-load-tmpdir	
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	No
DESCRIPTION: The location where the slave should put its temporary files when replicating a LOAD DATA INFILE statement		
	slave-max-allowed-packet	
Yes	No	No
Yes		No
DESCRIPTION: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.		
	slave_net_timeout	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Number of seconds to wait for more data from a master/slave connection before aborting the read		
	slave-skip-errors	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Tells the slave thread to continue replication when a query returns an error from the provided list		
	slave_compressed_protocol	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Use compression on master/slave protocol		
	slave_exec_mode	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Allows for switching the slave thread between IDEMPOTENT mode (key and some other errors suppressed) and STRICT mode; STRICT mode is the default, except for MySQL Cluster, where IDEMPOTENT is always used		
	Slave_heartbeat_period	
No	No	Yes
No	Global	No
DESCRIPTION: The slave's replication heartbeat interval, in seconds		
	slave_max_allowed_packet	
No	Yes	No
No	Global	Yes
DESCRIPTION: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`Slave_open_temp_tables`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of temporary tables that the slave SQL thread currently has open		
`Slave_retried_transactions`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times since startup that the replication slave SQL thread has retried transactions		
`Slave_running`		
No	No	Yes
No	Global	No
DESCRIPTION: The state of this server as a replication slave (slave I/O thread status)		
`slave_transaction_retries`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Number of times the slave SQL thread will retry a transaction in case it failed with a deadlock or elapsed lock wait timeout, before giving up and stopping		
`slave_type_conversions`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Controls type conversion mode on replication slave. Value is a list of zero or more elements from the list: ALL_LOSSY, ALL_NON_LOSSY. Set to an empty string to disallow type conversions between master and slave.		
`sql_slave_skip_counter`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Number of events from the master that a slave server should skip. Not compatible with GTID replication.		
`sync_binlog`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronously flush binary log to disk after every #th event		

Section 16.1.3.2, "Replication Master Options and Variables", provides more detailed information about options and variables relating to replication master servers. For more information about options and variables relating to replication slaves, see Section 16.1.3.3, "Replication Slave Options and Variables".

Table 16.2 Summary of Binary Logging options and variables in MySQL 5.1

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
binlog-do-db		
Yes	No	No
Yes		No
DESCRIPTION: Limits binary logging to specific databases		
binlog_format		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies the format of the binary log		
binlog-ignore-db		
Yes	No	No
Yes		No
DESCRIPTION: Tells the master that updates to the given database should not be logged to the binary log		
binlog-row-event-max-size		
Yes	No	No
Yes		No
DESCRIPTION: Binary log max event size		
Binlog_cache_disk_use		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions that used a temporary file instead of the binary log cache		
binlog_cache_size		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Size of the cache to hold the SQL statements for the binary log during a transaction		
Binlog_cache_use		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions that used the temporary binary log cache		
binlog_direct_non_transactional_updates		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Causes updates using statement format to nontransactional engines to be written directly to binary log. See documentation before using.		
Com_show_binlog_events		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW BINLOG EVENTS statements		
	Com_show_binlogs	
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW BINLOGS statements		
	log-bin-use-v1-row-events	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Use version 1 binary log row events		
	log_bin_use_v1_row_events	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Shows whether server is using version 1 binary log row events		
	max-binlog-dump-events	
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
	max_binlog_cache_size	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Can be used to restrict the total size used to cache a multi-statement transaction		
	max_binlog_size	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Binary log will be rotated automatically when size exceeds this value		
	sporadic-binlog-dump-fail	
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		

Section 16.1.3.4, "Binary Log Options and Variables", provides more detailed information about options and variables relating to binary logging. For additional general information about the binary log, see Section 5.4.4, "The Binary Log".

For information about the `sql_log_bin` and `sql_log_off` variables, see Section 5.1.4, "Server System Variables".

For a table showing *all* command-line options, system and status variables used with `mysqld`, see Section 5.1.1, "Server Option and Variable Reference".

16.1.3.2 Replication Master Options and Variables

This section describes the server options and system variables that you can use on replication master servers. You can specify the options either on the command line or in an option file. You can specify system variable values using `SET`.

On the master and each slave, you must use the `server-id` option to establish a unique replication ID. For each server, you should pick a unique positive integer in the range from 1 to $2^{32} - 1$, and each ID must be different from every other ID in use by any other replication master or slave. Example: `server-id=3`.

For options used on the master for controlling binary logging, see Section 16.1.3.4, "Binary Log Options and Variables".

System Variables Used on Replication Masters

The following system variables are used in controlling replication masters:

- `auto_increment_increment`

System Variable	Name	`auto_increment_increment`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1`
	Min Value	`1`
	Max Value	`65535`

`auto_increment_increment` and `auto_increment_offset` are intended for use with master-to-master replication, and can be used to control the operation of `AUTO_INCREMENT` columns. Both variables have global and session values, and each can assume an integer value between 1 and 65,535 inclusive. Setting the value of either of these two variables to 0 causes its value to be set to 1 instead. Attempting to set the value of either of these two variables to an integer greater than 65,535 or less than 0 causes its value to be set to 65,535 instead. Attempting to set the value of `auto_increment_increment` or `auto_increment_offset` to a noninteger value gives rise to an error, and the actual value of the variable remains unchanged.

> **Note**
>
> `auto_increment_increment` is supported for use with `NDB` tables beginning with MySQL 5.1.20, MySQL Cluster NDB 6.2.5, and MySQL Cluster NDB 6.3.2. Previously, setting it when using MySQL Cluster tables or MySQL Cluster Replication produced unpredictable results.

These two variables affect `AUTO_INCREMENT` column behavior as follows:

- auto_increment_increment controls the interval between successive column values. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 1     |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc1
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
  Query OK, 0 rows affected (0.04 sec)

mysql> SET @@auto_increment_increment=10;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.01 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)
```

- auto_increment_offset determines the starting point for the AUTO_INCREMENT column value. Consider the following, assuming that these statements are executed during the same session as the example given in the description for auto_increment_increment:

```
mysql> SET @@auto_increment_offset=5;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc2
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.06 sec)
```

```
mysql> INSERT INTO autoinc2 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc2;
+-----+
| col |
+-----+
|   5 |
|  15 |
|  25 |
|  35 |
+-----+
4 rows in set (0.02 sec)
```

If the value of auto_increment_offset is greater than that of auto_increment_increment, the value of auto_increment_offset is ignored.

Should one or both of these variables be changed and then new rows inserted into a table containing an AUTO_INCREMENT column, the results may seem counterintuitive because the series of AUTO_INCREMENT values is calculated without regard to any values already present in the column, and the next value inserted is the least value in the series that is greater than the maximum existing value in the AUTO_INCREMENT column. In other words, the series is calculated like so:

$$\text{auto\_increment\_offset} + N \times \text{auto\_increment\_increment}$$

where N is a positive integer value in the series [1, 2, 3, ...]. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
|  35 |
|  45 |
|  55 |
|  65 |
```

```
+-----+
8 rows in set (0.00 sec)
```

The values shown for `auto_increment_increment` and `auto_increment_offset` generate the series 5 + *N* × 10, that is, [5, 15, 25, 35, 45, ...]. The greatest value present in the `col` column prior to the `INSERT` is 31, and the next available value in the `AUTO_INCREMENT` series is 35, so the inserted values for `col` begin at that point and the results are as shown for the `SELECT` query.

It is not possible to confine the effects of these two variables to a single table, and thus they do not take the place of the sequences offered by some other database management systems; these variables control the behavior of all `AUTO_INCREMENT` columns in *all* tables on the MySQL server. If the global value of either variable is set, its effects persist until the global value is changed or overridden by setting the session value, or until `mysqld` is restarted. If the local value is set, the new value affects `AUTO_INCREMENT` columns for all tables into which new rows are inserted by the current user for the duration of the session, unless the values are changed during that session.

The default value of `auto_increment_increment` is 1. See Section 16.4.1.1, "Replication and AUTO_INCREMENT".

- `auto_increment_offset`

System Variable	Name	`auto_increment_offset`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`1`
	Min Value	`1`
	Max Value	`65535`

This variable has a default value of 1. For particulars, see the description for `auto_increment_increment`.

> **Note**
>
> `auto_increment_offset` is supported for use with `NDB` tables beginning with MySQL 5.1.20, MySQL Cluster NDB 6.2.5, and MySQL Cluster NDB 6.3.2. Previously, setting it when using MySQL Cluster tables or MySQL Cluster Replication produced unpredictable results.

16.1.3.3 Replication Slave Options and Variables

Startup Options for Replication Slaves

System Variables Used on Replication Slaves

This section describes the server options and system variables that apply to slave replication servers. You can specify the options either on the command line or in an option file. Many of the options can be set while the server is running by using the `CHANGE MASTER TO` statement. You can specify system variable values using `SET`.

Server ID. On the master and each slave, you must use the `server-id` option to establish a unique replication ID in the range from 1 to $2^{32} - 1$. "Unique" means that each ID must be different from every other ID in use by any other replication master or slave. Example `my.cnf` file:

```
[mysqld]
server-id=3
```

> **Important**
>
> Certain `--master-xxx` options are handled in a special way to ensure that the active replication configuration is not inadvertently altered or affected:
>
> - `--master-host`
> - `--master-user`
> - `--master-password`
> - `--master-port`
> - `--master-connect-retry`
> - `--master-ssl`
> - `--master-ssl-ca`
> - `--master-ssl-capath`
> - `--master-ssl-cert`
> - `--master-ssl-cipher`
> - `--master-ssl-key`
>
> Before MySQL 5.1.17, these options are silently ignored if given unless there is no `master.info` file. If that file exists, the MySQL server has already previously been configured for replication, so the information in the file is used instead. Because the server gives an existing `master.info` file precedence over the startup options just described, you might elect not to use startup options for these values at all, and instead to specify the replication parameters associated with them by using the `CHANGE MASTER TO` statement. See Section 13.4.2.1, "CHANGE MASTER TO Syntax".
>
> Beginning with MySQL 5.1.17, these options are deprecated and have no effect when `mysqld` is started. If they are used, an appropriate warning is written to the error log. Instead, you *must* use `CHANGE MASTER TO` to set the values corresponding to the deprecated options. These options are removed in MySQL 5.5.

The `master.info` file format in MySQL 5.1 includes as its first line the number of lines in the file. (See Section 16.2.2, "Replication Relay and Status Logs".) If you upgrade an older server (before MySQL 4.1.1) to a newer version, the new server upgrades the `master.info` file to the new format automatically when it starts. However, if you downgrade a newer server to an older version, you should remove the first line manually before starting the older server for the first time.

If no `master.info` file exists when the slave server starts, it uses the values for those options that are specified in option files or on the command line. This occurs when you start the server as a replication

slave for the very first time, when you use `CHANGE MASTER TO`, or when you have run `RESET SLAVE` and then have shut down and restarted the slave.

Because the server uses `master.info` file contents and ignores any startup options that correspond to the values listed in the file, if you start the slave server with different values of the startup options that correspond to values in the file, the different values have no effect. To use different values, the preferred method is to use the `CHANGE MASTER TO` statement to reset the values while the slave is running. Alternatively, you can stop the server, remove the `master.info` file, and restart the server with different option values.

Suppose that you specify this option in your `my.cnf` file to configure a pre-5.1.17 slave server:

```
[mysqld]
master-host=some_host
```

The first time you start the server as a replication slave, it reads and uses that option from the `my.cnf` file. The server then records the value in the `master.info` file. The next time you start the server, it reads the master host value from the `master.info` file only and ignores the value in the option file. If you modify the `my.cnf` file to specify a different master host value of `some_other_host`, the change has no effect. Instead, use `CHANGE MASTER TO` to change the value.

This example shows a more extensive use of startup options to configure a pre-5.1.17 slave server:

```
[mysqld]
server-id=2
master-host=db-master.mycompany.com
master-port=3306
master-user=pertinax
master-password=freitag
master-connect-retry=60
report-host=db-slave.mycompany.com
```

As of 5.1.17, the `master-xxx` options are ignored and result in warnings in the error log.

Startup Options for Replication Slaves

The following list describes startup options for controlling replication slave servers. Many of these options can be set while the server is running by using the `CHANGE MASTER TO` statement. Others, such as the `--replicate-*` options, can be set only when the slave server starts. Replication-related system variables are discussed later in this section.

- `--abort-slave-event-count`

Command-Line Format	`--abort-slave-event-count=#`	
Permitted Values	Type	`integer`
	Default	0
	Min Value	0

  When this option is set to some positive integer `value` other than 0 (the default) it affects replication behavior as follows: After the slave SQL thread has started, `value` log events are permitted to be executed; after that, the slave SQL thread does not receive any more events, just as if the network connection from the master were cut. The slave thread continues to run, and the output from `SHOW SLAVE STATUS` displays `Yes` in both the `Slave_IO_Running` and the `Slave_SQL_Running` columns, but no further events are read from the relay log.

This option is used internally by the MySQL test suite for replication testing and debugging. It is not intended for use in a production setting.

- `--disconnect-slave-event-count`

Command-Line Format	`--disconnect-slave-event-count=#`	
Permitted Values	**Type**	`integer`
	Default	`0`

This option is used internally by the MySQL test suite for replication testing and debugging.

- `--log-slave-updates`

Command-Line Format	`--log-slave-updates`	
System Variable	**Name**	`log_slave_updates`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Normally, a slave does not log to its own binary log any updates that are received from a master server. This option tells the slave to log the updates performed by its SQL thread to its own binary log. For this option to have any effect, the slave must also be started with the `--log-bin` option to enable binary logging. `--log-slave-updates` is used when you want to chain replication servers. For example, you might want to set up replication servers using this arrangement:

```
A -> B -> C
```

Here, `A` serves as the master for the slave `B`, and `B` serves as the master for the slave `C`. For this to work, `B` must be both a master *and* a slave. You must start both `A` and `B` with `--log-bin` to enable binary logging, and `B` with the `--log-slave-updates` option so that updates received from `A` are logged by `B` to its binary log.

When using MySQL Cluster Replication prior to MySQL Cluster NDB 6.2.16 and MySQL Cluster NDB 6.3.13, records for "empty" epochs—that is, epochs in which no changes to `NDBCLUSTER` data or tables took place—were inserted into the `ndb_apply_status` and `ndb_binlog_index` tables on the slave even when `--log-slave-updates` was disabled (Bug #37472). Beginning with MySQL Cluster NDB 6.3.33, MySQL Cluster NDB 7.0.14, and MySQL Cluster NDB 7.1.3, it is possible to re-enable the older behavior by using the `--ndb-log-empty-epochs` option.

> **Note**
>
> The `--ndb-log-empty-epochs` option was first implemented in MySQL Cluster NDB 6.3.21 and MySQL Cluster NDB 6.4.1, but did not work correctly before the versions cited previously.

- `--log-slow-slave-statements`

Introduced	5.1.21

Command-Line Format	`--log-slow-slave-statements`	
Permitted Values	**Type**	`boolean`
	Default	`OFF`

When the slow query log is enabled, this option enables logging for queries that have taken more than `long_query_time` seconds to execute on the slave.

This option was added in MySQL 5.1.21.

- `--log-warnings[=level]`

Command-Line Format	`--log-warnings[=#]`	
System Variable	**Name**	`log_warnings`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`18446744073709547520`

This option causes a server to print more messages to the error log about what it is doing. With respect to replication, the server generates warnings that it succeeded in reconnecting after a network/connection failure, and informs you as to how each slave thread started. This option is enabled (1) by default; to disable it, use `--log-warnings=0`. Aborted connections are not logged to the error log unless the value is greater than 1.

Note that the effects of this option are not limited to replication. It produces warnings across a spectrum of server activities.

- `--master-connect-retry=seconds`

Deprecated	5.1.17	
Command-Line Format	`--master-connect-retry=#`	
Permitted Values	**Type**	`integer`
	Default	`60`

The number of seconds that the slave thread sleeps before trying to reconnect to the master in case the master goes down or the connection is lost. The value in the `master.info` file takes precedence

if it can be read. If not set, the default is 60. Connection retries are not invoked until the slave times out reading data from the master according to the value of `--slave-net-timeout`. The number of reconnection attempts is limited by the `--master-retry-count` option.

This option is deprecated as of MySQL 5.1.17 and is removed in MySQL 5.5.

- `slave-max-allowed-packet=bytes`

Introduced	5.1.64	
Command-Line Format	`--slave-max-allowed-packet=#`	
Permitted Values	**Type**	`integer`
	Default	`1073741824`
	Min Value	`1024`
	Max Value	`1073741824`

In MySQL 5.1.64 and later, this option sets the maximum packet size in bytes for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded `max_allowed_packet`. (Bug #12400221, Bug #60926)

The corresponding server variable `slave_max_allowed_packet` always has a value that is a positive integer multiple of 1024; if you set it to some value that is not such a multiple, the value is automatically rounded down to the next highest multiple of 1024. (For example, if you start the server with `--slave-max-allowed-packet=10000`, the value used is 9216; setting 0 as the value causes 1024 to be used.) A truncation warning is issued in such cases.

The maximum (and default) value is 1073741824 (1 GB); the minimum is 1024.

- `--master-host=host_name`

Deprecated	5.1.17	
Command-Line Format	`--master-host=name`	
Permitted Values	**Type**	`string`

The host name or IP address of the master replication server. The value in `master.info` takes precedence if it can be read. If no master host is specified, the slave thread does not start.

This option is deprecated as of MySQL 5.1.17 and is removed in MySQL 5.5.

- `--master-info-file=file_name`

Command-Line Format	`--master-info-file=file_name`	
Permitted Values	**Type**	`file name`
	Default	`master.info`

The name to use for the file in which the slave records information about the master. The default name is `master.info` in the data directory. For information about the format of this file, see Section 16.2.2.2, "Slave Status Logs".

- `--master-password=password`   1799

Deprecated	5.1.17	
Command-Line Format	`--master-password=name`	
Permitted Values	Type	`string`

The password of the account that the slave thread uses for authentication when it connects to the master. The value in the `master.info` file takes precedence if it can be read. If not set, an empty password is assumed.

This option is deprecated as of MySQL 5.1.17 and is removed in MySQL 5.5.

- `--master-port=port_number`

Deprecated	5.1.17	
Command-Line Format	`--master-port=#`	
Permitted Values	Type	`integer`
	Default	`3306`

The TCP/IP port number that the master is listening on. The value in the `master.info` file takes precedence if it can be read. If not set, the compiled-in setting is assumed (normally 3306).

This option is deprecated as of MySQL 5.1.17 and is removed in MySQL 5.5.

- `--master-retry-count=count`

Command-Line Format	`--master-retry-count=#`	
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`86400`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`86400`
	Min Value	`0`
	Max Value	`18446744073709551615`

The number of times that the slave tries to connect to the master before giving up. Reconnects are attempted at intervals set by the `--master-connect-retry` option (or the `MASTER_CONNECT_RETRY` option of the `CHANGE MASTER TO` statement) and reconnects are triggered when data reads by the slave time out according to the `--slave-net-timeout` option. The default value is 86400. A value of 0 means "infinite"; the slave attempts to connect forever.

- `--master-ssl`, `--master-ssl-ca=file_name`, `--master-ssl-capath=directory_name`, `--master-ssl-cert=file_name`, `--master-ssl-cipher=cipher_list`, `--master-ssl-key=file_name`

These options are used for setting up a secure replication connection to the master server using SSL. Their meanings are the same as the corresponding `--ssl`, `--ssl-ca`, `--ssl-capath`, `--ssl-cert`, `--ssl-cipher`, `--ssl-key` options that are described in Section 6.4.5, "Command Options for Secure Connections". The values in the `master.info` file take precedence if they can be read.

These options are deprecated as of MySQL 5.1.17 and are removed in MySQL 5.5.

- `--master-user=user_name`

Deprecated	5.1.17	
Command-Line Format	`--master-user=name`	
Permitted Values	**Type**	`string`
	Default	`test`

The user name of the account that the slave thread uses for authentication when it connects to the master. This account must have the `REPLICATION SLAVE` privilege. The value in the `master.info` file takes precedence if it can be read. If the master user name is not set, the name `test` is assumed.

This option is deprecated as of MySQL 5.1.17 and is removed in MySQL 5.5.

- `--max-relay-log-size=size`

Command-Line Format	`--max_relay_log_size=#`	
System Variable	**Name**	`max_relay_log_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	0
	Min Value	0
	Max Value	`1073741824`

The size at which the server rotates relay log files automatically. If this value is nonzero, the relay log is rotated automatically when its size exceeds this value. If this value is zero (the default), the size at which relay log rotation occurs is determined by the value of `max_binlog_size`. For more information, see Section 16.2.2.1, "The Slave Relay Log".

- `--relay-log=file_name`

Command-Line Format	`--relay-log=file_name`	
System Variable	**Name**	`relay_log`
	Variable Scope	Global
	Dynamic Variable	No

Permitted Values	Type	`file name`

The base name for the relay log. The default base name is `host_name-relay-bin`. The server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. The server creates relay log files in sequence by adding a numeric suffix to the base name.

Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default base name is used only if the option is not actually specified*. If you use the `--relay-log` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Section 4.2.3, "Specifying Program Options".

If you specify this option, the value specified is also used as the base name for the relay log index file. You can override this behavior by specifying a different relay log index file base name using the `--relay-log-index` option.

You may find the `--relay-log` option useful in performing the following tasks:

- Creating relay logs whose names are independent of host names.

- If you need to put the relay logs in some area other than the data directory because your relay logs tend to be very large and you do not want to decrease `max_relay_log_size`.

- To increase speed by using load-balancing between disks.

- `--relay-log-index=file_name`

Command-Line Format	`--relay-log-index=file_name`	
System Variable	Name	`relay_log_index`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`file name`

The name to use for the relay log index file. The default name is `host_name-relay-bin.index` in the data directory, where `host_name` is the name of the slave server.

Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default base name is used only if the option is not actually specified*. If you use the `--relay-log-index` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Section 4.2.3, "Specifying Program Options".

If you specify this option, the value specified is also used as the base name for the relay logs. You can override this behavior by specifying a different relay log file base name using the `--relay-log` option.

- `--relay-log-info-file=file_name`

Command-Line Format	`--relay-log-info-file=file_name`

Permitted Values	Type	`file name`
	Default	`relay-log.info`

The name to use for the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory. For information about the format of this file, see Section 16.2.2.2, "Slave Status Logs".

- `--relay-log-purge={0|1}`

Command-Line Format	`--relay_log_purge`	
System Variable	Name	`relay_log_purge`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`TRUE`

Disable or enable automatic purging of relay logs as soon as they are no longer needed. The default value is 1 (enabled). This is a global variable that can be changed dynamically with `SET GLOBAL relay_log_purge = N`.

- `--relay-log-space-limit=size`

Command-Line Format	`--relay_log_space_limit=#`	
System Variable	Name	`relay_log_space_limit`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`18446744073709547520`

This option places an upper limit on the total size in bytes of all relay logs on the slave. A value of 0 means "no limit." This is useful for a slave server host that has limited disk space. When the limit is reached, the I/O thread stops reading binary log events from the master server until the SQL thread has caught up and deleted some unused relay logs. Note that this limit is not absolute: There are cases where the SQL thread needs more events before it can delete relay logs. In that case, the I/O thread

exceeds the limit until it becomes possible for the SQL thread to delete some relay logs because not doing so would cause a deadlock. You should not set `--relay-log-space-limit` to less than twice the value of `--max-relay-log-size` (or `--max-binlog-size` if `--max-relay-log-size` is 0). In that case, there is a chance that the I/O thread waits for free space because `--relay-log-space-limit` is exceeded, but the SQL thread has no relay log to purge and is unable to satisfy the I/O thread. This forces the I/O thread to ignore `--relay-log-space-limit` temporarily.

- `--replicate-do-db=db_name`

Command-Line Format	`--replicate-do-db=name`	
Permitted Values	**Type**	`string`

The effects of this option depend on whether statement-based or row-based replication is in use.

Statement-based replication.   Tell the slave SQL thread to restrict replication to statements where the default database (that is, the one selected by `USE`) is *db_name*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* replicate cross-database statements such as `UPDATE some_db.some_table SET foo='bar'` while a different database (or no database) is selected.

> **Warning**
>
> To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

An example of what does not work as you might expect when using statement-based replication: If the slave is started with `--replicate-do-db=sales` and you issue the following statements on the master, the `UPDATE` statement is *not* replicated:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this "check just the default database" behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Row-based replication.   Tells the slave SQL thread to restrict replication to database *db_name*. Only tables belonging to *db_name* are changed; the current database has no effect on this. Suppose that the slave is started with `--replicate-do-db=sales` and row-based replication is in effect, and then the following statements are run on the master:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The `february` table in the `sales` database on the slave is changed in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, issuing the following statements on the master has no effect on the slave when using row-based replication and `--replicate-do-db=sales`:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the statement `USE prices` were changed to `USE sales`, the `UPDATE` statement's effects would still not be replicated.

Another important difference in how `--replicate-do-db` is handled in statement-based replication as opposed to row-based replication occurs with regard to statements that refer to multiple databases. Suppose that the slave is started with `--replicate-do-db=db1`, and the following statements are executed on the master:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based replication, then both tables are updated on the slave. However, when using row-based replication, only `table1` is affected on the slave; since `table2` is in a different database, `table2` on the slave is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement would have no effect on the slave when using statement-based replication. However, if you are using row-based replication, the `UPDATE` would change `table1` on the slave, but not `table2`—in other words, only tables in the database named by `--replicate-do-db` are changed, and the choice of default database has no effect on this behavior.

If you need cross-database updates to work, use `--replicate-wild-do-table=db_name.%` instead. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

> **Note**
>
> This option affects replication in the same manner that `--binlog-do-db` affects binary logging, and the effects of the replication format on how `--replicate-do-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-do-db`.
>
> Beginning with MySQL 5.1.35, this option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements. (Bug #43263)

- `--replicate-ignore-db=db_name`

Command-Line Format	`--replicate-ignore-db=name`	
Permitted Values	**Type**	`string`

As with `--replicate-do-db`, the effects of this option depend on whether statement-based or row-based replication is in use.

Statement-based replication.   Tells the slave SQL thread not to replicate any statement where the default database (that is, the one selected by `USE`) is *db_name*.

Row-based replication.   Tells the slave SQL thread not to update any tables in the database *db_name*. The default database has no effect.

When using statement-based replication, the following example does not work as you might expect. Suppose that the slave is started with `--replicate-ignore-db=sales` and you issue the following statements on the master:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The `UPDATE` statement *is* replicated in such a case because `--replicate-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based replication, the `UPDATE` statement's effects are *not* propagated to the slave, and the slave's copy of the `sales.january` table is unchanged; in this instance, `--replicate-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored by the slave.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

You should not use this option if you are using cross-database updates and you do not want these updates to be replicated. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

If you need cross-database updates to work, use `--replicate-wild-ignore-table=`*`db_name`*`.%` instead. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

> **Note**
>
> This option affects replication in the same manner that `--binlog-ignore-db` affects binary logging, and the effects of the replication format on how `--replicate-ignore-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-ignore-db`.
>
> Beginning with MySQL 5.1.35, this option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements. (Bug #43263)

- `--replicate-do-table=`*`db_name`*`.`*`tbl_name`*

Command-Line Format	`--replicate-do-table=name`	
Permitted Values	**Type**	`string`

Tells the slave SQL thread to restrict replication to the specified table. To specify more than one table, use this option multiple times, once for each table. This works for both cross-database updates and default database updates, in contrast to `--replicate-do-db`. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the `--replicate-*-db` options.

- `--replicate-ignore-table=`*`db_name`*`.`*`tbl_name`*

Command-Line Format	`--replicate-ignore-table=name`	
Permitted Values	**Type**	`string`

Tells the slave SQL thread not to replicate any statement that updates the specified table, even if any other tables might be updated by the same statement. To specify more than one table to ignore, use

this option multiple times, once for each table. This works for cross-database updates, in contrast to `--replicate-ignore-db`. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the `--replicate-*-db` options.

- `--replicate-rewrite-db=from_name->to_name`

Command-Line Format	`--replicate-rewrite-db=old_name->new_name`	
Permitted Values	**Type**	`string`

Tells the slave to translate the default database (that is, the one selected by `USE`) to `to_name` if it was `from_name` on the master. Only statements involving tables are affected (not statements such as `CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`), and only if `from_name` is the default database on the master. To specify multiple rewrites, use this option multiple times. The server uses the first one with a `from_name` value that matches. The database name translation is done *before* the `--replicate-*` rules are tested.

Statements in which table names are qualified with database names when using this option do not work with table-level replication filtering options such as `--replicate-do-table`. Suppose we have a database named `a` on the master, one named `b` on the slave, each containing a table `t`, and have started the master with `--replicate-rewrite-db='a->b'`. At a later point in time, we execute `DELETE FROM a.t`. In this case, no relevant filtering rule works, for the reasons shown here:

1. `--replicate-do-table=a.t` does not work because the slave has table `t` in database `b`.

2. `--replicate-do-table=b.t` does not match the original statement and so is ignored.

3. `--replicate-do-table=*.t` is handled identically to `--replicate-do-table=a.t`, and thus does not work, either.

Similarly, the `--replication-rewrite-db` option does not work with cross-database updates.

If you use this option on the command line and the ">" character is special to your command interpreter, quote the option value. For example:

```
shell> mysqld --replicate-rewrite-db="olddb->newdb"
```

- `--replicate-same-server-id`

Command-Line Format	`--replicate-same-server-id`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

To be used on slave servers. Usually you should use the default setting of 0, to prevent infinite loops caused by circular replication. If set to 1, the slave does not skip events having its own server ID. Normally, this is useful only in rare configurations. Cannot be set to 1 if `--log-slave-updates` is used. By default, the slave I/O thread does not write binary log events to the relay log if they have the slave's server ID (this optimization helps save disk usage). If you want to use `--replicate-same-server-id`, be sure to start the slave with this option before you make the slave read its own events that you want the slave SQL thread to execute.

- `--replicate-wild-do-table=db_name.tbl_name`

Command-Line Format	`--replicate-wild-do-table=name`	
Permitted Values	**Type**	`string`

Tells the slave thread to restrict replication to statements where any of the updated tables match the specified database and table name patterns. Patterns can contain the "`%`" and "`_`" wildcard characters, which have the same meaning as for the `LIKE` pattern-matching operator. To specify more than one table, use this option multiple times, once for each table. This works for cross-database updates. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

This option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the `--replicate-*-db` options.

Example: `--replicate-wild-do-table=foo%.bar%` replicates only updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

If the table name pattern is `%`, it matches any table name and the option also applies to database-level statements (`CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`). For example, if you use `--replicate-wild-do-table=foo%.%`, database-level statements are replicated if the database name matches the pattern `foo%`.

To include literal wildcard characters in the database or table name patterns, escape them with a backslash. For example, to replicate all tables of a database that is named `my_own%db`, but not replicate tables from the `my1ownAABCdb` database, you should escape the "`_`" and "`%`" characters like this: `--replicate-wild-do-table=my\_own\%db`. If you use the option on the command line, you might need to double the backslashes or quote the option value, depending on your command interpreter. For example, with the `bash` shell, you would need to type `--replicate-wild-do-table=my\\_own\\%db`.

- `--replicate-wild-ignore-table=`*`db_name.tbl_name`*

Command-Line Format	`--replicate-wild-ignore-table=name`	
Permitted Values	**Type**	`string`

Tells the slave thread not to replicate a statement where any table matches the given wildcard pattern. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates. See Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

Example: `--replicate-wild-ignore-table=foo%.bar%` does not replicate updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

For information about how matching works, see the description of the `--replicate-wild-do-table` option. The rules for including literal wildcard characters in the option value are the same as for `--replicate-wild-ignore-table` as well.

- `--report-host=`*`host_name`*

Command-Line Format	`--report-host=host_name`	
System Variable (>= 5.1.24)	**Name**	`report_host`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`string`

The host name or IP address of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server. Leave the value unset if you do not want the slave to register itself with the master. Note that it is not sufficient for the master to simply read the IP address of the slave from the TCP/IP socket after the slave connects. Due to NAT and other routing issues, that IP may not be valid for connecting to the slave from the master or other hosts.

- `--report-password=password`

Command-Line Format	`--report-password=name`	
System Variable (>= 5.1.24)	**Name**	`report_password`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

An arbitrary account password to be reported by the slave to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the `--show-slave-auth-info` option is given.

Although the name of this option might imply otherwise, `--report-password` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the password for the MySQL replication user account.

- `--report-port=slave_port_num`

Command-Line Format	`--report-port=#`	
System Variable (>= 5.1.24)	**Name**	`report_port`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`3306`
	Min Value	`0`
	Max Value	`65535`

The TCP/IP port number for connecting to the slave, to be reported to the master during slave registration. Set this only if the slave is listening on a nondefault port or if you have a special tunnel from the master or other clients to the slave. If you are not sure, do not use this option.

- `--report-user=user_name`

Command-Line Format	`--report-user=name`	
System Variable (>= 5.1.24)	**Name**	`report_user`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

The account user name of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the `--show-slave-auth-info` option is given.

Although the name of this option might imply otherwise, `--report-user` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the name of the MySQL replication user account.

- `--show-slave-auth-info`

Command-Line Format	`--show-slave-auth-info`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Display slave user names and passwords in the output of `SHOW SLAVE HOSTS` on the master server for slaves started with the `--report-user` and `--report-password` options.

- `--skip-slave-start`

Command-Line Format	`--skip-slave-start`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Tells the slave server not to start the slave threads when the server starts. To start the threads later, use a `START SLAVE` statement.

- `--slave_compressed_protocol={0|1}`

Command-Line Format	`--slave_compressed_protocol`	
System Variable	**Name**	`slave_compressed_protocol`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

If this option is set to 1, use compression for the slave/master protocol if both the slave and the master support it. The default is 0 (no compression).

- `--slave-load-tmpdir=dir_name`

Command-Line Format	`--slave-load-tmpdir=dir_name`	
System Variable	**Name**	`slave_load_tmpdir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`
	Default	`/tmp`

The name of the directory where the slave creates temporary files. This option is by default equal to the value of the `tmpdir` system variable. When the slave SQL thread replicates a `LOAD DATA INFILE` statement, it extracts the file to be loaded from the relay log into temporary files, and then loads these into the table. If the file loaded on the master is huge, the temporary files on the slave are huge, too. Therefore, it might be advisable to use this option to tell the slave to put temporary files in a directory located in some file system that has a lot of available space. In that case, the relay logs are huge as well, so you might also want to use the `--relay-log` option to place the relay logs in that file system.

The directory specified by this option should be located in a disk-based file system (not a memory-based file system) because the temporary files used to replicate `LOAD DATA INFILE` must survive machine restarts. The directory also should not be one that is cleared by the operating system during the system startup process.

- `--slave-net-timeout=seconds`

Command-Line Format	`--slave-net-timeout=#`	
System Variable	**Name**	`slave_net_timeout`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`3600`
	Min Value	`1`

The number of seconds to wait for more data from the master before the slave considers the connection broken, aborts the read, and tries to reconnect. The first retry occurs immediately after the timeout. The interval between retries is controlled by the `MASTER_CONNECT_RETRY` option for the `CHANGE MASTER TO` statement or `--master-connect-retry` option, and the number of reconnection attempts is limited by the `--master-retry-count` option. The default is 3600 seconds (one hour).

- `--slave-skip-errors=[err_code1,err_code2,...|all]`

(MySQL Cluster NDB 7.0.33 and later; MySQL Cluster NDB 7.1.22 and later:) `--slave-skip-errors=[err_code1,err_code2,...|all|ddl_exist_errors]`

Command-Line Format	`--slave-skip-errors=name`	
System Variable	**Name**	`slave_skip_errors`

		Variable Scope	Global
		Dynamic Variable	No
Permitted Values (<= 5.1.61-ndb-7.0.32)	Type	`string`	
	Default	`OFF`	
	Valid Values	`OFF`	
		`[list of error codes]`	
		`all`	
Permitted Values (>= 5.1.61-ndb-7.0.33)	Type	`string`	
	Default	`OFF`	
	Valid Values	`OFF`	
		`[list of error codes]`	
		`all`	
		`ddl_exist_errors`	
Permitted Values (>= 5.1.39-ndb-7.1.0, <= 5.1.61-ndb-7.1.21)	Type	`string`	
	Default	`OFF`	
	Valid Values	`OFF`	
		`[list of error codes]`	
		`all`	
Permitted Values (>= 5.1.61-ndb-7.1.22)	Type	`string`	
	Default	`OFF`	
	Valid Values	`OFF`	
		`[list of error codes]`	
		`all`	
		`ddl_exist_errors`	

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This option tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the option value.

Do not use this option unless you fully understand why you are getting errors. If there are no bugs in your replication setup and client programs, and no bugs in MySQL itself, an error that stops replication should never occur. Indiscriminate use of this option results in slaves becoming hopelessly out of synchrony with the master, with you having no idea why this has occurred.

Note

Prior to MySQL 5.1.35, this option had no effect with row-based logging. (Bug #39393)

For error codes, you should use the numbers provided by the error message in your slave error log and in the output of `SHOW SLAVE STATUS`. Appendix B, *Errors, Error Codes, and Common Problems*, lists server error codes.

You can also (but should not) use the very nonrecommended value of `all` to cause the slave to ignore all error messages and keeps going regardless of what happens. Needless to say, if you use `all`, there are no guarantees regarding the integrity of your data. Please do not complain (or file bug reports) in this case if the slave's data is not anywhere close to what it is on the master. *You have been warned*.

For MySQL Cluster Replication in MySQL Cluster NDB 7.0 beginning with version 7.0.33 and MySQL Cluster NDB 7.1 beginning with version 7.1.22, an additional shorthand value `ddl_exist_errors` is supported for use with the enhanced failover mechanism which is implemented in that and later version of MySQL Cluster NDB 7.2. This value is equivalent to the error code list `1007,1008,1050,1051,1054,1060,1061,1068,1094,1146`. *This value is not supported by the `mysqld` binary included with the MySQL Server 5.1 distribution*. (Bug #11762277, Bug #54854) For more information, see Section 17.6.8, "Implementing Failover with MySQL Cluster Replication".

Examples:

```
--slave-skip-errors=1062,1053
--slave-skip-errors=all
--slave-skip-errors=ddl_exist_errors
```

System Variables Used on Replication Slaves

The following list describes system variables for controlling replication slave servers. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used with replication slaves are listed earlier in this section.

- `init_slave`

Command-Line Format	`--init-slave=name`	
System Variable	**Name**	`init_slave`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

This variable is similar to `init_connect`, but is a string to be executed by a slave server each time the SQL thread starts. The format of the string is the same as for the `init_connect` variable.

> **Note**
>
> The SQL thread sends an acknowledgment to the client before it executes `init_slave`. Therefore, it is not guaranteed that `init_slave` has been executed when `START SLAVE` returns. See Section 13.4.2.7, "START SLAVE Syntax", for more information.

- `relay_log`

Command-Line Format	`--relay-log=file_name`	
System Variable	**Name**	`relay_log`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The name of the relay log file.

- `relay_log_index`

Command-Line Format	`--relay-log-index`	
System Variable	**Name**	`relay_log_index`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`
	Default	`*host_name*-relay-bin.index`

The name of the relay log index file. The default name is `host_name-relay-bin.index` in the data directory, where `host_name` is the name of the slave server.

- `relay_log_info_file`

Command-Line Format	`--relay-log-info-file=file_name`	
System Variable	**Name**	`relay_log_info_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`
	Default	`relay-log.info`

The name of the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory.

- `rpl_recovery_rank`

This variable is unused, and is removed in MySQL 5.6.

- `slave_compressed_protocol`

Command-Line Format	`--slave_compressed_protocol`	
System Variable	**Name**	`slave_compressed_protocol`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF` 1814

Whether to use compression of the slave/master protocol if both the slave and the master support it.

- `slave_exec_mode`

Introduced	5.1.24	
Command-Line Format	`--slave-exec-mode=mode`	
System Variable	**Name**	`slave_exec_mode`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`STRICT` (ALL)
	Default	`IDEMPOTENT` (NDB)
	Valid Values	`IDEMPOTENT`
		`STRICT`

Controls whether `IDEMPOTENT` or `STRICT` mode is used in replication conflict resolution and error checking. `IDEMPOTENT` mode causes suppression of duplicate-key and no-key-found errors.

This mode is needed for multi-master replication, circular replication, and some other special replication scenarios for MySQL Cluster Replication. (See Section 17.6.10, "MySQL Cluster Replication: Multi-Master and Circular Replication", and Section 17.6.11, "MySQL Cluster Replication Conflict Resolution", for more information.) The `mysqld` supplied with MySQL Cluster ignores any value explicitly set for `slave_exec_mode`, and always treats it as `IDEMPOTENT`.

In MySQL Server 5.1, `STRICT` mode is the default value. This should not be changed; currently, `IDEMPOTENT` mode is supported only by `NDB`.

- `slave_max_allowed_packet`

Introduced	5.1.64	
System Variable	**Name**	`slave_max_allowed_packet`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1073741824`
	Min Value	`1024`
	Max Value	`1073741824`

In MySQL 5.1.64 and later, this variable sets the maximum packet size for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded `max_allowed_packet`.

This global variable always has a value that is a positive integer multiple of 1024; if you set it to some value that is not, the value is rounded down to the next highest multiple of 1024 for it is stored or used; setting `slave_max_allowed_packet` to 0 causes 1024 to be used. (A truncation warning is issued in all such cases.) The default and maximum value is 1073741824 (1 GB); the minimum is 1024.

`slave_max_allowed_packet` can also be set at startup, using the `--slave-max-allowed-packet` option.

- `slave_load_tmpdir`

Command-Line Format	`--slave-load-tmpdir=dir_name`	
System Variable	Name	`slave_load_tmpdir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`directory name`
	Default	`/tmp`

The name of the directory where the slave creates temporary files for replicating `LOAD DATA INFILE` statements.

- `slave_net_timeout`

Command-Line Format	`--slave-net-timeout=#`	
System Variable	Name	`slave_net_timeout`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`
	Default	`3600`
	Min Value	`1`

The number of seconds to wait for more data from a master/slave connection before aborting the read. Before MySQL 5.1.41, this timeout applies only to TCP/IP connections, not to connections made through Unix socket files, named pipes, or shared memory.

- `slave_skip_errors`

Command-Line Format	`--slave-skip-errors=name`	
System Variable	Name	`slave_skip_errors`
	Variable Scope	Global
	Dynamic Variable	No

Permitted Values (<= 5.1.61-ndb-7.0.32)	Type	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
Permitted Values (>= 5.1.61-ndb-7.0.33)	Type	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`
Permitted Values (>= 5.1.39-ndb-7.1.0, <= 5.1.61-ndb-7.1.21)	Type	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
Permitted Values (>= 5.1.61-ndb-7.1.22)	Type	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This variable tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the variable value.

- `slave_transaction_retries`

Command-Line Format	`--slave_transaction_retries=#`
System Variable	Name	`slave_transaction_retries`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	Type	`integer`
	Default	`10`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	Type	`integer`

Default	10
Min Value	0
Max Value	18446744073709547520

If a replication slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because the transaction's execution time exceeded `InnoDB`'s `innodb_lock_wait_timeout` or `NDBCLUSTER`'s `TransactionDeadlockDetectionTimeout` or `TransactionInactiveTimeout`, it automatically retries `slave_transaction_retries` times before stopping with an error. The default value is 10.

- `slave_type_conversions`

Introduced	5.1.44-ndb-7.1.3	
Command-Line Format	`--slave_type_conversions=set`	
System Variable	Name	`slave_type_conversions`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`set`
	Default	
	Valid Values	`ALL_LOSSY`
		`ALL_NON_LOSSY`

Controls the type conversion mode in effect on the slave when using MySQL Cluster Replication. Its value is a comma-delimited set of zero or more elements from the list: `ALL_LOSSY`, `ALL_NON_LOSSY`. Set this variable to an empty string to disallow type conversions between the master and the slave. Changes require a restart of the slave to take effect.

For additional information on type conversion modes applicable to MySQL Cluster replication attribute promotion and demotion, see Attribute promotion and demotion (MySQL Cluster).

This variable was added in MySQL Cluster NDB 6.3.33, 7.0.14, and 7.1.3.

- `sql_slave_skip_counter`

System Variable	Name	`sql_slave_skip_counter`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`integer`

The number of events from the master that a slave server should skip.

> **Important**
>
> If skipping the number of events specified by setting this variable would cause the slave to begin in the middle of an event group, the slave continues to skip until it finds the beginning of the next event group and begins from that point. For more information, see Section 13.4.2.6, "SET GLOBAL sql_slave_skip_counter Syntax".

16.1.3.4 Binary Log Options and Variables

Startup Options Used with Binary Logging

System Variables Used with Binary Logging

You can use the `mysqld` options and system variables that are described in this section to affect the operation of the binary log as well as to control which statements are written to the binary log. For additional information about the binary log, see Section 5.4.4, "The Binary Log". For additional information about using MySQL server options and system variables, see Section 5.1.3, "Server Command Options", and Section 5.1.4, "Server System Variables".

Startup Options Used with Binary Logging

The following list describes startup options for enabling and configuring the binary log. System variables used with binary logging are discussed later in this section.

- `--binlog-row-event-max-size=N`

Introduced	5.1.5	
Command-Line Format	`--binlog-row-event-max-size=#`	
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`1024`
	Min Value	`256`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`1024`
	Min Value	`256`
	Max Value	`18446744073709547520`

Specify the maximum size of a row-based binary log event, in bytes. Rows are grouped into events smaller than this size if possible. The value should be a multiple of 256. The default is 1024. See Section 16.1.2, "Replication Formats". This option was added in MySQL 5.1.5.

- `--log-bin[=base_name]`

Command-Line Format	`--log-bin`	
System Variable	**Name**	`log_bin`

	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`file name`

Enable binary logging. The server logs all statements that change data to the binary log, which is used for backup and replication. See Section 5.4.4, "The Binary Log".

The option value, if given, is the base name for the log sequence. The server creates binary log files in sequence by adding a numeric suffix to the base name. It is recommended that you specify a base name (see Section B.5.7, "Known Issues in MySQL", for the reason). Otherwise, MySQL uses *host_name-bin* as the base name.

Setting this option causes the `log_bin` system variable to be set to `ON` (or `1`), and not to the base name. This is a known issue; see Bug #19614 for more information.

- `--log-bin-index[=file_name]`

Command-Line Format	`--log-bin-index=file_name`
Permitted Values	Type	`file name`

The index file for binary log file names. See Section 5.4.4, "The Binary Log". If you omit the file name, and if you did not specify one with `--log-bin`, MySQL uses *host_name-bin.index* as the file name.

- `--log-bin-trust-function-creators[={0|1}]`

Command-Line Format	`--log-bin-trust-function-creators`	
System Variable	Name	`log_bin_trust_function_creators`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`FALSE`

This option sets the corresponding `log_bin_trust_function_creators` system variable. If no argument is given, the option sets the variable to 1. `log_bin_trust_function_creators` affects how MySQL enforces restrictions on stored function and trigger creation. See Section 19.7, "Binary Logging of Stored Programs".

> **Note**
>
> Previously, this option was known as `--log-bin-trust-routine-creators`, which is now deprecated.

- `--log-bin-use-v1-row-events[={0|1}]`

Introduced	5.1.56-ndb-7.1.16
Command-Line Format	`--log-bin-use-v1-row-events[={0|1}]`
System Variable	Name	`log_bin_use_v1_row_events`

		Variable Scope	Global
		Dynamic Variable	No
Permitted Values (>= 5.1.56-ndb-7.0.27)	**Type**	`boolean`	
	Default	`1`	
Permitted Values (>= 5.1.56-ndb-7.1.16)	**Type**	`boolean`	
	Default	`1`	

Version 2 binary log row events are available beginning with MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16; however, Version 2 events cannot be read by previous MySQL Cluster releases. Setting `--log-bin-use-v1-row-events` to 0 causes `mysqld` to use Version 2 binary log events. Setting this option to 1 (the default) causes `mysqld` to write the binary log using Version 1 logging events, which is the only version of binary log events used in previous releases, and thus produce binary logs that can be read by older slaves.

The value used for this option can be obtained from the read-only `log_bin_use_v1_row_events` system variable.

`--log-bin-use-v1-row-events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB$EPOCH_TRANS()` as the conflict detection function, which requires Version 2 binary log row events. Thus, this option and `--ndb-log-transaction-id` are not compatible.

> **Note**
>
> MySQL Cluster NDB 7.2.1 and later use Version 2 binary log events by default (and so the default value for this option changes to 0 in those versions). You should keep this mind when planning upgrades for setups using MySQL Cluster Replication.

`--log-bin-use-v1-row-events` is not supported in mainline MySQL Server 5.1 releases.

For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

Statement selection options.   The options in the following list affect which statements are written to the binary log, and thus sent by a replication master server to its slaves. There are also options for slave servers that control which statements received from the master should be executed or ignored. For details, see Section 16.1.3.3, "Replication Slave Options and Variables".

- `--binlog-do-db=db_name`

Command-Line Format	`--binlog-do-db=name`	
Permitted Values	**Type**	`string`

This option affects binary logging in a manner similar to the way that `--replicate-do-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-do-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without

regard to the logging format in effect, so the following statement-based rules for `--binlog-do-db` always apply in determining whether or not the statement is logged.

Statement-based logging. Only those statements are written to the binary log where the default database (that is, the one selected by `USE`) is *db_name*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* cause cross-database statements such as `UPDATE some_db.some_table SET foo='bar'` to be logged while a different database (or no database) is selected.

> **Warning**
>
> To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

An example of what does not work as you might expect when using statement-based logging: If the server is started with `--binlog-do-db=sales` and you issue the following statements, the `UPDATE` statement is *not* logged:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this "just check the default database" behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Another case which may not be self-evident occurs when a given database is replicated even though it was not specified when setting the option. If the server is started with `--binlog-do-db=sales`, the following `UPDATE` statement is logged even though `prices` was not included when setting `--binlog-do-db`:

```
USE sales;
UPDATE prices.discounts SET percentage = percentage + 10;
```

Because `sales` is the default database when the `UPDATE` statement is issued, the `UPDATE` is logged.

Row-based logging. Logging is restricted to database *db_name*. Only changes to tables belonging to *db_name* are logged; the default database has no effect on this. Suppose that the server is started with `--binlog-do-db=sales` and row-based logging is in effect, and then the following statements are executed:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The changes to the `february` table in the `sales` database are logged in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, when using the row-based logging format and `--binlog-do-db=sales`, changes made by the following `UPDATE` are not logged:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the `USE prices` statement were changed to `USE sales`, the `UPDATE` statement's effects would still not be written to the binary log.

Another important difference in `--binlog-do-db` handling for statement-based logging as opposed to the row-based logging occurs with regard to statements that refer to multiple databases. Suppose that the server is started with `--binlog-do-db=db1`, and the following statements are executed:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based logging, the updates to both tables are written to the binary log. However, when using the row-based format, only the changes to `table1` are logged; `table2` is in a different database, so it is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement is not written to the binary log when using statement-based logging. However, when using row-based logging, the change to `table1` is logged, but not that to `table2`—in other words, only changes to tables in the database named by `--binlog-do-db` are logged, and the choice of default database has no effect on this behavior.

- `--binlog-ignore-db=db_name`

Command-Line Format	`--binlog-ignore-db=name`	
Permitted Values	**Type**	`string`

This option affects binary logging in a manner similar to the way that `--replicate-ignore-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-ignore-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for `--binlog-ignore-db` always apply in determining whether or not the statement is logged.

Statement-based logging.   Tells the server to not log any statement where the default database (that is, the one selected by `USE`) is *db_name*.

Prior to MySQL 5.1.70, this option caused any statements containing fully qualified table names not to be logged if there was no default database specified (that is, when `SELECT DATABASE()` returned `NULL`). In MySQL 5.1.70 and later, when there is no default database, no `--binlog-ignore-db` options are applied, and such statements are always logged. (Bug #11829838, Bug #60188)

Row-based format.   Tells the server not to log updates to any tables in the database *db_name*. The current database has no effect.

When using statement-based logging, the following example does not work as you might expect. Suppose that the server is started with `--binlog-ignore-db=sales` and you issue the following statements:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The `UPDATE` statement *is* logged in such a case because `--binlog-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based logging, the `UPDATE` statement's effects are *not* written to the binary log, which means that no changes to the `sales.january` table are logged; in this instance, `--binlog-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored for purposes of binary logging.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

You should not use this option if you are using cross-database updates and you do not want these updates to be logged.

Testing and debugging options.   The following binary log options are used in replication testing and debugging. They are not intended for use in normal operations.

- `--max-binlog-dump-events=N`

Command-Line Format	`--max-binlog-dump-events=#`	
Permitted Values	**Type**	`integer`
	Default	`0`

This option is used internally by the MySQL test suite for replication testing and debugging.

- `--sporadic-binlog-dump-fail`

Command-Line Format	`--sporadic-binlog-dump-fail`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This option is used internally by the MySQL test suite for replication testing and debugging.

System Variables Used with Binary Logging

The following list describes system variables for controlling binary logging. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used to control binary logging are listed earlier in this section. For information about the `sql_log_bin` and `sql_log_off` variables, see Section 5.1.4, "Server System Variables".

- `binlog_cache_size`

Command-Line Format	`--binlog_cache_size=#`	
System Variable	**Name**	`binlog_cache_size`
	Variable Scope	Global
	Dynamic Variable	Yes

Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`32768`
	Min Value	`4096`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`32768`
	Min Value	`4096`
	Max Value	`18446744073709547520`

The size of the cache to hold the SQL statements for the binary log during a transaction. A binary log cache is allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large, multiple-statement transactions, you can increase this cache size to get better performance. The `Binlog_cache_use` and `Binlog_cache_disk_use` status variables can be useful for tuning the size of this variable. See Section 5.4.4, "The Binary Log".

- `binlog_direct_non_transactional_updates`

Introduced	5.1.44
Command-Line Format	`--binlog_direct_non_transactional_updates[=value]`
System Variable	**Name**	`binlog_direct_non_transactional_updates`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Due to concurrency issues, a slave can become inconsistent when a transaction contains updates to both transactional and nontransactional tables. MySQL tries to preserve causality among these statements by writing nontransactional statements to the transaction cache, which is flushed upon commit. However, problems arise when modifications done to nontransactional tables on behalf of a transaction become immediately visible to other connections because these changes may not be written immediately into the binary log.

Beginning with MySQL 5.1.44, the `binlog_direct_non_transactional_updates` variable offers one possible workaround to this issue. By default, this variable is disabled. Enabling `binlog_direct_non_transactional_updates` causes updates to nontransactional tables to be written directly to the binary log, rather than to the transaction cache.

`binlog_direct_non_transactional_updates` works only for statements that are replicated using the statement-based binary logging format; that is, it works only when the value of `binlog_format` is `STATEMENT`, or when `binlog_format` is `MIXED` and a given statement is being replicated using the statement-based format. This variable has no effect when the binary log format is `ROW`, or when `binlog_format` is set to `MIXED` and a given statement is replicated using the row-based format.

Important

Before enabling this variable, you must make certain that there are no dependencies between transactional and nontransactional tables; an example of such a dependency would be the statement `INSERT INTO myisam_table SELECT * FROM innodb_table`. Otherwise, such statements are likely to cause the slave to diverge from the master.

- `binlog_format`

Introduced	5.1.5	
Command-Line Format	`--binlog-format=format`	
System Variable (>= 5.1.8)	**Name**	`binlog_format`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (>= 5.1.5, <= 5.1.7)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
Permitted Values (>= 5.1.8, <= 5.1.11)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.12, <= 5.1.28)	**Type**	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.29)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.14-ndb-6.1.0, <= 5.1.15-ndb-6.1.23)	**Type**	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`

Permitted Values (>= 5.1.16-ndb-6.2.0, <= 5.1.34-ndb-6.2.18)	Type	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.19-ndb-6.3.0, <= 5.1.73-ndb-6.3.54)	Type	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.32-ndb-7.0.4, <= 5.1.73-ndb-7.0.42)	Type	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.1.39-ndb-7.1.0, <= 5.1.51-ndb-7.2.0)	Type	`enumeration`
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`

This variable sets the binary logging format, and can be any one of `STATEMENT`, `ROW`, or `MIXED`. See Section 16.1.2, "Replication Formats". `binlog_format` is set by the `--binlog-format` option at startup, or by the `binlog_format` variable at runtime.

> **Note**
>
> While you can change the logging format at runtime, it is *not* recommended that you change it while replication is ongoing. This is due in part to the fact that slaves do not honor the master's `binlog_format` setting; a given MySQL Server can change only its own logging format.

The startup variable was added in MySQL 5.1.5, and the runtime variable in MySQL 5.1.8. `MIXED` was added in MySQL 5.1.8.

`STATEMENT` was used by default prior to MySQL 5.1.12; in MySQL 5.1.12, the default was changed to `MIXED`. In MySQL 5.1.29, the default was changed back to `STATEMENT`.

You must have the `SUPER` privilege to set the global `binlog_format` value. Starting with MySQL 5.1.29, you must have the `SUPER` privilege to set either the global or session `binlog_format` value. (Bug #39106)

The rules governing when changes to this variable take effect and how long the effect lasts are the same as for other MySQL server system variables. For more information, see Section 13.7.4.1, "SET Syntax for Variable Assignment".

When `MIXED` is specified, statement-based replication is used, except for cases where only row-based replication is guaranteed to lead to proper results. For example, this happens when statements contain user-defined functions (UDF) or the `UUID()` function. An exception to this rule is that `MIXED` always uses statement-based replication for stored functions and triggers.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger.

- If the `NDBCLUSTER` storage engine is enabled.

- If the session is currently in row-based replication mode and has open temporary tables.

Trying to switch the format in those cases results in an error.

Before MySQL 5.1.8, switching to row-based replication format would implicitly set `--log-bin-trust-function-creators=1` and `--innodb_locks_unsafe_for_binlog`. This does not occur for MySQL 5.1.8 and later.

The binary log format affects the behavior of the following server options:

- `--replicate-do-db`

- `--replicate-ignore-db`

- `--binlog-do-db`

- `--binlog-ignore-db`

These effects are discussed in detail in the descriptions of the individual options.

- `log_bin`

System Variable	Name	`log_bin`
	Variable Scope	Global
	Dynamic Variable	No

Whether the binary log is enabled. If the `--log-bin` option is used, then the value of this variable is `ON`; otherwise it is `OFF`. This variable reports only on the status of binary logging (enabled or disabled); it does not actually report the value to which `--log-bin` is set.

See Section 5.4.4, "The Binary Log".

- `log_bin_use_v1_row_events`

Introduced	5.1.56-ndb-7.1.16
Command-Line Format	`--log-bin-use-v1-row-events[={0|1}]`
System Variable	**Name**	`log_bin_use_v1_row_events`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values (>= 5.1.56-ndb-7.0.27)	**Type**	`boolean`
	Default	`1`
Permitted Values (>= 5.1.56-ndb-7.1.16)	**Type**	`boolean`
	Default	`1`

Shows whether Version 2 binary logging, available beginning with MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, is in use. A value of 1 shows that the server is writing the binary log using Version 1 logging events (the only version of binary log events used in previous releases), and thus producing a binary log that can be read by older slaves. 0 indicates that Version 2 binary log events are in use.

This variable is read-only. To switch between Version 1 and Version 2 binary event binary logging, it is necessary to restart `mysqld` with the `--log-bin-use-v1-row-events` option.

Other than when performing upgrades of MySQL Cluster Replication, `--log-bin-use-v1-events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB$EPOCH_TRANS()`, which requires Version 2 binary row event logging. Thus, this option and `--ndb-log-transaction-id` are not compatible.

> **Note**
>
> MySQL Cluster NDB 7.2.1 and later use Version 2 binary log row events by default (and so the default value for this variable changes to 0 in those versions). You should keep this mind when planning upgrades for setups using MySQL Cluster Replication.

This variable is not supported in mainline MySQL Server 5.1.

For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `log_slave_updates`

Command-Line Format	`--log-slave-updates`	
System Variable	**Name**	`log_slave_updates`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Whether updates received by a slave server from a master server should be logged to the slave's own binary log. Binary logging must be enabled on the slave for this variable to have any effect. See Section 16.1.3, "Replication and Binary Logging Options and Variables".

- `max_binlog_cache_size`

Command-Line Format	`--max_binlog_cache_size=#`	
System Variable	**Name**	`max_binlog_cache_size`

	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (>= 5.1.36)	**Type**	`integer`
	Default	`18446744073709547520`
	Min Value	`4096`
	Max Value	`18446744073709547520`
Permitted Values (32-bit platforms, <= 5.1.35)	**Type**	`integer`
	Default	`4294967295`
	Min Value	`4096`
	Max Value	`4294967295`
Permitted Values (64-bit platforms, <= 5.1.35)	**Type**	`integer`
	Default	`18446744073709547520`
	Min Value	`4096`
	Max Value	`18446744073709547520`

If a multiple-statement transaction requires more than this many bytes of memory, the server generates a `Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage` error. The minimum value is 4096. The maximum and default values are 4GB on 32-bit platforms and 16EB (exabytes) on 64-bit platforms. As of MySQL 5.1.36, the maximum value is 16EB (exabytes) on all platforms. The maximum recommended value is 4GB; this is due to the fact that MySQL currently cannot work with binary log positions greater than 4GB.

In MySQL 5.1, a change in `max_binlog_cache_size` takes immediate effect for all active sessions.

- `max_binlog_size`

Command-Line Format	`--max_binlog_size=#`	
System Variable	**Name**	`max_binlog_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1073741824`
	Min Value	`4096`
	Max Value	`1073741824`

If a write to the binary log causes the current log file size to exceed the value of this variable, the server rotates the binary logs (closes the current file and opens the next one). The minimum value is 4096 bytes. The maximum and default value is 1GB.

A transaction is written in one chunk to the binary log, so it is never split between several binary logs. Therefore, if you have big transactions, you might see binary log files larger than `max_binlog_size`.

If `max_relay_log_size` is 0, the value of `max_binlog_size` applies to relay logs as well.

- `sync_binlog`

Command-Line Format	`--sync-binlog=#`	
System Variable	**Name**	`sync_binlog`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`18446744073709547520`

If the value of this variable is greater than 0, the MySQL server synchronizes its binary log to disk (using `fdatasync()`) after every `sync_binlog` writes to the binary log. There is one write to the binary log per statement if autocommit is enabled, and one write per transaction otherwise. The default value of `sync_binlog` is 0, which does no synchronizing to disk—in this case, the server relies on the operating system to flush the binary log's contents from time to time as for any other file. A value of 1 is the safest choice because in the event of a crash you lose at most one statement or transaction from the binary log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

16.1.4 Common Replication Administration Tasks

Once replication has been started it should execute without requiring much regular administration. Depending on your replication environment, you will want to check the replication status of each slave periodically, daily, or even more frequently.

16.1.4.1 Checking Replication Status

The most common task when managing a replication process is to ensure that replication is taking place and that there have been no errors between the slave and the master. The primary statement for this is `SHOW SLAVE STATUS`, which you must execute on each slave:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
               Slave_IO_State: Waiting for master to send event
                  Master_Host: master1
                  Master_User: root
                  Master_Port: 3306
                Connect_Retry: 60
              Master_Log_File: mysql-bin.000004
          Read_Master_Log_Pos: 931
               Relay_Log_File: slave1-relay-bin.000056
                Relay_Log_Pos: 950
        Relay_Master_Log_File: mysql-bin.000004
             Slave_IO_Running: Yes
            Slave_SQL_Running: Yes
              Replicate_Do_DB:
          Replicate_Ignore_DB:
           Replicate_Do_Table:
       Replicate_Ignore_Table:
      Replicate_Wild_Do_Table:
  Replicate_Wild_Ignore_Table:
                   Last_Errno: 0
                   Last_Error:
                 Skip_Counter: 0
          Exec_Master_Log_Pos: 931
              Relay_Log_Space: 1365
              Until_Condition: None
               Until_Log_File:
                Until_Log_Pos: 0
           Master_SSL_Allowed: No
           Master_SSL_CA_File:
           Master_SSL_CA_Path:
              Master_SSL_Cert:
            Master_SSL_Cipher:
               Master_SSL_Key:
        Seconds_Behind_Master: 0
Master_SSL_Verify_Server_Cert: No
                Last_IO_Errno: 0
                Last_IO_Error:
               Last_SQL_Errno: 0
               Last_SQL_Error:
```

The key fields from the status report to examine are:

- `Slave_IO_State`: The current status of the slave. See Section 8.14.6, "Replication Slave I/O Thread States", and Section 8.14.7, "Replication Slave SQL Thread States", for more information.

- `Slave_IO_Running`: Whether the I/O thread for reading the master's binary log is running. Normally, you want this to be `Yes` unless you have not yet started replication or have explicitly stopped it with `STOP SLAVE`.

- `Slave_SQL_Running`: Whether the SQL thread for executing events in the relay log is running. As with the I/O thread, this should normally be `Yes`.

- `Last_IO_Error`, `Last_SQL_Error`: The last errors registered by the I/O and SQL threads when processing the relay log. Ideally these should be blank, indicating no errors.

- `Seconds_Behind_Master`: The number of seconds that the slave SQL thread is behind processing the master binary log. A high number (or an increasing one) can indicate that the slave is unable to handle events from the master in a timely fashion.

  A value of 0 for `Seconds_Behind_Master` can usually be interpreted as meaning that the slave has caught up with the master, but there are some cases where this is not strictly true. For example, this can

occur if the network connection between master and slave is broken but the slave I/O thread has not yet noticed this—that is, `slave_net_timeout` has not yet elapsed.

It is also possible that transient values for `Seconds_Behind_Master` may not reflect the situation accurately. When the slave SQL thread has caught up on I/O, `Seconds_Behind_Master` displays 0; but when the slave I/O thread is still queuing up a new event, `Seconds_Behind_Master` may show a large value until the SQL thread finishes executing the new event. This is especially likely when the events have old timestamps; in such cases, if you execute `SHOW SLAVE STATUS` several times in a relatively short period, you may see this value change back and forth repeatedly between 0 and a relatively large value.

Several pairs of fields provide information about the progress of the slave in reading events from the master binary log and processing them in the relay log:

- (`Master_Log_file`, `Read_Master_Log_Pos`): Coordinates in the master binary log indicating how far the slave I/O thread has read events from that log.

- (`Relay_Master_Log_File`, `Exec_Master_Log_Pos`): Coordinates in the master binary log indicating how far the slave SQL thread has executed events received from that log.

- (`Relay_Log_File`, `Relay_Log_Pos`): Coordinates in the slave relay log indicating how far the slave SQL thread has executed the relay log. These correspond to the preceding coordinates, but are expressed in slave relay log coordinates rather than master binary log coordinates.

On the master, you can check the status of connected slaves using `SHOW PROCESSLIST` to examine the list of running processes. Slave connections have `Binlog Dump` in the `Command` field:

```
mysql> SHOW PROCESSLIST \G;
*************************** 4. row ***************************
     Id: 10
   User: root
   Host: slave1:58371
     db: NULL
Command: Binlog Dump
   Time: 777
  State: Has sent all binlog to slave; waiting for binlog to be updated
   Info: NULL
```

Because it is the slave that drives the replication process, very little information is available in this report.

For slaves that were started with the `--report-host` option and are connected to the master, the `SHOW SLAVE HOSTS` statement on the master shows basic information about the slaves. The output includes the ID of the slave server, the value of the `--report-host` option, the connecting port, and master ID:

```
mysql> SHOW SLAVE HOSTS;
+-----------+--------+------+-------------------+-----------+
| Server_id | Host   | Port | Rpl_recovery_rank | Master_id |
+-----------+--------+------+-------------------+-----------+
|        10 | slave1 | 3306 |                 0 |         1 |
+-----------+--------+------+-------------------+-----------+
1 row in set (0.00 sec)
```

16.1.4.2 Pausing Replication on the Slave

You can stop and start the replication of statements on the slave using the `STOP SLAVE` and `START SLAVE` statements.

To stop processing of the binary log from the master, use `STOP SLAVE`:

```
mysql> STOP SLAVE;
```

When replication is stopped, the slave I/O thread stops reading events from the master binary log and writing them to the relay log, and the SQL thread stops reading events from the relay log and executing them. You can pause the I/O or SQL thread individually by specifying the thread type:

```
mysql> STOP SLAVE IO_THREAD;
mysql> STOP SLAVE SQL_THREAD;
```

To start execution again, use the START SLAVE statement:

```
mysql> START SLAVE;
```

To start a particular thread, specify the thread type:

```
mysql> START SLAVE IO_THREAD;
mysql> START SLAVE SQL_THREAD;
```

For a slave that performs updates only by processing events from the master, stopping only the SQL thread can be useful if you want to perform a backup or other task. The I/O thread will continue to read events from the master but they are not executed. This makes it easier for the slave to catch up when you restart the SQL thread.

Stopping only the I/O thread enables the events in the relay log to be executed by the SQL thread up to the point where the relay log ends. This can be useful when you want to pause execution to catch up with events already received from the master, when you want to perform administration on the slave but also ensure that it has processed all updates to a specific point. This method can also be used to pause event receipt on the slave while you conduct administration on the master. Stopping the I/O thread but permitting the SQL thread to run helps ensure that there is not a massive backlog of events to be executed when replication is started again.

16.2 Replication Implementation

Replication is based on the master server keeping track of all changes to its databases (updates, deletes, and so on) in its binary log. The binary log serves as a written record of all events that modify database structure or content (data) from the moment the server was started. Typically, SELECT statements are not recorded because they modify neither database structure nor content.

Each slave that connects to the master requests a copy of the binary log. That is, it pulls the data from the master, rather than the master pushing the data to the slave. The slave also executes the events from the binary log that it receives. This has the effect of repeating the original changes just as they were made on the master. Tables are created or their structure modified, and data is inserted, deleted, and updated according to the changes that were originally made on the master.

Because each slave is independent, the replaying of the changes from the master's binary log occurs independently on each slave that is connected to the master. In addition, because each slave receives a copy of the binary log only by requesting it from the master, the slave is able to read and update the copy of the database at its own pace and can start and stop the replication process at will without affecting the ability to update to the latest database status on either the master or slave side.

For more information on the specifics of the replication implementation, see Section 16.2.1, "Replication Implementation Details".

Masters and slaves report their status in respect of the replication process regularly so that you can monitor them. See Section 8.14, "Examining Thread Information", for descriptions of all replicated-related states.

The master binary log is written to a local relay log on the slave before it is processed. The slave also records information about the current position with the master's binary log and the local relay log. See Section 16.2.2, "Replication Relay and Status Logs".

Database changes are filtered on the slave according to a set of rules that are applied according to the various configuration options and variables that control event evaluation. For details on how these rules are applied, see Section 16.2.3, "How Servers Evaluate Replication Filtering Rules".

16.2.1 Replication Implementation Details

MySQL replication capabilities are implemented using three threads, one on the master server and two on the slave:

- **Binlog dump thread.**   The master creates a thread to send the binary log contents to a slave when the slave connects. This thread can be identified in the output of `SHOW PROCESSLIST` on the master as the `Binlog Dump` thread.

  The binary log dump thread acquires a lock on the master's binary log for reading each event that is to be sent to the slave. As soon as the event has been read, the lock is released, even before the event is sent to the slave.

- **Slave I/O thread.**   When a `START SLAVE` statement is issued on a slave server, the slave creates an I/O thread, which connects to the master and asks it to send the updates recorded in its binary logs.

  The slave I/O thread reads the updates that the master's `Binlog Dump` thread sends (see previous item) and copies them to local files that comprise the slave's relay log.

  The state of this thread is shown as `Slave_IO_running` in the output of `SHOW SLAVE STATUS` or as `Slave_running` in the output of `SHOW STATUS`.

- **Slave SQL thread.**   The slave creates an SQL thread to read the relay log that is written by the slave I/O thread and execute the events contained therein.

In the preceding description, there are three threads per master/slave connection. A master that has multiple slaves creates one binary log dump thread for each currently connected slave, and each slave has its own I/O and SQL threads.

A slave uses two threads to separate reading updates from the master and executing them into independent tasks. Thus, the task of reading statements is not slowed down if statement execution is slow. For example, if the slave server has not been running for a while, its I/O thread can quickly fetch all the binary log contents from the master when the slave starts, even if the SQL thread lags far behind. If the slave stops before the SQL thread has executed all the fetched statements, the I/O thread has at least fetched everything so that a safe copy of the statements is stored locally in the slave's relay logs, ready for execution the next time that the slave starts. This enables the master server to purge its binary logs sooner because it no longer needs to wait for the slave to fetch their contents.

The `SHOW PROCESSLIST` statement provides information that tells you what is happening on the master and on the slave regarding replication. For information on master states, see Section 8.14.5, "Replication Master Thread States". For slave states, see Section 8.14.6, "Replication Slave I/O Thread States", and Section 8.14.7, "Replication Slave SQL Thread States".

The following example illustrates how the three threads show up in the output from `SHOW PROCESSLIST`.

On the master server, the output from SHOW PROCESSLIST looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 2
   User: root
   Host: localhost:32931
     db: NULL
Command: Binlog Dump
   Time: 94
  State: Has sent all binlog to slave; waiting for binlog to
         be updated
   Info: NULL
```

Here, thread 2 is a Binlog Dump replication thread that services a connected slave. The State information indicates that all outstanding updates have been sent to the slave and that the master is waiting for more updates to occur. If you see no Binlog Dump threads on a master server, this means that replication is not running; that is, no slaves are currently connected.

On a slave server, the output from SHOW PROCESSLIST looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 10
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Waiting for master to send event
   Info: NULL
*************************** 2. row ***************************
     Id: 11
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Has read all relay log; waiting for the slave I/O
         thread to update it
   Info: NULL
```

The State information indicates that thread 10 is the I/O thread that is communicating with the master server, and thread 11 is the SQL thread that is processing the updates stored in the relay logs. At the time that SHOW PROCESSLIST was run, both threads were idle, waiting for further updates.

The value in the Time column can show how late the slave is compared to the master. See Section A.13, "MySQL 5.1 FAQ: Replication". If sufficient time elapses on the master side without activity on the Binlog Dump thread, the master determines that the slave is no longer connected. As for any other client connection, the timeouts for this depend on the values of net_write_timeout and net_retry_count; for more information about these, see Section 5.1.4, "Server System Variables".

The SHOW SLAVE STATUS statement provides additional information about replication processing on a slave server. See Section 16.1.4.1, "Checking Replication Status".

16.2.2 Replication Relay and Status Logs

During replication, a slave server creates several logs that hold the binary log events relayed from the master to the slave, and to record information about the current status and location within the relay log. There are three types of logs used in the process, listed here:

- The *relay log* consists of the events read from the binary log of the master and written by the slave I/O thread. Events in the relay log are executed on the slave as part of the SQL thread.

- The *master info log* contains status and current configuration information for the slave's connection to the master. This log holds information on the master host name, login credentials, and coordinates indicating how far the slave has read from the master's binary log.

- The *relay log info log* holds status information about the execution point within the slave's relay log.

16.2.2.1 The Slave Relay Log

The relay log, like the binary log, consists of a set of numbered files containing events that describe database changes, and an index file that contains the names of all used relay log files.

The term "relay log file" generally denotes an individual numbered file containing database events. The term "relay log" collectively denotes the set of numbered relay log files plus the index file.

Relay log files have the same format as binary log files and can be read using `mysqlbinlog` (see Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files").

By default, relay log file names have the form *host_name*-relay-bin.*nnnnnn* in the data directory, where *host_name* is the name of the slave server host and *nnnnnn* is a sequence number. Successive relay log files are created using successive sequence numbers, beginning with `000001`. The slave uses an index file to track the relay log files currently in use. The default relay log index file name is *host_name-relay-bin.index* in the data directory.

The default relay log file and relay log index file names can be overridden with, respectively, the `--relay-log` and `--relay-log-index` server options (see Section 16.1.3, "Replication and Binary Logging Options and Variables").

If a slave uses the default host-based relay log file names, changing a slave's host name after replication has been set up can cause replication to fail with the errors `Failed to open the relay log` and `Could not find target log during relay log initialization`. This is a known issue (see Bug #2122). If you anticipate that a slave's host name might change in the future (for example, if networking is set up on the slave such that its host name can be modified using DHCP), you can avoid this issue entirely by using the `--relay-log` and `--relay-log-index` options to specify relay log file names explicitly when you initially set up the slave. This will make the names independent of server host name changes.

If you encounter the issue after replication has already begun, one way to work around it is to stop the slave server, prepend the contents of the old relay log index file to the new one, and then restart the slave. On a Unix system, this can be done as shown here:

```
shell> cat new_relay_log_name.index >> old_relay_log_name.index
shell> mv old_relay_log_name.index new_relay_log_name.index
```

A slave server creates a new relay log file under the following conditions:

- Each time the I/O thread starts.

- When the logs are flushed; for example, with `FLUSH LOGS` or `mysqladmin flush-logs`.

- When the size of the current relay log file becomes "too large," determined as follows:

  - If the value of `max_relay_log_size` is greater than 0, that is the maximum relay log file size.

- If the value of `max_relay_log_size` is 0, `max_binlog_size` determines the maximum relay log file size.

The SQL thread automatically deletes each relay log file as soon as it has executed all events in the file and no longer needs it. There is no explicit mechanism for deleting relay logs because the SQL thread takes care of doing so. However, `FLUSH LOGS` rotates relay logs, which influences when the SQL thread deletes them.

16.2.2.2 Slave Status Logs

A replication slave server creates two logs. By default, these logs are files named `master.info` and `relay-log.info` and created in the data directory. The names and locations of these files can be changed by using the `--master-info-file` and `--relay-log-info-file` options, respectively. See Section 16.1.3, "Replication and Binary Logging Options and Variables".

The two status logs contain information like that shown in the output of the `SHOW SLAVE STATUS` statement, which is discussed in Section 13.4.2, "SQL Statements for Controlling Slave Servers". Because the status logs are stored on disk, they survive a slave server's shutdown. The next time the slave starts up, it reads the two logs to determine how far it has proceeded in reading binary logs from the master and in processing its own relay logs.

The master info log should be protected because it contains the password for connecting to the master. See Section 6.1.2.3, "Passwords and Logging".

The slave I/O thread updates the master info log. The following table shows the correspondence between the lines in the `master.info` file and the columns displayed by `SHOW SLAVE STATUS`.

Line in `master.info`	`SHOW SLAVE STATUS` Column	Description
1		Number of lines in the file
2	`Master_Log_File`	The name of the master binary log currently being read from the master
3	`Read_Master_Log_Pos`	The current position within the master binary log that have been read from the master
4	`Master_Host`	The host name of the master
5	`Master_User`	The user name used to connect to the master
6	Password (not shown by `SHOW SLAVE STATUS`)	The password used to connect to the master
7	`Master_Port`	The network port used to connect to the master
8	`Connect_Retry`	The period (in seconds) that the slave will wait before trying to reconnect to the master
9	`Master_SSL_Allowed`	Indicates whether the server supports SSL connections
10	`Master_SSL_CA_File`	The file used for the Certificate Authority (CA) certificate
11	`Master_SSL_CA_Path`	The path to the Certificate Authority (CA) certificates
12	`Master_SSL_Cert`	The name of the SSL certificate file

Line in `master.info`	`SHOW SLAVE STATUS` Column	Description
13	`Master_SSL_Cipher`	The list of possible ciphers used in the handshake for the SSL connection
14	`Master_SSL_Key`	The name of the SSL key file
15	`Master_SSL_Verify_Server_Cert`	Whether to verify the server certificate (added in MySQL 5.1.18)

The slave SQL thread updates the relay log info log. The following table shows the correspondence between the lines in the `relay-log.info` file and the columns displayed by `SHOW SLAVE STATUS`.

Line in `relay-log.info`	`SHOW SLAVE STATUS` Column	Description
1	`Relay_Log_File`	The name of the current relay log file
2	`Relay_Log_Pos`	The current position within the relay log file; events up to this position have been executed on the slave database
3	`Relay_Master_Log_File`	The name of the master binary log file from which the events in the relay log file were read
4	`Exec_Master_Log_Pos`	The equivalent position within the master's binary log file of events that have already been executed

The contents of the `relay-log.info` file and the states shown by the `SHOW SLAVE STATUS` statement might not match if the `relay-log.info` file has not been flushed to disk. Ideally, you should only view `relay-log.info` on a slave that is offline (that is, `mysqld` is not running). For a running system, `SHOW SLAVE STATUS` should be used.

When you back up the slave's data, you should back up these two status logs, along with the relay log files. The status logs are needed to resume replication after you restore the data from the slave. If you lose the relay logs but still have the relay log info log, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. Of course, this requires that the binary logs still exist on the master.

16.2.3 How Servers Evaluate Replication Filtering Rules

If a master server does not write a statement to its binary log, the statement is not replicated. If the server does log the statement, the statement is sent to all slaves and each slave determines whether to execute it or ignore it.

On the master, you can control which databases to log changes for by using the `--binlog-do-db` and `--binlog-ignore-db` options to control binary logging. For a description of the rules that servers use in evaluating these options, see Section 16.2.3.1, "Evaluation of Database-Level Replication and Binary Logging Options". You should not use these options to control which databases and tables are replicated. Instead, use filtering on the slave to control the events that are executed on the slave.

On the slave side, decisions about whether to execute or ignore statements received from the master are made according to the `--replicate-*` options that the slave was started with. (See Section 16.1.3, "Replication and Binary Logging Options and Variables".)

In the simplest case, when there are no `--replicate-*` options, the slave executes all statements that it receives from the master. Otherwise, the result depends on the particular options given.

Database-level options (`--replicate-do-db`, `--replicate-ignore-db`) are checked first; see Section 16.2.3.1, "Evaluation of Database-Level Replication and Binary Logging Options", for a description of this process. If no database-level options are used, option checking proceeds to any table-level options that may be in use (see Section 16.2.3.2, "Evaluation of Table-Level Replication Options", for a discussion of these). If one or more database-level options are used but none are matched, the statement is not replicated.

To make it easier to determine what effect an option set will have, it is recommended that you avoid mixing "do" and "ignore" options, or wildcard and nonwildcard options. An example of the latter that may have unintended effects is the use of `--replicate-do-db` and `--replicate-wild-do-table` together, where `--replicate-wild-do-table` uses a pattern for the database name that matches the name given for `--replicate-do-db`. Suppose a replication slave is started with `--replicate-do-db=dbx` `--replicate-wild-do-table=db%.t1`. Then, suppose that on the master, you issue the statement `CREATE DATABASE dbx`. Although you might expect it, this statement is not replicated because it does not reference a table named `t1`.

If any `--replicate-rewrite-db` options were specified, they are applied before the `--replicate-*` filtering rules are tested.

> **Note**
>
> Database-level filtering options are case-sensitive on platforms supporting case sensitivity in filenames, whereas table-level filtering options are not (regardless of platform). This is true regardless of the value of the `lower_case_table_names` system variable. These are known issues which are fixed in MySQL 5.5.

16.2.3.1 Evaluation of Database-Level Replication and Binary Logging Options

When evaluating replication options, the slave begins by checking to see whether there are any `--replicate-do-db` or `--replicate-ignore-db` options that apply. When using `--binlog-do-db` or `--binlog-ignore-db`, the process is similar, but the options are checked on the master.

With statement-based replication, the default database is checked for a match. With row-based replication, the database where data is to be changed is the database that is checked. Regardless of the binary logging format, checking of database-level options proceeds as shown in the following diagram.
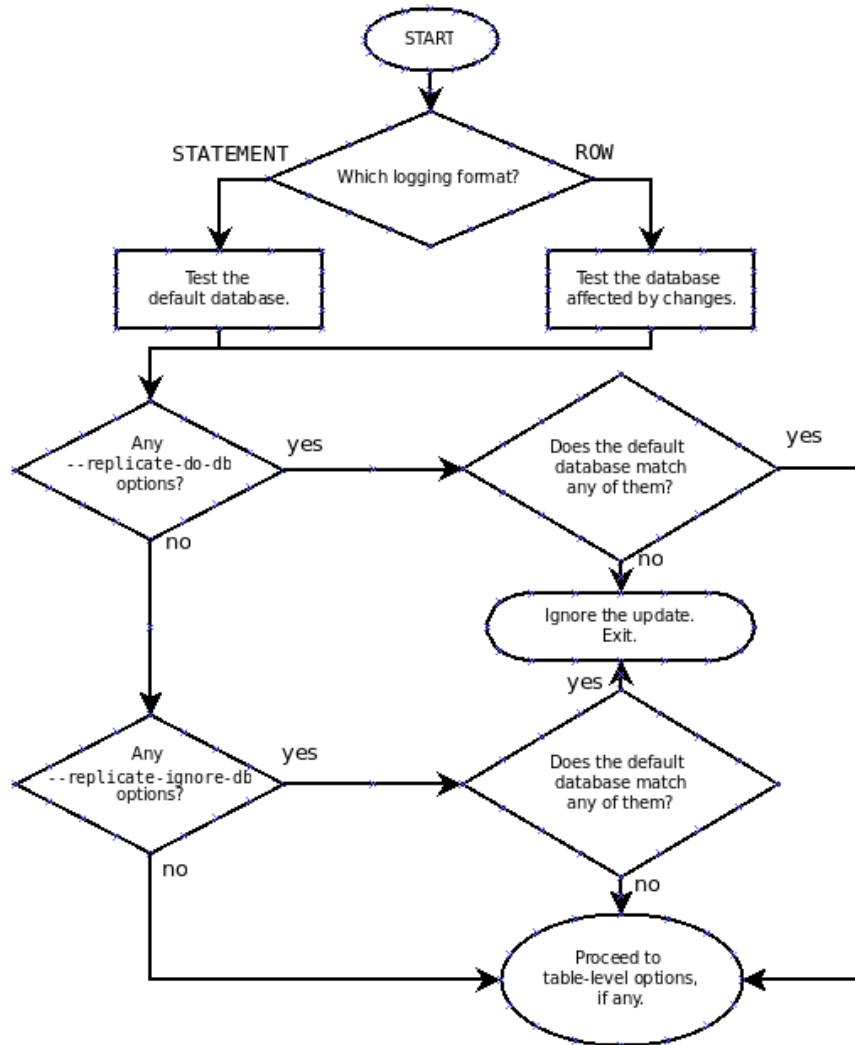
The steps involved are listed here:

1. Are there any `--replicate-do-db` options?

    *   **Yes.**   Do any of them match the database?

        *   **Yes.**   Execute the statement and exit.

        *   **No.**   Ignore the statement and exit.

    *   **No.**   Continue to step 2.

2. Are there any `--replicate-ignore-db` options?

    *   **Yes.**   Do any of them match the database?

        *   **Yes.**   Ignore the statement and exit.

        *   **No.**   Continue to step 3.

    *   **No.**   Continue to step 3.

3. Proceed to checking the table-level replication options, if there are any. For a description of how these options are checked, see Section 16.2.3.2, "Evaluation of Table-Level Replication Options".

> **Important**
>
> A statement that is still permitted at this stage is not yet actually executed. The statement is not executed until all table-level options (if any) have also been checked, and the outcome of that process permits execution of the statement.

For binary logging, the steps involved are listed here:

1. Are there any `--binlog-do-db` or `--binlog-ignore-db` options?

   - **Yes.** Continue to step 2.

   - **No.** Log the statement and exit.

2. Is there a default database (has any database been selected by `USE`)?

   - **Yes.** Continue to step 3.

   - **No.** Ignore the statement and exit.

3. There is a default database. Are there any `--binlog-do-db` options?

   - **Yes.** Do any of them match the database?

     - **Yes.** Log the statement and exit.

     - **No.** Ignore the statement and exit.

   - **No.** Continue to step 4.

4. Do any of the `--binlog-ignore-db` options match the database?

   - **Yes.** Ignore the statement and exit.

   - **No.** Log the statement and exit.

> **Important**
>
> For statement-based logging, an exception is made in the rules just given for the `CREATE DATABASE`, `ALTER DATABASE`, and `DROP DATABASE` statements. In those cases, the database being *created, altered, or dropped* replaces the default database when determining whether to log or ignore updates.

`--binlog-do-db` can sometimes mean "ignore other databases". For example, when using statement-based logging, a server running with only `--binlog-do-db=sales` does not write to the binary log statements for which the default database differs from `sales`. When using row-based logging with the same option, the server logs only those updates that change data in `sales`.

16.2.3.2 Evaluation of Table-Level Replication Options

The slave checks for and evaluates table options only if either of the following two conditions is true:

- No matching database options were found.

- One or more database options were found, and were evaluated to arrive at an "execute" condition according to the rules described in the previous section (see Section 16.2.3.1, "Evaluation of Database-Level Replication and Binary Logging Options").

First, as a preliminary condition, the slave checks whether statement-based replication is enabled. If so, and the statement occurs within a stored function, the slave executes the statement and exits. If row-based replication is enabled, the slave does not know whether a statement occurred within a stored function on the master, so this condition does not apply.

> **Note**
>
> For statement-based replication, replication events represent statements (all changes making up a given event are associated with a single SQL statement); for row-based replication, each event represents a change in a single table row (thus a single statement such as `UPDATE mytable SET mycol = 1` may yield many row-based events). When viewed in terms of events, the process of checking table options is the same for both row-based and statement-based replication.

Having reached this point, if there are no table options, the slave simply executes all events. If there are any `--replicate-do-table` or `--replicate-wild-do-table` options, the event must match one of these if it is to be executed; otherwise, it is ignored. If there are any `--replicate-ignore-table` or `--replicate-wild-ignore-table` options, all events are executed except those that match any of these options. This process is illustrated in the following diagram.
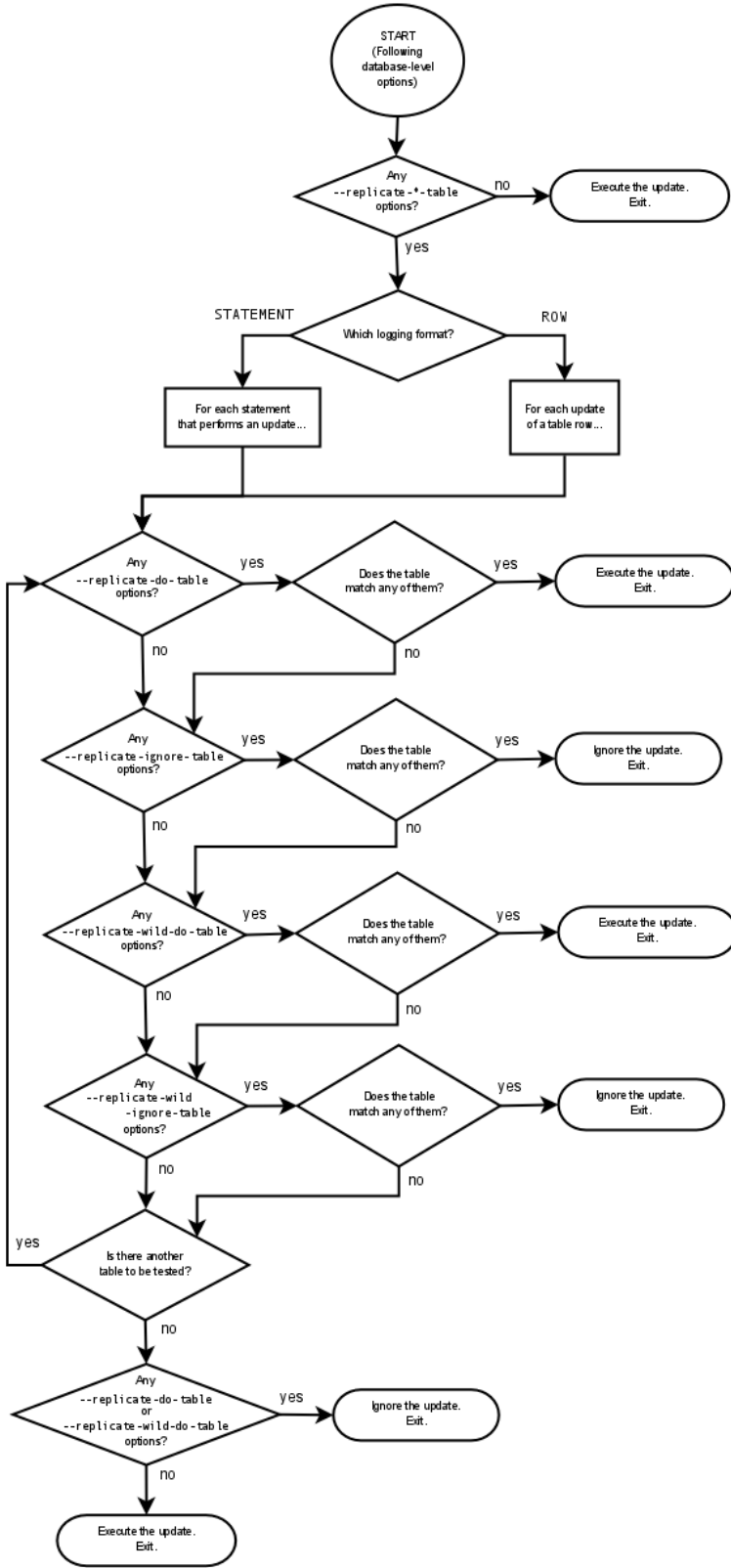
The following steps describe this evaluation in more detail:

1. Are there any table options?

   - **Yes.**   Continue to step 2.

   - **No.**   Execute the event and exit.

2. Are there any `--replicate-do-table` options?

   - **Yes.**   Does the table match any of them?

     - **Yes.**   Execute the event and exit.

     - **No.**   Continue to step 3.

   - **No.**   Continue to step 3.

3. Are there any `--replicate-ignore-table` options?

   - **Yes.**   Does the table match any of them?

     - **Yes.**   Ignore the event and exit.

     - **No.**   Continue to step 4.

   - **No.**   Continue to step 4.

4. Are there any `--replicate-wild-do-table` options?

   - **Yes.**   Does the table match any of them?

     - **Yes.**   Execute the event and exit.

     - **No.**   Continue to step 5.

   - **No.**   Continue to step 5.

5. Are there any `--replicate-wild-ignore-table` options?

   - **Yes.**   Does the table match any of them?

     - **Yes.**   Ignore the event and exit.

     - **No.**   Continue to step 6.

   - **No.**   Continue to step 6.

6. Are there any `--replicate-do-table` or `--replicate-wild-do-table` options?

   - **Yes.**   Ignore the event and exit.

   - **No.**   Execute the event and exit.

16.2.3.3 Replication Rule Application

This section provides additional explanation and examples of usage for different combinations of replication filtering options.

Some typical combinations of replication filter rule types are given in the following table:

Condition (Types of Options)	Outcome
No `--replicate-*` options at all:	The slave executes all events that it receives from the master.
`--replicate-*-db` options, but no table options:	The slave accepts or ignores events using the database options. It executes all events permitted by those options because there are no table restrictions.
`--replicate-*-table` options, but no database options:	All events are accepted at the database-checking stage because there are no database conditions. The slave executes or ignores events based solely on the table options.
A combination of database and table options:	The slave accepts or ignores events using the database options. Then it evaluates all events permitted by those options according to the table options. This can sometimes lead to results that seem counterintuitive, and that may be different depending on whether you are using statement-based or row-based replication; see the text for an example.

A more complex example follows, in which we examine the outcomes for both statement-based and row-based settings.

Suppose that we have two tables `mytbl1` in database `db1` and `mytbl2` in database `db2` on the master, and the slave is running with the following options (and no other replication filtering options):

```
replicate-ignore-db = db1
replicate-do-table  = db2.tbl2
```

Now we execute the following statements on the master:

```
USE db1;
INSERT INTO db2.tbl2 VALUES (1);
```

The results on the slave vary considerably depending on the binary log format, and may not match initial expectations in either case.

Statement-based replication.   The `USE` statement causes `db1` to be the default database. Thus the `--replicate-ignore-db` option matches, *and the `INSERT` statement is ignored.* The table options are not checked.

Row-based replication.   The default database has no effect on how the slave reads database options when using row-based replication. Thus, the `USE` statement makes no difference in how the `--replicate-ignore-db` option is handled: the database specified by this option does not match the database where the `INSERT` statement changes data, so the slave proceeds to check the table options. The table specified by `--replicate-do-table` matches the table to be updated, *and the row is inserted.*

16.3 Replication Solutions

Replication can be used in many different environments for a range of purposes. This section provides general notes and advice on using replication for specific solution types.

For information on using replication in a backup environment, including notes on the setup, backup procedure, and files to back up, see Section 16.3.1, "Using Replication for Backups".

For advice and tips on using different storage engines on the master and slaves, see Section 16.3.2, "Using Replication with Different Master and Slave Storage Engines".

Using replication as a scale-out solution requires some changes in the logic and operation of applications that use the solution. See Section 16.3.3, "Using Replication for Scale-Out".

For performance or data distribution reasons, you may want to replicate different databases to different replication slaves. See Section 16.3.4, "Replicating Different Databases to Different Slaves"

As the number of replication slaves increases, the load on the master can increase and lead to reduced performance (because of the need to replicate the binary log to each slave). For tips on improving your replication performance, including using a single secondary server as a replication master, see Section 16.3.5, "Improving Replication Performance".

For guidance on switching masters, or converting slaves into masters as part of an emergency failover solution, see Section 16.3.6, "Switching Masters During Failover".

To secure your replication communication, you can encrypt the communication channel. For step-by-step instructions, see Section 16.3.7, "Setting Up Replication to Use Secure Connections".

16.3.1 Using Replication for Backups

To use replication as a backup solution, replicate data from the master to a slave, and then back up the data slave. The slave can be paused and shut down without affecting the running operation of the master, so you can produce an effective snapshot of "live" data that would otherwise require the master to be shut down.

How you back up a database depends on its size and whether you are backing up only the data, or the data and the replication slave state so that you can rebuild the slave in the event of failure. There are therefore two choices:

- If you are using replication as a solution to enable you to back up the data on the master, and the size of your database is not too large, the `mysqldump` tool may be suitable. See Section 16.3.1.1, "Backing Up a Slave Using mysqldump".

- For larger databases, where `mysqldump` would be impractical or inefficient, you can back up the raw data files instead. Using the raw data files option also means that you can back up the binary and relay logs that will enable you to recreate the slave in the event of a slave failure. For more information, see Section 16.3.1.2, "Backing Up Raw Data from a Slave".

Another backup strategy, which can be used for either master or slave servers, is to put the server in a read-only state. The backup is performed against the read-only server, which then is changed back to its usual read/write operational status. See Section 16.3.1.3, "Backing Up a Master or Slave by Making It Read Only".

16.3.1.1 Backing Up a Slave Using mysqldump

Using `mysqldump` to create a copy of a database enables you to capture all of the data in the database in a format that enables the information to be imported into another instance of MySQL Server (see Section 4.5.4, "`mysqldump` — A Database Backup Program"). Because the format of the information is SQL statements, the file can easily be distributed and applied to running servers in the event that you need access to the data in an emergency. However, if the size of your data set is very large, `mysqldump` may be impractical.

When using `mysqldump`, you should stop replication on the slave before starting the dump process to ensure that the dump contains a consistent set of data:

1. Stop the slave from processing requests. You can stop replication completely on the slave using `mysqladmin`:

```
shell> mysqladmin stop-slave
```

Alternatively, you can stop only the slave SQL thread to pause event execution:

```
shell> mysql -e 'STOP SLAVE SQL_THREAD;'
```

This enables the slave to continue to receive data change events from the master's binary log and store them in the relay logs using the I/O thread, but prevents the slave from executing these events and changing its data. Within busy replication environments, permitting the I/O thread to run during backup may speed up the catch-up process when you restart the slave SQL thread.

2. Run `mysqldump` to dump your databases. You may either dump all databases or select databases to be dumped. For example, to dump all databases:

```
shell> mysqldump --all-databases > fulldb.dump
```

3. Once the dump has completed, start slave operations again:

```
shell> mysqladmin start-slave
```

In the preceding example, you may want to add login credentials (user name, password) to the commands, and bundle the process up into a script that you can run automatically each day.

If you use this approach, make sure you monitor the slave replication process to ensure that the time taken to run the backup does not affect the slave's ability to keep up with events from the master. See Section 16.1.4.1, "Checking Replication Status". If the slave is unable to keep up, you may want to add another slave and distribute the backup process. For an example of how to configure this scenario, see Section 16.3.4, "Replicating Different Databases to Different Slaves".

16.3.1.2 Backing Up Raw Data from a Slave

To guarantee the integrity of the files that are copied, backing up the raw data files on your MySQL replication slave should take place while your slave server is shut down. If the MySQL server is still running, background tasks may still be updating the database files, particularly those involving storage engines with background processes such as `InnoDB`. With `InnoDB`, these problems should be resolved during crash recovery, but since the slave server can be shut down during the backup process without affecting the execution of the master it makes sense to take advantage of this capability.

To shut down the server and back up the files:

1. Shut down the slave MySQL server:

```
shell> mysqladmin shutdown
```

2. Copy the data files. You can use any suitable copying or archive utility, including `cp`, `tar` or `WinZip`. For example, assuming that the data directory is located under the current directory, you can archive the entire directory as follows:

```
shell> tar cf /tmp/dbbackup.tar ./data
```

3. Start the MySQL server again. Under Unix:

```
shell> mysqld_safe &
```

Under Windows:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqld"
```

Normally you should back up the entire data directory for the slave MySQL server. If you want to be able to restore the data and operate as a slave (for example, in the event of failure of the slave), then in addition

to the slave's data, you should also back up the slave status files, `master.info` and `relay-log.info`, along with the relay log files. These files are needed to resume replication after you restore the slave's data.

If you lose the relay logs but still have the `relay-log.info` file, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. This requires that the binary logs still exist on the master server.

If your slave is replicating `LOAD DATA INFILE` statements, you should also back up any `SQL_LOAD-*` files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA INFILE` operations. The location of this directory is the value of the `--slave-load-tmpdir` option. If the server was not started with that option, the directory location is the value of the `tmpdir` system variable.

16.3.1.3 Backing Up a Master or Slave by Making It Read Only

It is possible to back up either master or slave servers in a replication setup by acquiring a global read lock and manipulating the `read_only` system variable to change the read-only state of the server to be backed up:

1. Make the server read-only, so that it processes only retrievals and blocks updates.

2. Perform the backup.

3. Change the server back to its normal read/write state.

> **Note**
>
> The instructions in this section place the server to be backed up in a state that is safe for backup methods that get the data from the server, such as `mysqldump` (see Section 4.5.4, "`mysqldump` — A Database Backup Program"). You should not attempt to use these instructions to make a binary backup by copying files directly because the server may still have modified data cached in memory and not flushed to disk.
>
> These instructions also require MySQL 5.1.15 or higher. For earlier versions, setting `read_only` does not block while table locks or outstanding transactions are pending, so data changes can still occur during the backup operation and produce inconsistent backup results.

The following instructions describe how to do this for a master server and for a slave server. For both scenarios discussed here, suppose that you have the following replication setup:

• A master server M1

• A slave server S1 that has M1 as its master

• A client C1 connected to M1

• A client C2 connected to S1

In either scenario, the statements to acquire the global read lock and manipulate the `read_only` variable are performed on the server to be backed up and do not propagate to any slaves of that server.

Scenario 1: Backup with a Read-Only Master

Put the master M1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While M1 is in a read-only state, the following properties are true:

- Requests for updates sent by C1 to M1 will block because the server is in read-only mode.

- Requests for query results sent by C1 to M1 will succeed.

- Making a backup on M1 is safe.

- Making a backup on S1 is not safe. This server is still running, and might be processing the binary log or update requests coming from client C2

While M1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on M1 completes, restore M1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

Although performing the backup on M1 is safe (as far as the backup is concerned), it is not optimal for performance because clients of M1 are blocked from executing updates.

This strategy applies to backing up a master server in a replication setup, but can also be used for a single server in a nonreplication setting.

Scenario 2: Backup with a Read-Only Slave

Put the slave S1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While S1 is in a read-only state, the following properties are true:

- The master M1 will continue to operate, so making a backup on the master is not safe.

- The slave S1 is stopped, so making a backup on the slave S1 is safe.

These properties provide the basis for a popular backup scenario: Having one slave busy performing a backup for a while is not a problem because it does not affect the entire network, and the system is still running during the backup. In particular, clients can still perform updates on the master server, which remains unaffected by backup activity on the slave.

While S1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on S1 completes, restore S1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

After the slave is restored to normal operation, it again synchronizes to the master by catching up with any outstanding updates from the binary log of the master.

16.3.2 Using Replication with Different Master and Slave Storage Engines

It does not matter for the replication process whether the source table on the master and the replicated table on the slave use different engine types. In fact, the system variables `storage_engine` and `table_type` are not replicated.

This provides a number of benefits in the replication process in that you can take advantage of different engine types for different replication scenarios. For example, in a typical scale-out scenario (see Section 16.3.3, "Using Replication for Scale-Out"), you want to use `InnoDB` tables on the master to take advantage of the transactional functionality, but use `MyISAM` on the slaves where transaction support is not required because the data is only read. When using replication in a data-logging environment you may want to use the `Archive` storage engine on the slave.

Configuring different engines on the master and slave depends on how you set up the initial replication process:

- If you used `mysqldump` to create the database snapshot on your master, you could edit the dump file text to change the engine type used on each table.

  Another alternative for `mysqldump` is to disable engine types that you do not want to use on the slave before using the dump to build the data on the slave. For example, you can add the `--skip-innodb` option on your slave to disable the `InnoDB` engine. If a specific engine does not exist for a table to be created, MySQL will use the default engine type, usually `MyISAM`. (This requires that the `NO_ENGINE_SUBSTITUTION` SQL mode is not enabled.) If you want to disable additional engines in this way, you may want to consider building a special binary to be used on the slave that only supports the engines you want.

- If you are using raw data files (a binary backup) to set up the slave, you will be unable to change the initial table format. Instead, use `ALTER TABLE` to change the table types after the slave has been started.

- For new master/slave replication setups where there are currently no tables on the master, avoid specifying the engine type when creating new tables.

If you are already running a replication solution and want to convert your existing tables to another engine type, follow these steps:

1. Stop the slave from running replication updates:

   ```
   mysql> STOP SLAVE;
   ```

   This will enable you to change engine types without interruptions.

2. Execute an `ALTER TABLE ... ENGINE='engine_type'` for each table to be changed.

3. Start the slave replication process again:

   ```
   mysql> START SLAVE;
   ```

Although the `storage_engine` and `table_type` variables are not replicated, be aware that `CREATE TABLE` and `ALTER TABLE` statements that include the engine specification will be correctly replicated to the slave. For example, if you have a CSV table and you execute:

```
mysql> ALTER TABLE csvtable Engine='MyISAM';
```

The above statement will be replicated to the slave and the engine type on the slave will be converted to `MyISAM`, even if you have previously changed the table type on the slave to an engine other than CSV. If you want to retain engine differences on the master and slave, you should be careful to use the `storage_engine` variable on the master when creating a new table. For example, instead of:

```
mysql> CREATE TABLE tablea (columna int) Engine=MyISAM;
```

Use this format:

```
mysql> SET storage_engine=MyISAM;
mysql> CREATE TABLE tablea (columna int);
```

When replicated, the `storage_engine` variable will be ignored, and the `CREATE TABLE` statement will execute on the slave using the slave's default engine.

16.3.3 Using Replication for Scale-Out

You can use replication as a scale-out solution; that is, where you want to split up the load of database queries across multiple database servers, within some reasonable limitations.

Because replication works from the distribution of one master to one or more slaves, using replication for scale-out works best in an environment where you have a high number of reads and low number of writes/updates. Most Web sites fit into this category, where users are browsing the Web site, reading articles, posts, or viewing products. Updates only occur during session management, or when making a purchase or adding a comment/message to a forum.

Replication in this situation enables you to distribute the reads over the replication slaves, while still enabling your web servers to communicate with the replication master when a write is required. You can see a sample replication layout for this scenario in Figure 16.1, "Using Replication to Improve Performance During Scale-Out".

Figure 16.1 Using Replication to Improve Performance During Scale-Out
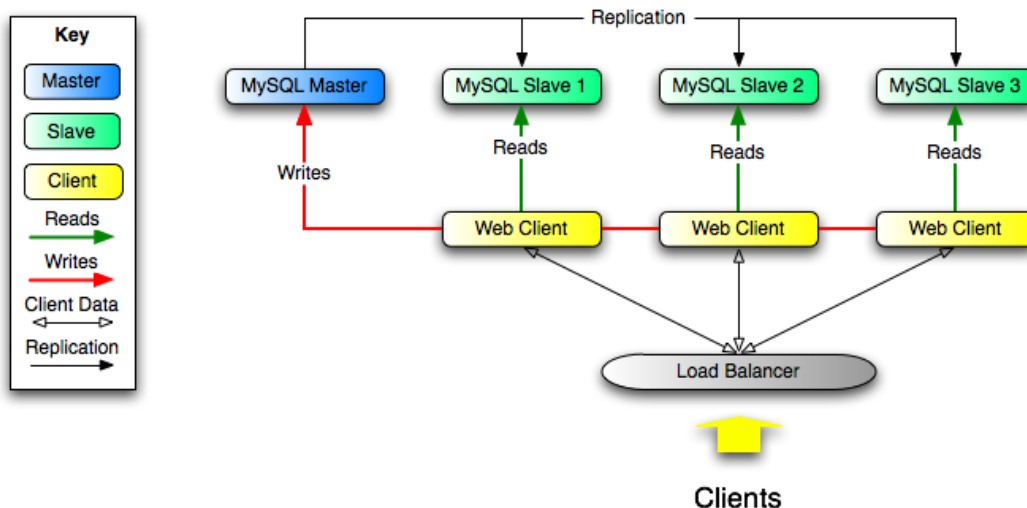
If the part of your code that is responsible for database access has been properly abstracted/modularized, converting it to run with a replicated setup should be very smooth and easy. Change the implementation of your database access to send all writes to the master, and to send reads to either the master or a slave. If your code does not have this level of abstraction, setting up a replicated system gives you the opportunity

and motivation to clean it up. Start by creating a wrapper library or module that implements the following functions:

- `safe_writer_connect()`

- `safe_reader_connect()`

- `safe_reader_statement()`

- `safe_writer_statement()`

`safe_` in each function name means that the function takes care of handling all error conditions. You can use different names for the functions. The important thing is to have a unified interface for connecting for reads, connecting for writes, doing a read, and doing a write.

Then convert your client code to use the wrapper library. This may be a painful and scary process at first, but it pays off in the long run. All applications that use the approach just described are able to take advantage of a master/slave configuration, even one involving multiple slaves. The code is much easier to maintain, and adding troubleshooting options is trivial. You need modify only one or two functions; for example, to log how long each statement took, or which statement among those issued gave you an error.

If you have written a lot of code, you may want to automate the conversion task by using the `replace` utility that comes with standard MySQL distributions, or write your own conversion script. Ideally, your code uses consistent programming style conventions. If not, then you are probably better off rewriting it anyway, or at least going through and manually regularizing it to use a consistent style.

16.3.4 Replicating Different Databases to Different Slaves

There may be situations where you have a single master and want to replicate different databases to different slaves. For example, you may want to distribute different sales data to different departments to help spread the load during data analysis. A sample of this layout is shown in Figure 16.2, "Using Replication to Replicate Databases to Separate Replication Slaves".

Figure 16.2 Using Replication to Replicate Databases to Separate Replication Slaves
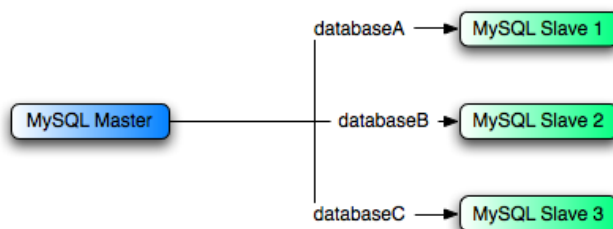
You can achieve this separation by configuring the master and slaves as normal, and then limiting the binary log statements that each slave processes by using the `--replicate-wild-do-table` configuration option on each slave.

> ⚠️ **Important**
>
> You should *not* use `--replicate-do-db` for this purpose when using statement-based replication, since statement-based replication causes this option's affects to vary according to the database that is currently selected. This applies to mixed-format replication as well, since this enables some updates to be replicated using the statement-based format.

> However, it should be safe to use `--replicate-do-db` for this purpose if you are using row-based replication only, since in this case the currently selected database has no effect on the option's operation.

For example, to support the separation as shown in Figure 16.2, "Using Replication to Replicate Databases to Separate Replication Slaves", you should configure each replication slave as follows, before executing `START SLAVE`:

- Replication slave 1 should use `--replicate-wild-do-table=databaseA.%`.

- Replication slave 2 should use `--replicate-wild-do-table=databaseB.%`.

- Replication slave 3 should use `--replicate-wild-do-table=databaseC.%`.

Each slave in this configuration receives the entire binary log from the master, but executes only those events from the binary log that apply to the databases and tables included by the `--replicate-wild-do-table` option in effect on that slave.

If you have data that must be synchronized to the slaves before replication starts, you have a number of choices:

- Synchronize all the data to each slave, and delete the databases, tables, or both that you do not want to keep.

- Use `mysqldump` to create a separate dump file for each database and load the appropriate dump file on each slave.

- Use a raw data file dump and include only the specific files and databases that you need for each slave.

> **Note**
>
> This does not work with `InnoDB` databases unless you use `innodb_file_per_table`.

16.3.5 Improving Replication Performance

As the number of slaves connecting to a master increases, the load, although minimal, also increases, as each slave uses a client connection to the master. Also, as each slave must receive a full copy of the master binary log, the network load on the master may also increase and create a bottleneck.

If you are using a large number of slaves connected to one master, and that master is also busy processing requests (for example, as part of a scale-out solution), then you may want to improve the performance of the replication process.

One way to improve the performance of the replication process is to create a deeper replication structure that enables the master to replicate to only one slave, and for the remaining slaves to connect to this primary slave for their individual replication requirements. A sample of this structure is shown in Figure 16.3, "Using an Additional Replication Host to Improve Performance".

Figure 16.3 Using an Additional Replication Host to Improve Performance
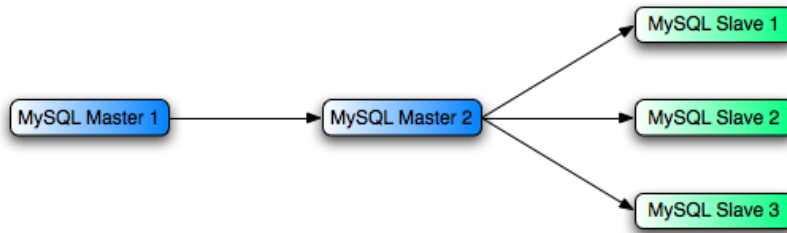
For this to work, you must configure the MySQL instances as follows:

- Master 1 is the primary master where all changes and updates are written to the database. Binary logging should be enabled on this machine.

- Master 2 is the slave to the Master 1 that provides the replication functionality to the remainder of the slaves in the replication structure. Master 2 is the only machine permitted to connect to Master 1. Master 2 also has binary logging enabled, and the `--log-slave-updates` option so that replication instructions from Master 1 are also written to Master 2's binary log so that they can then be replicated to the true slaves.

- Slave 1, Slave 2, and Slave 3 act as slaves to Master 2, and replicate the information from Master 2, which actually consists of the upgrades logged on Master 1.

The above solution reduces the client load and the network interface load on the primary master, which should improve the overall performance of the primary master when used as a direct database solution.

If your slaves are having trouble keeping up with the replication process on the master, there are a number of options available:

- If possible, put the relay logs and the data files on different physical drives. To do this, use the `--relay-log` option to specify the location of the relay log.

- If the slaves are significantly slower than the master, you may want to divide up the responsibility for replicating different databases to different slaves. See Section 16.3.4, "Replicating Different Databases to Different Slaves".

- If your master makes use of transactions and you are not concerned about transaction support on your slaves, use `MyISAM` or another nontransactional engine on the slaves. See Section 16.3.2, "Using Replication with Different Master and Slave Storage Engines".

- If your slaves are not acting as masters, and you have a potential solution in place to ensure that you can bring up a master in the event of failure, then you can switch off `--log-slave-updates`. This prevents "dumb" slaves from also logging events they have executed into their own binary log.

16.3.6 Switching Masters During Failover

There is in MySQL 5.1 no official solution for providing failover between master and slaves in the event of a failure. Instead, you must set up a master and one or more slaves; then, you need to write an application or script that monitors the master to check whether it is up, and instructs the slaves and applications to change master in case of failure. This section discusses some of the issues encountered when setting up failover in this fashion.

> **Note**
>
> The MySQL Utilities include a `mysqlfailover` tool that provides failover capability using GTIDs, support for which requires MySQL 5.6 or later. For more information, see `mysqlfailover` — Automatic replication health monitoring and failover, and Replication with Global Transaction Identifiers.

You can tell a slave to change to a new master using the `CHANGE MASTER TO` statement. The slave does not check whether the databases on the master are compatible with those on the slave; it simply begins reading and executing events from the specified coordinates in the new master's binary log. In a failover situation, all the servers in the group are typically executing the same events from the same binary log file, so changing the source of the events should not affect the structure or integrity of the database, provided that you exercise care in making the change.

Slaves should be run with the `--log-bin` option and without `--log-slave-updates`. In this way, the slave is ready to become a master without restarting the slave `mysqld`. Assume that you have the structure shown in Figure 16.4, "Redundancy Using Replication, Initial Structure".

Figure 16.4 Redundancy Using Replication, Initial Structure
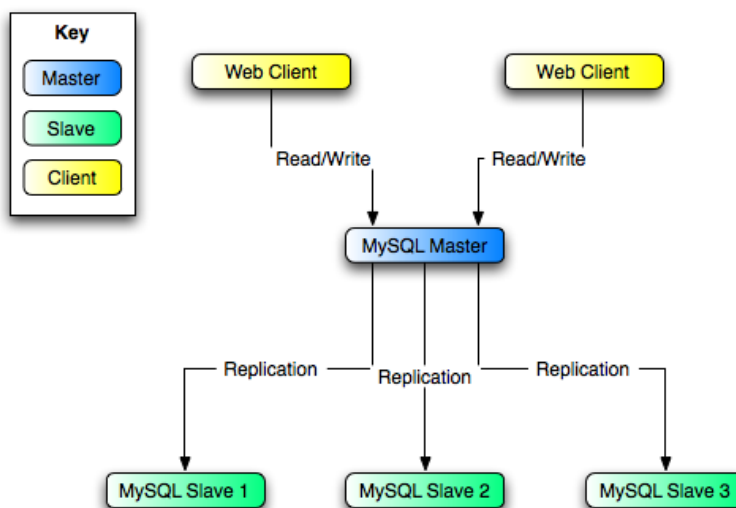
In this diagram, the `MySQL Master` holds the master database, the `MySQL Slave` hosts are replication slaves, and the `Web Client` machines are issuing database reads and writes. Web clients that issue only reads (and would normally be connected to the slaves) are not shown, as they do not need to switch to a new server in the event of failure. For a more detailed example of a read/write scale-out replication structure, see Section 16.3.3, "Using Replication for Scale-Out".

Each MySQL Slave (`Slave 1`, `Slave 2`, and `Slave 3`) is a slave running with `--log-bin` and without `--log-slave-updates`. Because updates received by a slave from the master are not logged in the binary log unless `--log-slave-updates` is specified, the binary log on each slave is empty initially. If for some reason `MySQL Master` becomes unavailable, you can pick one of the slaves to become the new master. For example, if you pick `Slave 1`, all `Web Clients` should be redirected to `Slave 1`, which writes the updates to its binary log. `Slave 2` and `Slave 3` should then replicate from `Slave 1`.

The reason for running the slave without `--log-slave-updates` is to prevent slaves from receiving updates twice in case you cause one of the slaves to become the new master. If `Slave 1` has `--log-slave-updates` enabled, it writes any updates that it receives from `Master` in its own binary log. This

means that, when `Slave 2` changes from `Master` to `Slave 1` as its master, it may receive updates from `Slave 1` that it has already received from `Master`.

Make sure that all slaves have processed any statements in their relay log. On each slave, issue `STOP SLAVE IO_THREAD`, then check the output of `SHOW PROCESSLIST` until you see `Has read all relay log`. When this is true for all slaves, they can be reconfigured to the new setup. On the slave `Slave 1` being promoted to become the master, issue `STOP SLAVE` and `RESET MASTER`.

On the other slaves `Slave 2` and `Slave 3`, use `STOP SLAVE` and `CHANGE MASTER TO MASTER_HOST='Slave1'` (where `'Slave1'` represents the real host name of `Slave 1`). To use `CHANGE MASTER TO`, add all information about how to connect to `Slave 1` from `Slave 2` or `Slave 3` (`user`, `password`, `port`). When issuing the `CHANGE MASTER TO` statement in this, there is no need to specify the name of the `Slave 1` binary log file or log position to read from, since the first binary log file and position 4, are the defaults. Finally, execute `START SLAVE` on `Slave 2` and `Slave 3`.

Once the new replication setup is in place, you need to tell each `Web Client` to direct its statements to `Slave 1`. From that point on, all updates statements sent by `Web Client` to `Slave 1` are written to the binary log of `Slave 1`, which then contains every update statement sent to `Slave 1` since `Master` died.

The resulting server structure is shown in Figure 16.5, "Redundancy Using Replication, After Master Failure".

Figure 16.5 Redundancy Using Replication, After Master Failure
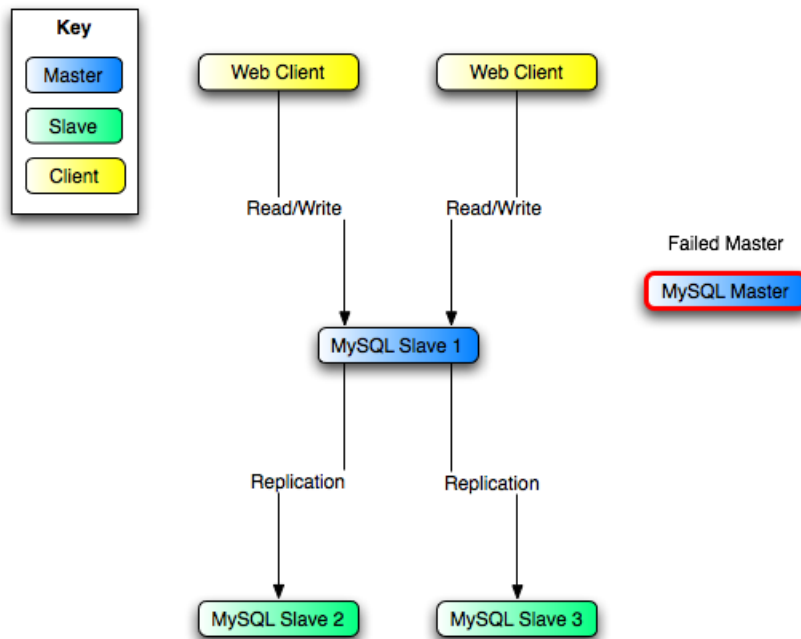
When `Master` becomes available again, you should make it a slave of `Slave 1`. To do this, issue on `Master` the same `CHANGE MASTER TO` statement as that issued on `Slave 2` and `Slave 3` previously. `Master` then becomes a slave of `Slave 1` and picks up the `Web Client` writes that it missed while it was offline.

To make `Master` a master again, use the preceding procedure as if `Slave 1` was unavailable and `Master` was to be the new master. During this procedure, do not forget to run `RESET MASTER` on `Master` before making `Slave 1`, `Slave 2`, and `Slave 3` slaves of `Master`. If you fail to do this, the slaves may

pick up stale writes from the `Web Client` applications dating from before the point at which `Master` became unavailable.

You should be aware that there is no synchronization between slaves, even when they share the same master, and thus some slaves might be considerably ahead of others. This means that in some cases the procedure outlined in the previous example might not work as expected. In practice, however, relay logs on all slaves should be relatively close together.

One way to keep applications informed about the location of the master is to have a dynamic DNS entry for the master. With `bind` you can use `nsupdate` to update the DNS dynamically.

16.3.7 Setting Up Replication to Use Secure Connections

To use a secure connection for encrypting the transfer of the binary log required during replication, both the master and the slave servers must support encrypted network connections. If either server does not support secure connections (because it has not been compiled or configured for them), replication through an encrypted connection is not possible.

Setting up secure connections for replication is similar to doing so for client/server connections. You must obtain (or create) a suitable security certificate that you can use on the master, and a similar certificate (from the same certificate authority) on each slave. You must also obtain suitable key files.

For more information on setting up a server and client for secure connections, see Section 6.4.4, "Configuring MySQL to Use Secure Connections".

To enable secure connections on the master, you must create or obtain suitable certificate and key files, and then add the following configuration options to the master's configuration within the `[mysqld]` section of the master's `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=cacert.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

The paths to the files may be relative or absolute; we recommend that you always use complete paths for this purpose.

The options are as follows:

- `ssl-ca` identifies the Certificate Authority (CA) certificate.

- `ssl-cert` identifies the server public key certificate. This can be sent to the client and authenticated against the CA certificate that it has.

- `ssl-key` identifies the server private key.

On the slave, there are two ways to specify the information required for connecting securely to the master. You can either name the slave certificate and key files in the `[client]` section of the slave's `my.cnf` file, or you can explicitly specify that information using the `CHANGE MASTER TO` statement:

- To name the slave certificate and key files using an option file, add the following lines to the `[client]` section of the slave's `my.cnf` file, changing the file names as necessary:

  ```
  [client]
  ssl-ca=cacert.pem
  ssl-cert=client-cert.pem
  ssl-key=client-key.pem
  ```

Restart the slave server, using the `--skip-slave-start` option to prevent the slave from connecting to the master. Use `CHANGE MASTER TO` to specify the master configuration, using the `MASTER_SSL` option to connect securely:

```
mysql> CHANGE MASTER TO
    -> MASTER_HOST='master_hostname',
    -> MASTER_USER='replicate',
    -> MASTER_PASSWORD='password',
    -> MASTER_SSL=1;
```

- To specify the certificate and key names using the `CHANGE MASTER TO` statement, append the appropriate `MASTER_SSL_xxx` options:

```
mysql> CHANGE MASTER TO
    -> MASTER_HOST='master_hostname',
    -> MASTER_USER='replicate',
    -> MASTER_PASSWORD='password',
    -> MASTER_SSL=1,
    -> MASTER_SSL_CA = 'ca_file_name',
    -> MASTER_SSL_CAPATH = 'ca_directory_name',
    -> MASTER_SSL_CERT = 'cert_file_name',
    -> MASTER_SSL_KEY = 'key_file_name';
```

After the master information has been updated, start the slave replication process:

```
mysql> START SLAVE;
```

You can use the `SHOW SLAVE STATUS` statement to confirm that a secure connection was established successfully.

For more information on the `CHANGE MASTER TO` statement, see Section 13.4.2.1, "CHANGE MASTER TO Syntax".

If you want to enforce the use of secure connections during replication, then create a user with the `REPLICATION SLAVE` privilege and use the `REQUIRE SSL` option for that user. For example:

```
mysql> CREATE USER 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass';
mysql> GRANT REPLICATION SLAVE ON *.*
    -> TO 'repl'@'%.mydomain.com' REQUIRE SSL;
```

If the account already exists, you can add `REQUIRE SSL` to it with this statement:

```
mysql> GRANT USAGE ON *.*
    -> TO 'repl'@'%.mydomain.com' REQUIRE SSL;
```

16.4 Replication Notes and Tips

16.4.1 Replication Features and Issues

The following sections provide information about what is supported and what is not in MySQL replication, and about specific issues and situations that may occur when replicating certain statements.

Statement-based replication depends on compatibility at the SQL level between the master and slave. In others, successful SBR requires that any SQL features used be supported by both the master and the slave servers. For example, if you use a feature on the master server that is available only in MySQL 5.1 (or later), you cannot replicate to a slave that uses MySQL 5.0 (or earlier).

Such incompatibilities also can occur within a release series when using pre-production releases of MySQL. For example, the `SLEEP()` function is available beginning with MySQL 5.0.12. If you use this function on the master, you cannot replicate to a slave that uses MySQL 5.0.11 or earlier.

For this reason, use Generally Available (GA) releases of MySQL for statement-based replication in a production setting, since we do not introduce new SQL statements or change their behavior within a given release series once that series reaches GA release status.

If you are planning to use statement-based replication between MySQL 5.1 and a previous MySQL release series, it is also a good idea to consult the edition of the *MySQL Reference Manual* corresponding to the earlier release series for information regarding the replication characteristics of that series.

With MySQL's statement-based replication, there may be issues with replicating stored routines or triggers. You can avoid these issues by using MySQL's row-based replication instead. For a detailed list of issues, see Section 19.7, "Binary Logging of Stored Programs". For more information about row-based logging and row-based replication, see Section 5.4.4.1, "Binary Logging Formats", and Section 16.1.2, "Replication Formats".

For additional information specific to replication and `InnoDB`, see Section 14.6.11, "InnoDB and MySQL Replication". For information relating to replication with MySQL Cluster, see Section 17.6, "MySQL Cluster Replication".

16.4.1.1 Replication and AUTO_INCREMENT

Statement-based replication of `AUTO_INCREMENT`, `LAST_INSERT_ID()`, and `TIMESTAMP` values is done correctly, subject to the following exceptions:

- When using statement-based replication, `AUTO_INCREMENT` columns in tables on the slave must match the same columns on the master; that is, `AUTO_INCREMENT` columns must be replicated to `AUTO_INCREMENT` columns.

  This is a known issue which is fixed in MySQL 5.5. (Bug #12669186)

- Prior to MySQL 5.1.12, a stored procedure that uses `LAST_INSERT_ID()` does not replicate properly using statement-based binary logging.

- Prior to MySQL 5.1.12, when a stored routine or trigger caused an `INSERT` into an `AUTO_INCREMENT` column, the generated `AUTO_INCREMENT` value was not written into the binary log, so a different value could in some cases be inserted on the slave.

- An insert into an `AUTO_INCREMENT` column caused by a stored routine or trigger running on a master that uses MySQL 5.0.60 or earlier does not replicate correctly to a slave running MySQL 5.1.12 through 5.1.23 (inclusive). (Bug #33029)

  A statement invoking a trigger or function that causes an update to an `AUTO_INCREMENT` column is not replicated correctly using statement-based replication. Beginning with MySQL 5.1.40, such statements are marked as unsafe. (Bug #45677)

- The `AUTO_INCREMENT` table option was not replicated correctly prior to MySQL 5.1.31. (Bug #41986)

- An `INSERT` into a table that has a composite primary key that includes an `AUTO_INCREMENT` column that is not the first column of this composite key is not safe for statement-based logging or replication. Beginning with MySQL 5.1.64, such statements are marked as unsafe. (Bug #11754117, Bug #45670)

  This issue does not affect tables using the `InnoDB` storage engine, since an `InnoDB` table with an AUTO_INCREMENT column requires at least one key where the auto-increment column is the only or leftmost column.

- Adding an `AUTO_INCREMENT` column to a table with `ALTER TABLE` might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to a table `t1` that has columns `col1` and `col2`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
```

> **Important**
>
> To guarantee the same ordering on both master and slave, the `ORDER BY` clause must name *all* columns of `t1`.

The instructions just given are subject to the limitations of `CREATE TABLE ... LIKE`: Foreign key definitions are ignored, as are the `DATA DIRECTORY` and `INDEX DIRECTORY` table options. If a table definition includes any of those characteristics, create `t2` using a `CREATE TABLE` statement that is identical to the one used to create `t1`, but with the addition of the `AUTO_INCREMENT` column.

Regardless of the method used to create and populate the copy having the `AUTO_INCREMENT` column, the final step is to drop the original table and then rename the copy:

```
DROP t1;
ALTER TABLE t2 RENAME t1;
```

See also Section B.5.6.1, "Problems with ALTER TABLE".

16.4.1.2 Replication and BLACKHOLE Tables

The `BLACKHOLE` storage engine accepts data but discards it and does not store it. When performing binary logging, all inserts to such tables are always logged, regardless of the logging format in use. Updates and deletes are handled differently depending on whether statement based or row based logging is in use. With the statement based logging format, all statements affecting `BLACKHOLE` tables are logged, but their effects ignored. When using row-based logging, updates and deletes to such tables are simply skipped— they are not written to the binary log.

For this reason we recommend when you replicate to tables using the `BLACKHOLE` storage engine that you have the `binlog_format` server variable set to `STATEMENT`, and not to either `ROW` or `MIXED`.

16.4.1.3 Replication and Character Sets

The following applies to replication between MySQL servers that use different character sets:

- If the master has databases with a character set different from the global `character_set_server` value, you should design your `CREATE TABLE` statements so that they do not implicitly rely on the database default character set. A good workaround is to state the character set and collation explicitly in `CREATE TABLE` statements.

16.4.1.4 Replication and CHECKSUM TABLE

`CHECKSUM TABLE` returns a checksum that is calculated row by row, using a method that depends on the table row storage format, which is not guaranteed to remain the same between MySQL release series.

For example, the storage format for `VARCHAR` changed between MySQL 4.1 and 5.0, so if a 4.1 table is upgraded to MySQL 5.0, the checksum value may change.

16.4.1.5 Replication of CREATE ... IF NOT EXISTS Statements

This section discusses the rules that are applied when various `CREATE ... IF NOT EXISTS` statements are replicated.

Previous to MySQL 5.1.38.   `CREATE DATABASE IF NOT EXISTS` was replicated only if the database named in the statement did not exist on the master. `CREATE TABLE IF NOT EXISTS` was replicated only if the table named in the statement did not exist on the master.

MySQL 5.1.39 and later.   Every `CREATE DATABASE IF NOT EXISTS` statement is replicated, whether or not the database already exists on the master. Similarly, every `CREATE TABLE IF NOT EXISTS` statement is replicated, whether or not the table already exists on the master. This includes `CREATE TABLE IF NOT EXISTS ... LIKE`. However, replication of `CREATE TABLE IF NOT EXISTS ... SELECT` follows somewhat different rules; see Section 16.4.1.6, "Replication of CREATE TABLE ... SELECT Statements", for more information.

Replication of CREATE EVENT IF NOT EXISTS.   `CREATE EVENT IF NOT EXISTS` is always replicated, whether or not the event named in the statement already exists on the master. This is true for all MySQL 5.1 releases beginning with MySQL 5.1.6, when this statement was introduced.

See also Bug #45574.

16.4.1.6 Replication of CREATE TABLE ... SELECT Statements

This section discusses how MySQL replicates `CREATE TABLE ... SELECT` statements.

These behaviors are not dependent on MySQL version:

- `CREATE TABLE ... SELECT` always performs an implicit commit (Section 13.3.3, "Statements That Cause an Implicit Commit").

- If destination table does not exist, logging occurs as follows. It does not matter whether `IF NOT EXISTS` is present.

  - `STATEMENT` or `MIXED` format: The statement is logged as written.

  - `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

- If the statement fails, nothing is logged. This includes the case that the destination table exists and `IF NOT EXISTS` is not given.

When the destination table exists and `IF NOT EXISTS` is given, MySQL handles the statement in a version-dependent way.

In MySQL 5.1 before 5.1.51 and in MySQL 5.5 before 5.5.6 (this is the original behavior):

- `STATEMENT` or `MIXED` format: The statement is logged as written.

- `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

In MySQL 5.1 as of 5.1.51:

- `STATEMENT` or `MIXED` format: The statement is logged as the equivalent pair of `CREATE TABLE` and `INSERT INTO ... SELECT` statements.

- `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

In MySQL 5.5 as of 5.5.6:

- Nothing is inserted or logged.

These version dependencies arise due to a change in MySQL 5.5.6 in handling of `CREATE TABLE ... SELECT` not to insert rows if the destination table already exists, and a change made in MySQL 5.1.51 to preserve forward compatibility in replication of such statements from a 5.1 master to a 5.5 slave. For details, see Section 13.1.17.2, "CREATE TABLE ... SELECT Syntax".

16.4.1.7 Replication of CURRENT_USER()

The following statements support use of the `CURRENT_USER()` function to take the place of the name of (and, possibly, the host for) an affected user or a definer; in such cases, `CURRENT_USER()` is expanded where and as needed:

- `DROP USER`

- `RENAME USER`

- `GRANT`

- `REVOKE`

- `CREATE FUNCTION`

- `CREATE PROCEDURE`

- `CREATE TRIGGER`

- `CREATE EVENT`

- `CREATE VIEW`

- `ALTER EVENT`

- `ALTER VIEW`

- `SET PASSWORD`

In all MySQL 5.1 releases, when `CURRENT_USER()` or `CURRENT_USER` is used as the definer in any of the statements `CREATE FUNCTION`, `CREATE PROCEDURE`, `CREATE TRIGGER`, `CREATE EVENT`, `CREATE VIEW`, or `ALTER VIEW` when binary logging is enabled, the function reference is expanded before it is written to the binary log, so that the statement refers to the same user on both the master and the slave when the statement is replicated. Beginning with MySQL 5.1.49, `CURRENT_USER()` or `CURRENT_USER` is also expanded prior to being written to the binary log when used in `DROP USER`, `RENAME USER`, `GRANT`, `REVOKE`, or `ALTER EVENT`. (Bug #48321)

16.4.1.8 Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER

In MySQL 5.1, the statements `CREATE SERVER`, `ALTER SERVER`, and `DROP SERVER` are logged only when `binlog_format` is equal to `ROW`. These statements are not written to the binary log when using either the statement-based or mixed logging format.

16.4.1.9 Replication of DROP ... IF EXISTS Statements

The `DROP DATABASE IF EXISTS`, `DROP TABLE IF EXISTS`, and `DROP VIEW IF EXISTS` statements are always replicated, even if the database, table, or view to be dropped does not exist on the master. This is to ensure that the object to be dropped no longer exists on either the master or the slave, once the slave has caught up with the master.

Beginning with MySQL 5.1.33, `DROP ... IF EXISTS` statements for stored programs (stored procedures and functions, triggers, and events) are also replicated, even if the stored program to be dropped does not exist on the master. (Bug #13684)

16.4.1.10 Replication with Differing Table Definitions on Master and Slave

Starting with MySQL 5.1.21, source and target tables for replication do not have to be identical. A table on the master can have more or fewer columns than the slave's copy of the table. In addition, corresponding table columns on the master and the slave can use different data types, subject to certain conditions.

> **Note**
>
> Replication between tables which are partitioned differently from one another is not supported. See Section 16.4.1.26, "Replication and Partitioning".

In all cases where the source and target tables do not have identical definitions, the database and table names must be the same on both the master and the slave. Additional conditions are discussed, with examples, in the following two sections.

Replication with More Columns on Master or Slave

Starting with MySQL 5.1.21, you can replicate a table from the master to the slave such that the master and slave copies of the table have differing numbers of columns, subject to the following conditions:

- Columns common to both versions of the table must be defined in the same order on the master and the slave.

  (This is true even if both tables have the same number of columns.)

- Columns common to both versions of the table must be defined before any additional columns.

  This means that executing an `ALTER TABLE` statement on the slave where a new column is inserted into the table within the range of columns common to both tables causes replication to fail, as shown in the following example:

  Suppose that a table `t`, existing on the master and the slave, is defined by the following `CREATE TABLE` statement:

```
CREATE TABLE t (
    c1 INT,
    c2 INT,
    c3 INT
);
```

  Suppose that the `ALTER TABLE` statement shown here is executed on the slave:

```
ALTER TABLE t ADD COLUMN cnew1 INT AFTER c3;
```

  The previous `ALTER TABLE` is permitted on the slave because the columns `c1`, `c2`, and `c3` that are common to both versions of table `t` remain grouped together in both versions of the table, before any columns that differ.

However, the following `ALTER TABLE` statement cannot be executed on the slave without causing replication to break:

```
ALTER TABLE t ADD COLUMN cnew2 INT AFTER c2;
```

Replication fails after execution on the slave of the `ALTER TABLE` statement just shown, because the new column `cnew2` comes between columns common to both versions of `t`.

• Each "extra" column in the version of the table having more columns must have a default value.

> **Note**
>
> A column's default value is determined by a number of factors, including its type, whether it is defined with a `DEFAULT` option, whether it is declared as `NULL`, and the server SQL mode in effect at the time of its creation; for more information, see Section 11.6, "Data Type Default Values").

In addition, when the slave's copy of the table has more columns than the master's copy, each column common to the tables must use the same data type in both tables.

Examples. The following examples illustrate some valid and invalid table definitions:

More columns on the master. The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

The following table definitions would raise an error because the definitions of the columns common to both versions of the table are in a different order on the slave than they are on the master:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT);
```

The following table definitions would also raise an error because the definition of the extra column on the master appears before the definitions of the columns common to both versions of the table:

```
master> CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

More columns on the slave. The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

The following definitions raise an error because the columns common to both versions of the table are not defined in the same order on both the master and the slave:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT, c3 INT);
```

The following table definitions also raise an error because the definition for the extra column in the slave's version of the table appears before the definitions for the columns which are common to both versions of the table:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
```

The following table definitions fail because the slave's version of the table has additional columns compared to the master's version, and the two versions of the table use different data types for the common column `c2`:

```
master> CREATE TABLE t1 (c1 INT, c2 BIGINT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

Replication of Columns Having Different Data Types

Corresponding columns on the master's and the slave's copies of the same table ideally should have the same data type. However, beginning with MySQL 5.1.21, this is not always strictly enforced, as long as certain conditions are met.

All other things being equal, it is always possible to replicate from a column of a given data type to another column of the same type and same size or width, where applicable, or larger. For example, you can replicate from a `CHAR(10)` column to another `CHAR(10)`, or from a `CHAR(10)` column to a `CHAR(25)` column without any problems. In certain cases, it also possible to replicate from a column having one data type (on the master) to a column having a different data type (on the slave); when the data type of the master's version of the column is promoted to a type that is the same size or larger on the slave, this is known as *attribute promotion*.

Attribute promotion can be used with both statement-based and row-based replication, and is not dependent on the storage engine used by either the master or the slave. However, the choice of logging format does have an effect on the type conversions that are permitted; the particulars are discussed later in this section.

> **Important**
>
> Whether you use statement-based or row-based replication, the slave's copy of the table cannot contain more columns than the master's copy if you wish to employ attribute promotion.

Statement-based replication.   When using statement-based replication, a simple rule of thumb to follow is, "If the statement run on the master would also execute successfully on the slave, it should also replicate successfully". In other words, if the statement uses a value that is compatible with the type of a given column on the slave, the statement can be replicated. For example, you can insert any value that fits in a `TINYINT` column into a `BIGINT` column as well; it follows that, even if you change the type of a `TINYINT` column in the slave's copy of a table to `BIGINT`, any insert into that column on the master that succeeds should also succeed on the slave, since it is impossible to have a legal `TINYINT` value that is large enough to exceed a `BIGINT` column.

When using statement-based replication, `AUTO_INCREMENT` columns must be the same on both the master and the slave; otherwise, updates may be applied to the wrong table on the slave. This is a known issue which is fixed in MySQL 5.5. (Bug #12669186)

> **Note**
>
> The restrictions described in the next few paragraphs do not apply to MySQL Cluster Replication, beginning with MySQL Cluster NDB 6.3.33, 7.0.14, and 7.1.3. These and later versions of MySQL Cluster support attribute promotion and demotion (such as `TINYINT` to `BIGINT`, and `VARCHAR(50)` to `CHAR(25)`, respectively) in replication; see Attribute promotion and demotion (MySQL Cluster), for more information.

Row-based replication.   For row-based replication, the case is not so simple, due to the fact that changes rather than statements are replicated, and these changes are transmitted from master to slave using formats that do not always map directly to MySQL server column data types. For example, with row-based binary logging, you cannot replicate between different `INT` subtypes, such as from `TINYINT` to `BIGINT`, because changes to columns of these types are represented differently from one another in the binary log when using row-based logging. However, you can replicate from `BLOB` to `TEXT` using row-based replication because changes to `BLOB` and `TEXT` columns are represented using the same format in the binary log.

Supported conversions for attribute promotion when using row-based replication are shown in the following table:

From (Master)	To (Slave)
BINARY	CHAR
BLOB	TEXT
CHAR	BINARY
DECIMAL	NUMERIC
NUMERIC	DECIMAL
TEXT	BLOB
VARBINARY	VARCHAR
VARCHAR	VARBINARY

Note

In all cases, the size or width of the column on the slave must be equal to or greater than that of the column on the master. For example, you can replicate from a `CHAR(10)` column on the master to a column that uses `BINARY(10)` or `BINARY(25)` on the slave, but you cannot replicate from a `CHAR(10)` column on the master to `BINARY(5)` column on the slave.

Any unique index (including primary keys) having a prefix must use a prefix of the same length on both master and slave; in such cases, differing prefix lengths are disallowed. It is possible to use a nonunique index whose prefix length differs between master and slave, but this can cause serious performance issues, particularly when the prefix used on the master is longer. This is due to the fact that 2 unique prefixes of a given length may no longer be unique at a shorter length; for example, the words *catalogue* and *catamount* have the 5-character prefixes *catal* and *catam*, respectively, but share the same 4-character prefix (*cata*). This can lead to queries that use such indexes executing less efficiently on the slave, when a shorter prefix is employed in the slave' definition of the same index than on the master.

For `DECIMAL` and `NUMERIC` columns, both the mantissa (*M*) and the number of decimals (*D*) must be the same size or larger on the slave as compared with the master. For example, replication from a `NUMERIC(5,4)` to a `DECIMAL(6,4)` works, but not from a `NUMERIC(5,4)` to a `DECIMAL(5,3)`.

MySQL (except for MySQL Cluster) does *not* support attribute promotion of any of the following data types to or from any other data type when using row-based replication:

• `INT` (including `TINYINT`, `SMALLINT`, `MEDIUMINT`, `BIGINT`).

Promotion between `INT` subtypes—for example, from `SMALLINT` to `BIGINT`—is also not supported.

- `SET` or `ENUM`.

- `FLOAT` or `DOUBLE`.

- All of the data types relating to dates, times, or both: `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, and `YEAR`.

Attribute promotion and demotion (MySQL Cluster).   Beginning with MySQL Cluster NDB 6.3.33, 7.0.14, and 7.1.3, MySQL Cluster Replication supports attribute promotion and demotion between smaller data types and larger types. It is also possible to specify whether or not to permit lossy (truncated) or non-lossy conversions of demoted column values, as explained later in this section.

Lossy and non-lossy conversions.   In the event that the target type cannot represent the value being inserted, a decision must be made on how to handle the conversion. If we permit the conversion but truncate (or otherwise modify) the source value to achieve a "fit" in the target column, we make what is known as a *lossy conversion*. A conversion which does not require truncation or similar modifications to fit the source column value in the target column is a *non-lossy* conversion.

Type conversion modes (slave_type_conversions variable).   The setting of the `slave_type_conversions` global server variable controls the type conversion mode used on the slave. This variable takes a set of values from the following table, which shows the effects of each mode on the slave's type-conversion behavior:

Mode	Effect
`ALL_LOSSY`	In this mode, type conversions that would mean loss of information are permitted. This does not imply that non-lossy conversions are permitted, merely that only cases requiring either lossy conversions or no conversion at all are permitted; for example, enabling *only* this mode permits an `INT` column to be converted to `TINYINT` (a lossy conversion), but not a `TINYINT` column to an `INT` column (non-lossy). Attempting the latter conversion in this case would cause replication to stop with an error on the slave.
`ALL_NON_LOSSY`	This mode permits conversions that do not require truncation or other special handling of the source value; that is, it permits conversions where the target type has a wider range than the source type. Setting this mode has no bearing on whether lossy conversions are permitted; this is controlled with the `ALL_LOSSY` mode. If only `ALL_NON_LOSSY` is set, but not `ALL_LOSSY`, then attempting a conversion that would result in the loss of data (such as `INT` to `TINYINT`, or `CHAR(25)` to `VARCHAR(20)`) causes the slave to stop with an error.
`ALL_LOSSY,ALL_NON_LOSSY`	When this mode is set, all supported type conversions are permitted, whether or not they are lossy conversions.
[*empty*]	When `slave_type_conversions` is not set, no attribute promotion or demotion is permitted; this means that all columns in the source and target tables must be of the same types. This mode is the default.

Changing the type conversion mode requires restarting the slave with the new `slave_type_conversions` setting.

Supported conversions.   Supported conversions between different but similar data types are shown in the following list:

- Between any of the integer types `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT`, and `BIGINT`.

  This includes conversions between the signed and unsigned versions of these types.

  Lossy conversions are made by truncating the source value to the maximum (or minimum) permitted by the target column. For insuring non-lossy conversions when going from unsigned to signed types, the target column must be large enough to accommodate the range of values in the source column. For example, you can demote `TINYINT UNSIGNED` non-lossily to `SMALLINT`, but not to `TINYINT`.

- Between any of the decimal types `DECIMAL`, `FLOAT`, `DOUBLE`, and `NUMERIC`.

  `FLOAT` to `DOUBLE` is a non-lossy conversion; `DOUBLE` to `FLOAT` can only be handled lossily. A conversion from `DECIMAL(M,D)` to `DECIMAL(M',D')` where $D' >= D$ and $(M'-D') >= (M-D)$ are non-lossy; for any case where $M' < M$, $D' < D$, or both, only a lossy conversion can be made.

  For any of the decimal types, if a value to be stored cannot be fit in the target type, the value is rounded down according to the rounding rules defined for the server elsewhere in the documentation. See Section 12.18.4, "Rounding Behavior", for information about how this is done for decimal types.

- Between any of the string types `CHAR`, `VARCHAR`, and `TEXT`, including conversions between different widths.

  Conversion of a `CHAR`, `VARCHAR`, or `TEXT` to a `CHAR`, `VARCHAR`, or `TEXT` column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first N characters of the string on the slave, where N is the width of the target column.

  > **Important**
  >
  > Replication between columns using different character sets is not supported.

- Between any of the binary data types `BINARY`, `VARBINARY`, and `BLOB`, including conversions between different widths.

  Conversion of a `BINARY`, `VARBINARY`, or `BLOB` to a `BINARY`, `VARBINARY`, or `BLOB` column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first N bytes of the string on the slave, where N is the width of the target column.

- Between any 2 `BIT` columns of any 2 sizes.

  When inserting a value from a `BIT(M)` column into a `BIT(M')` column, where $M' > M$, the most significant bits of the `BIT(M')` columns are cleared (set to zero) and the M bits of the `BIT(M)` value are set as the least significant bits of the `BIT(M')` column.

  When inserting a value from a source `BIT(M)` column into a target `BIT(M')` column, where $M' < M$, the maximum possible value for the `BIT(M')` column is assigned; in other words, an "all-set" value is assigned to the target column.

Conversions between types not in the previous list are not permitted.

16.4.1.11 Replication and DIRECTORY Table Options

If a `DATA DIRECTORY` or `INDEX DIRECTORY` table option is used in a `CREATE TABLE` statement on the master server, the table option is also used on the slave. This can cause problems if no corresponding

directory exists in the slave host file system or if it exists but is not accessible to the slave server. This can be overridden by using the `NO_DIR_IN_CREATE` server SQL mode on the slave, which causes the slave to ignore the `DATA DIRECTORY` and `INDEX DIRECTORY` table options when replicating `CREATE TABLE` statements. The result is that `MyISAM` data and index files are created in the table's database directory.

For more information, see Section 5.1.7, "Server SQL Modes".

16.4.1.12 Replication of Invoked Features

Replication of invoked features such as user-defined functions (UDFs) and stored programs (stored procedures and functions, triggers, and events) was re-implemented in MySQL 5.1.18 to provide the following characteristics:

- The effects of the feature are always replicated.

- The following statements are replicated using statement-based replication:

    - `CREATE EVENT`

    - `ALTER EVENT`

    - `DROP EVENT`

    - `CREATE PROCEDURE`

    - `DROP PROCEDURE`

    - `CREATE FUNCTION`

    - `DROP FUNCTION`

    - `CREATE TRIGGER`

    - `DROP TRIGGER`

    However, the *effects* of features created, modified, or dropped using these statements are replicated using row-based replication.

    > **Note**
    >
    > Attempting to replicate invoked features using statement-based replication produces the warning `Statement may not be safe to log in statement format`. (Prior to MySQL 5.1.36, this was `Statement is not safe to log in statement format`; see Bug #42415.) For example, trying to replicate a UDF with statement-based replication generates this warning because it currently cannot be determined by the MySQL server whether the UDF is deterministic. If you are absolutely certain that the invoked feature's effects are deterministic, you can safely disregard such warnings.

- In the case of `CREATE EVENT` and `ALTER EVENT`:

    - The status of the event is set to `SLAVESIDE_DISABLED` on the slave regardless of the state specified (this does not apply to `DROP EVENT`).

    - The master on which the event was created is identified on the slave by its server ID. The `ORIGINATOR` column in `INFORMATION_SCHEMA.EVENTS` and the `originator` column in `mysql.event` were added to these tables in MySQL 5.1.18 to store this information. See

Section 20.7, "The INFORMATION_SCHEMA EVENTS Table", and Section 13.7.5.19, "SHOW EVENTS Syntax", for more information.

• The feature implementation resides on the slave in a renewable state so that if the master fails, the slave can be used as the master without loss of event processing.

To determine whether there are any scheduled events on a MySQL server that were created on a different server (that was acting as a replication master), query the `INFORMATION_SCHEMA.EVENTS` table in a manner similar to what is shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME
    FROM INFORMATION_SCHEMA.EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

Alternatively, you can use the `SHOW EVENTS` statement, like this:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

When promoting a replication slave having such events to a replication master, you must enable each event using `ALTER EVENT event_name ENABLE`, where `event_name` is the name of the event.

If more than one master was involved in creating events on this slave, and you wish to identify events that were created only on a given master having the server ID `master_id`, modify the previous query on the `EVENTS` table to include the `ORIGINATOR` column, as shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME, ORIGINATOR
    FROM INFORMATION_SCHEMA.EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED'
    AND   ORIGINATOR = 'master_id'
```

You can employ `ORIGINATOR` with the `SHOW EVENTS` statement in a similar fashion:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED'
    AND   ORIGINATOR = 'master_id'
```

Before enabling events that were replicated from the master, you should disable the MySQL Event Scheduler on the slave (using a statement such as `SET GLOBAL event_scheduler = OFF;`), run any necessary `ALTER EVENT` statements, restart the server, then re-enable the Event Scheduler on the slave afterward (using a statement such as `SET GLOBAL event_scheduler = ON;`)-

If you later demote the new master back to being a replication slave, you must disable manually all events enabled by the `ALTER EVENT` statements. You can do this by storing in a separate table the event names from the `SELECT` statement shown previously, or using `ALTER EVENT` statements to rename the events with a common prefix such as `replicated_` to identify them.

If you rename the events, then when demoting this server back to being a replication slave, you can identify the events by querying the `EVENTS` table, as shown here:

```
SELECT CONCAT(EVENT_SCHEMA, '.', EVENT_NAME) AS 'Db.Event'
      FROM INFORMATION_SCHEMA.EVENTS
      WHERE INSTR(EVENT_NAME, 'replicated_') = 1;
```

16.4.1.13 Replication and Floating-Point Values

With statement-based replication, values are converted from decimal to binary. Because conversions between decimal and binary representations of them may be approximate, comparisons involving floating-point values are inexact. This is true for operations that use floating-point values explicitly, or that use values that are converted to floating-point implicitly. Comparisons of floating-point values might yield different results on master and slave servers due to differences in computer architecture, the compiler used to build MySQL, and so forth. See Section 12.2, "Type Conversion in Expression Evaluation", and Section B.5.4.8, "Problems with Floating-Point Values".

16.4.1.14 Replication and FLUSH

Some forms of the `FLUSH` statement are not logged because they could cause problems if replicated to a slave: `FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, and `FLUSH TABLES WITH READ LOCK`. For a syntax example, see Section 13.7.6.3, "FLUSH Syntax". The `FLUSH TABLES`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements are written to the binary log and thus replicated to slaves. This is not normally a problem because these statements do not modify table data.

However, this behavior can cause difficulties under certain circumstances. If you replicate the privilege tables in the `mysql` database and update those tables directly without using `GRANT`, you must issue a `FLUSH PRIVILEGES` on the slaves to put the new privileges into effect. In addition, if you use `FLUSH TABLES` when renaming a `MyISAM` table that is part of a `MERGE` table, you must issue `FLUSH TABLES` manually on the slaves. These statements are written to the binary log unless you specify `NO_WRITE_TO_BINLOG` or its alias `LOCAL`.

16.4.1.15 Replication and System Functions

Certain functions do not replicate well under some conditions:

- The `USER()`, `CURRENT_USER()` (or `CURRENT_USER`), `UUID()`, `VERSION()`, `LOAD_FILE()`, and `RAND()` functions are replicated without change and thus do not work reliably on the slave unless row-based replication is enabled. (See Section 16.1.2, "Replication Formats".)

  For early implementations of mixed-format logging, stored functions, triggers, and views that use these functions in their body do not replicate reliably in mixed-format logging mode because the logging did not switch from statement-based to row-based format. For example, `INSERT INTO t SELECT FROM v`, where `v` is a view that selects `UUID()` could cause problems. This limitation is lifted in MySQL 5.1.12.

  Beginning with MySQL 5.1.23, `USER()` and `CURRENT_USER()` are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #28086) (See also Section 16.4.1.7, "Replication of CURRENT_USER()".)

  Beginning with MySQL 5.1.42, `VERSION()` is also automatically replicated using row-based replication when using `MIXED` mode, and generates a warning in `STATEMENT` mode. (Bug #47995) Beginning with MySQL 5.1.43, this is also true with regard to the `RAND()` function. (Bug #49222)

- For `NOW()`, the binary log includes the timestamp. This means that the value *as returned by the call to this function on the master* is replicated to the slave. This can lead to a possibly unexpected result when replicating between MySQL servers in different time zones. Suppose that the master is located in New York, the slave is located in Stockholm, and both servers are using local time. Suppose further that, on the master, you create a table `mytable`, perform an `INSERT` statement on this table, and then select from the table, as shown here:

```
mysql> CREATE TABLE mytable (mycol TEXT);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO mytable VALUES ( NOW() );
Query OK, 1 row affected (0.00 sec)
```

```
mysql> SELECT * FROM mytable;
+---------------------+
| mycol               |
+---------------------+
| 2009-09-01 12:00:00 |
+---------------------+
1 row in set (0.00 sec)
```

Local time in Stockholm is 6 hours later than in New York; so, if you issue `SELECT NOW()` on the slave at that exact same instant, the value `2009-09-01 18:00:00` is returned. For this reason, if you select from the slave's copy of `mytable` after the `CREATE TABLE` and `INSERT` statements just shown have been replicated, you might expect `mycol` to contain the value `2009-09-01 18:00:00`. However, this is not the case; when you select from the slave's copy of `mytable`, you obtain exactly the same result as on the master:

```
mysql> SELECT * FROM mytable;
+---------------------+
| mycol               |
+---------------------+
| 2009-09-01 12:00:00 |
+---------------------+
1 row in set (0.00 sec)
```

Unlike `NOW()`, the `SYSDATE()` function is not replication-safe because it is not affected by `SET TIMESTAMP` statements in the binary log and is nondeterministic if statement-based logging is used. This is not a problem if row-based logging is used.

An alternative is to use the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`. This must be done on the master and the slave to work correctly. In such cases, a warning is still issued by this function, but can safely be ignored as long as `--sysdate-is-now` is used on both the master and the slave.

Beginning with MySQL 5.1.42, `SYSDATE()` is automatically replicated using row-based replication when using `MIXED` mode, and generates a warning in `STATEMENT` mode. (Bug #47995)

See also Section 16.4.1.34, "Replication and Time Zones".

- *The following restriction applies to statement-based replication only, not to row-based replication.* The `GET_LOCK()`, `RELEASE_LOCK()`, `IS_FREE_LOCK()`, and `IS_USED_LOCK()` functions that handle user-level locks are replicated without the slave knowing the concurrency context on the master. Therefore, these functions should not be used to insert into a master table because the content on the slave would differ. For example, do not issue a statement such as `INSERT INTO mytable VALUES(GET_LOCK(...))`.

  Beginning with MySQL 5.1.42, these functions are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #47995)

As a workaround for the preceding limitations when statement-based replication is in effect, you can use the strategy of saving the problematic function result in a user variable and referring to the variable in a later statement. For example, the following single-row `INSERT` is problematic due to the reference to the `UUID()` function:

```
INSERT INTO t VALUES(UUID());
```

To work around the problem, do this instead:

```
SET @my_uuid = UUID();
INSERT INTO t VALUES(@my_uuid);
```

That sequence of statements replicates because the value of @my_uuid is stored in the binary log as a user-variable event prior to the INSERT statement and is available for use in the INSERT.

The same idea applies to multiple-row inserts, but is more cumbersome to use. For a two-row insert, you can do this:

```
SET @my_uuid1 = UUID(); @my_uuid2 = UUID();
INSERT INTO t VALUES(@my_uuid1),(@my_uuid2);
```

However, if the number of rows is large or unknown, the workaround is difficult or impracticable. For example, you cannot convert the following statement to one in which a given individual user variable is associated with each row:

```
INSERT INTO t2 SELECT UUID(), * FROM t1;
```

Within a stored function, RAND() replicates correctly as long as it is invoked only once during the execution of the function. (You can consider the function execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

The FOUND_ROWS() and ROW_COUNT() functions are not replicated reliably using statement-based replication. A workaround is to store the result of the function call in a user variable, and then use that in the INSERT statement. For example, if you wish to store the result in a table named mytable, you might normally do so like this:

```
SELECT SQL_CALC_FOUND_ROWS FROM mytable LIMIT 1;
INSERT INTO mytable VALUES( FOUND_ROWS() );
```

However, if you are replicating mytable, you should use SELECT ... INTO, and then store the variable in the table, like this:

```
SELECT SQL_CALC_FOUND_ROWS INTO @found_rows FROM mytable LIMIT 1;
INSERT INTO mytable VALUES(@found_rows);
```

In this way, the user variable is replicated as part of the context, and applied on the slave correctly.

Beginning with MySQL 5.1.23, these functions are automatically replicated using row-based replication when using MIXED mode, and generate a warning in STATEMENT mode. (Bug #12092, Bug #30244)

Prior to MySQL 5.1.73, the value of LAST_INSERT_ID() was not replicated correctly if any filtering options such as --replicate-ignore-db and --replicate-do-table were enabled on the slave. (Bug #17234370, BUG# 69861)

16.4.1.16 Replication and LIMIT

Statement-based replication of LIMIT clauses in DELETE, UPDATE, and INSERT ... SELECT statements is unsafe since the order of the rows affected is not defined. (Such statements can be replicated correctly with statement-based replication only if they also contain an ORDER BY clause.) Beginning with MySQL 5.1.24, when such a statement is encountered:

- When using STATEMENT mode, a warning that the statement is not safe for statement-based replication is now issued.

When using `STATEMENT` mode, warnings are issued for DML statements containing `LIMIT` even when they also have an `ORDER BY` clause (and so are made deterministic). This is a known issue. (Bug #42851)

- When using `MIXED` mode, the statement is now automatically replicated using row-based mode.

16.4.1.17 Replication and LOAD DATA INFILE

The `LOAD DATA INFILE` statement was not always replicated correctly to a slave running MySQL 5.1.42 or earlier from a master running MySQL 4.0 or earlier. When using statement-based replication, the `LOAD DATA INFILE` statement `CONCURRENT` option was not replicated. This issue was fixed in MySQL 5.1.43. This issue does not have any impact on `CONCURRENT` option handling when using row-based replication in MySQL 5.1 or later. (Bug #34628)

In MySQL 5.1.52 and later, `LOAD DATA INFILE` is considered unsafe (see Section 16.1.2.3, "Determination of Safe and Unsafe Statements in Binary Logging"). It causes a warning when using statement-based logging format, and is logged using row-based format when using mixed-format logging.

16.4.1.18 Replication and the Slow Query Log

Prior to MySQL 5.1.45, replication slaves did not write replicated queries to the slow query log, even if the same queries were written to the slow query log on the master. (Bug #23300)

16.4.1.19 Replication and REPAIR TABLE

When used on a corrupted or otherwise damaged table, it is possible for the `REPAIR TABLE` statement to delete rows that cannot be recovered. However, any such modifications of table data performed by this statement are not replicated, which can cause master and slave to lose synchronization. For this reason, in the event that a table on the master becomes damaged and you use `REPAIR TABLE` to repair it, you should first stop replication (if it is still running) before using `REPAIR TABLE`, then afterward compare the master's and slave's copies of the table and be prepared to correct any discrepancies manually, before restarting replication.

16.4.1.20 Replication and Master or Slave Shutdowns

It is safe to shut down a master server and restart it later. When a slave loses its connection to the master, the slave tries to reconnect immediately and retries periodically if that fails. The default is to retry every 60 seconds. This may be changed with the `CHANGE MASTER TO` statement or `--master-connect-retry` option. A slave also is able to deal with network connectivity outages. However, the slave notices the network outage only after receiving no data from the master for `slave_net_timeout` seconds. If your outages are short, you may want to decrease `slave_net_timeout`. See Section 5.1.4, "Server System Variables".

An unclean shutdown (for example, a crash) on the master side can result in the master binary log having a final position less than the most recent position read by the slave, due to the master binary log file not being flushed. This can cause the slave not to be able to replicate when the master comes back up. Setting `sync_binlog=1` in the master `my.cnf` file helps to minimize this problem because it causes the master to flush its binary log more frequently.

Shutting down a slave cleanly is safe because it keeps track of where it left off. However, be careful that the slave does not have temporary tables open; see Section 16.4.1.23, "Replication and Temporary Tables". Unclean shutdowns might produce problems, especially if the disk cache was not flushed to disk before the problem occurred:

- For transactions, the slave commits and then updates `relay-log.info`. If a crash occurs between these two operations, relay log processing will have proceeded further than the information file indicates

and the slave will re-execute the events from the last transaction in the relay log after it has been restarted.

- A similar problem can occur if the slave updates `relay-log.info` but the server host crashes before the write has been flushed to disk. Writes are not forced to disk because the server relies on the operating system to flush the file from time to time.

The fault tolerance of your system for these types of problems is greatly increased if you have a good uninterruptible power supply.

16.4.1.21 Replication and max_allowed_packet

`max_allowed_packet` sets an upper limit on the size of any single message between the MySQL server and clients, including replication slaves. If you are replicating large column values (such as might be found in `TEXT` or `BLOB` columns) and `max_allowed_packet` is too small on the master, the master fails with an error, and the slave shuts down the I/O thread. If `max_allowed_packet` is too small on the slave, this also causes the slave to stop the I/O thread.

Prior to MySQL 5.1.40, `Last_IO_Error` and `Last_IO_Errno` in the output of `SHOW SLAVE STATUS` were not set in the event that replication failed due to exceeding `max_allowed_packet` (Bug #42914).

Row-based replication currently sends all columns and column values for updated rows from the master to the slave, including values of columns that were not actually changed by the update. This means that, when you are replicating large column values using row-based replication, you must take care to set `max_allowed_packet` large enough to accommodate the largest row in any table to be replicated, even if you are replicating updates only, or you are inserting only relatively small values.

16.4.1.22 Replication and MEMORY Tables

When a master server shuts down and restarts, its `MEMORY` tables become empty. To replicate this effect to slaves, the first time that the master uses a given `MEMORY` table after startup, it logs an event that notifies slaves that the table must to be emptied by writing a `DELETE` statement for that table to the binary log.

When a slave server shuts down and restarts, its `MEMORY` tables become empty. This causes the slave to be out of synchrony with the master and may lead to other failures or cause the slave to stop:

- Row-format updates and deletes received from the master may fail with `Can't find record in 'memory_table'`.

- Statements such as `INSERT INTO ... SELECT FROM memory_table` may insert a different set of rows on the master and slave.

The safe way to restart a slave that is replicating `MEMORY` tables is to first drop or delete all rows from the `MEMORY` tables on the master and wait until those changes have replicated to the slave. Then it is safe to restart the slave.

An alternative restart method may apply in some cases. When `binlog_format=ROW`, you can prevent the slave from stopping if you set `slave_exec_mode=IDEMPOTENT` before you start the slave again. This allows the slave to continue to replicate, but its `MEMORY` tables will still be different from those on the master. This can be okay if the application logic is such that the contents of `MEMORY` tables can be safely lost (for example, if the `MEMORY` tables are used for caching). `slave_exec_mode=IDEMPOTENT` applies globally to all tables, so it may hide other replication errors in non-`MEMORY` tables.

(The method just described is not applicable in MySQL Cluster, where `slave_exec_mode` is always `IDEMPOTENT`, and cannot be changed.)

The size of `MEMORY` tables is limited by the value of the `max_heap_table_size` system variable, which is not replicated (see Section 16.4.1.38, "Replication and Variables"). A change in `max_heap_table_size` takes effect for `MEMORY` tables that are created or updated using `ALTER TABLE ... ENGINE = MEMORY` or `TRUNCATE TABLE` following the change, or for all `MEMORY` tables following a server restart. If you increase the value of this variable on the master without doing so on the slave, it becomes possible for a table on the master to grow larger than its counterpart on the slave, leading to inserts that succeed on the master but fail on the slave with `Table is full` errors. This is a known issue (Bug #48666). In such cases, you must set the global value of `max_heap_table_size` on the slave as well as on the master, then restart replication. It is also recommended that you restart both the master and slave MySQL servers, to insure that the new value takes complete (global) effect on each of them.

See Section 14.9, "The MEMORY Storage Engine", for more information about `MEMORY` tables.

16.4.1.23 Replication and Temporary Tables

The discussion in the following paragraphs does not apply when `binlog_format=ROW` because, in that case, temporary tables are not replicated; this means that there are never any temporary tables on the slave to be lost in the event of an unplanned shutdown by the slave. The remainder of this section applies only when using statement-based or mixed-format replication. Loss of replicated temporary tables on the slave can be an issue, whenever `binlog_format` is `STATEMENT` or `MIXED`, for statements involving temporary tables that can be logged safely using statement-based format. For more information about row-based replication and temporary tables, see RBL, RBR, and temporary tables.

Safe slave shutdown when using temporary tables. Temporary tables are replicated except in the case where you stop the slave server (not just the slave threads) and you have replicated temporary tables that are open for use in updates that have not yet been executed on the slave. If you stop the slave server, the temporary tables needed by those updates are no longer available when the slave is restarted. To avoid this problem, do not shut down the slave while it has temporary tables open. Instead, use the following procedure:

1. Issue a `STOP SLAVE SQL_THREAD` statement.

2. Use `SHOW STATUS` to check the value of the `Slave_open_temp_tables` variable.

3. If the value is not 0, restart the slave SQL thread with `START SLAVE SQL_THREAD` and repeat the procedure later.

4. When the value is 0, issue a `mysqladmin shutdown` command to stop the slave.

Temporary tables and replication options. By default, all temporary tables are replicated; this happens whether or not there are any matching `--replicate-do-db`, `--replicate-do-table`, or `--replicate-wild-do-table` options in effect. However, the `--replicate-ignore-table` and `--replicate-wild-ignore-table` options are honored for temporary tables.

A recommended practice when using statement-based or mixed-format replication is to designate a prefix for exclusive use in naming temporary tables that you do not want replicated, then employ a `--replicate-wild-ignore-table` option to match that prefix. For example, you might give all such tables names beginning with `norep` (such as `norepmytable`, `norepyourtable`, and so on), then use `--replicate-wild-ignore-table=norep%` to prevent them from being replicated.

16.4.1.24 Replication of the mysql System Database

MySQL 5.1.14 and later. Data modification statements made to tables in the `mysql` database are replicated according to the value of `binlog_format`; if this value is `MIXED`, these statement are replicated using the row-based format. However, statements that would normally update this information

indirectly—such `GRANT`, `REVOKE`, and statements manipulating triggers, stored routines, and views—are replicated to slaves using statement-based replication.

MySQL 5.1.13 and earlier.   User privileges are replicated only if the `mysql` database is replicated. That is, the `GRANT`, `REVOKE`, `SET PASSWORD`, `CREATE USER`, and `DROP USER` statements take effect on the slave only if the replication setup includes the `mysql` database.

16.4.1.25 Replication and the Query Optimizer

It is possible for the data on the master and slave to become different if a statement is written in such a way that the data modification is nondeterministic; that is, left up the query optimizer. (In general, this is not a good practice, even outside of replication.) Examples of nondeterministic statements include `DELETE` or `UPDATE` statements that use `LIMIT` with no `ORDER BY` clause; see Section 16.4.1.16, "Replication and LIMIT", for a detailed discussion of these.

16.4.1.26 Replication and Partitioning

Replication is supported between partitioned tables as long as they use the same partitioning scheme and otherwise have the same structure except where an exception is specifically allowed (see Section 16.4.1.10, "Replication with Differing Table Definitions on Master and Slave").

Replication between tables having different partitioning is generally not supported. This because statements (such as `ALTER TABLE ... DROP PARTITION`) acting directly on partitions in such cases may produce different results on master and slave. In the case where a table is partitioned on the master but not on the slave, any statements operating on partitions on the master's copy of the slave fail on the slave. When the slave's copy of the table is partitioned but the master's copy is not, statements acting on partitions cannot be run on the master without causing errors there.

Due to these dangers of causing replication to fail entirely (on account of failed statements) and of inconsistencies (when the result of a partition-level SQL statement produces different results on master and slave), we recommend that insure that the partitioning of any tables to be replicated from the master is matched by the slave's versions of these tables.

16.4.1.27 Replication and Reserved Words

You can encounter problems when you attempt to replicate from an older master to a newer slave and you make use of identifiers on the master that are reserved words in the newer MySQL version running on the slave. An example of this is using a table column named `range` on a 5.0 master that is replicating to a 5.1 or higher slave because `RANGE` is a reserved word beginning in MySQL 5.1. Replication can fail in such cases with Error 1064 `You have an error in your SQL syntax...`, *even if a database or table named using the reserved word or a table having a column named using the reserved word is excluded from replication*. This is due to the fact that each SQL event must be parsed by the slave prior to execution, so that the slave knows which database object or objects would be affected; only after the event is parsed can the slave apply any filtering rules defined by `--replicate-do-db`, `--replicate-do-table`, `--replicate-ignore-db`, and `--replicate-ignore-table`.

To work around the problem of database, table, or column names on the master which would be regarded as reserved words by the slave, do one of the following:

- Use one or more `ALTER TABLE` statements on the master to change the names of any database objects where these names would be considered reserved words on the slave, and change any SQL statements that use the old names to use the new names instead.

- In any SQL statements using these database object names, write the names as quoted identifiers using backtick characters (`` ` ``).

For listings of reserved words by MySQL version, see Reserved Words, in the *MySQL Server Version Reference*. For identifier quoting rules, see Section 9.2, "Schema Object Names".

16.4.1.28 SET PASSWORD and Row-Based Replication

Row-based replication of `SET PASSWORD` statements from a MySQL 5.1 master to a MySQL 5.5 slave did not work correctly prior to MySQL 5.1.53 on the master and MySQL 5.5.7 on the slave (see Bug #57098, Bug #57357).

16.4.1.29 Slave Errors During Replication

If a statement produces the same error (identical error code) on both the master and the slave, the error is logged, but replication continues.

If a statement produces different errors on the master and the slave, the slave SQL thread terminates, and the slave writes a message to its error log and waits for the database administrator to decide what to do about the error. This includes the case that a statement produces an error on the master or the slave, but not both. To address the issue, connect to the slave manually and determine the cause of the problem. `SHOW SLAVE STATUS` is useful for this. Then fix the problem and run `START SLAVE`. For example, you might need to create a nonexistent table before you can start the slave again.

If this error code validation behavior is not desirable, some or all errors can be masked out (ignored) with the `--slave-skip-errors` option.

For nontransactional storage engines such as `MyISAM`, it is possible to have a statement that only partially updates a table and returns an error code. This can happen, for example, on a multiple-row insert that has one row violating a key constraint, or if a long update statement is killed after updating some of the rows. If that happens on the master, the slave expects execution of the statement to result in the same error code. If it does not, the slave SQL thread stops as described previously.

If you are replicating between tables that use different storage engines on the master and slave, keep in mind that the same statement might produce a different error when run against one version of the table, but not the other, or might cause an error for one version of the table, but not the other. For example, since `MyISAM` ignores foreign key constraints, an `INSERT` or `UPDATE` statement accessing an `InnoDB` table on the master might cause a foreign key violation but the same statement performed on a `MyISAM` version of the same table on the slave would produce no such error, causing replication to stop.

16.4.1.30 Replication of Server-Side Help Tables

The server maintains tables in the `mysql` database that store information for the `HELP` statement (see Section 13.8.3, "HELP Syntax". These tables can be loaded manually as described at Section 5.1.9, "Server-Side Help".

Help table content is derived from the MySQL Reference Manual. There are versions of the manual specific to each MySQL release series, so help content is specific to each series as well. Normally, you load a version of help content that matches the server version. This has implications for replication. For example, you would load MySQL 5.5 help content into a MySQL 5.5 master server, but not necessarily replicate that content to a MySQL 5.6 slave server for which 5.6 help content is more appropriate.

This section describes how to manage help table content upgrades when your servers participate in replication. Server versions are one factor in this task. Another is that help table structure may differ between the master and the slave.

Assume that help content is stored in a file named `fill_help_tables.sql`. In MySQL distributions, this file is located under the `share` or `share/mysql` directory, and the most recent version is always available for download from http://dev.mysql.com/doc/index-other.html.

To upgrade help tables, using the following procedure. Connection parameters are not shown for the `mysql` commands discussed here; in all cases, connect to the server using an account such as `root` that has privileges for modifying tables in the `mysql` database.

1. Upgrade your servers by running `mysql_upgrade`, first on the slaves and then on the master. This is the usual principle of upgrading slaves first.

2. Decide whether you want to replicate help table content from the master to its slaves. If not, load the content on the master and each slave individually. Otherwise, check for and resolve any incompatibilities between help table structure on the master and its slaves, then load the content into the master and let it replicate to the slaves.

   More detail about these two methods of loading help table content follows.

Loading Help Table Content Without Replication to Slaves

To load help table content without replication, run this command on the master and each slave individually, using a `fill_help_tables.sql` file containing content appropriate to the server version (enter the command on one line):

```
mysql --init-command="SET sql_log_bin=0"
  mysql < fill_help_tables.sql
```

Use the `--init-command` option on each server, including the slaves, in case a slave also acts as a master to other slaves in your replication topology. The `SET` statement suppresses binary logging. After the command has been run on each server to be upgraded, you are done.

Loading Help Table Content With Replication to Slaves

If you do want to replicate help table content, check for help table incompatibilities between your master and its slaves. The `url` column in the `help_category` and `help_topic` tables was originally `CHAR(128)`, but is `TEXT` in newer MySQL versions to accommodate longer URLs. To check help table structure, use this statement:

```
SELECT TABLE_NAME, COLUMN_NAME, COLUMN_TYPE
FROM INFORMATION_SCHEMA.COLUMNS
WHERE TABLE_SCHEMA = 'mysql'
AND COLUMN_NAME = 'url';
```

For tables with the old structure, the statement produces this result:

```
+---------------+-------------+-------------+
| TABLE_NAME    | COLUMN_NAME | COLUMN_TYPE |
+---------------+-------------+-------------+
| help_category | url         | char(128)   |
| help_topic    | url         | char(128)   |
+---------------+-------------+-------------+
```

For tables with the new structure, the statement produces this result:

```
+---------------+-------------+-------------+
| TABLE_NAME    | COLUMN_NAME | COLUMN_TYPE |
+---------------+-------------+-------------+
| help_category | url         | text        |
| help_topic    | url         | text        |
+---------------+-------------+-------------+
```

If the master and slave both have the old structure or both have the new structure, they are compatible and you can replicate help table content by executing this command on the master:

```
mysql mysql < fill_help_tables.sql
```

The table content will load into the master, then replicate to the slaves.

If the master and slave have incompatible help tables (one server has the old structure and the other has the new), you have a choice between not replicating help table content after all, or making the table structures compatible so that you can replicate the content.

- If you decide not to replicate the content after all, upgrade the master and slaves individually using `mysql` with the `--init-command` option, as described previously.

- If instead you decide to make the table structures compatible, upgrade the tables on the server that has the old structure. Suppose that your master server has the old table structure. Upgrade its tables to the new structure manually by executing these statements (binary logging is disabled here to prevent replication of the changes to the slaves, which already have the new structure):

```
SET sql_log_bin=0;
ALTER TABLE mysql.help_category ALTER COLUMN url TEXT;
ALTER TABLE mysql.help_topic ALTER COLUMN url TEXT;
```

Then run this command on the master:

```
mysql mysql < fill_help_tables.sql
```

The table content will load into the master, then replicate to the slaves.

16.4.1.31 Replication and Server SQL Mode

Using different server SQL mode settings on the master and the slave may cause the same `INSERT` statements to be handled differently on the master and the slave, leading the master and slave to diverge. For best results, you should always use the same server SQL mode on the master and on the slave. This advice applies whether you are using statement-based or row-based replication.

If you are replicating partitioned tables, using different SQL modes on the master and the slave is likely to cause issues. At a minimum, this is likely to cause the distribution of data among partitions to be different in the master's and slave's copies of a given table. It may also cause inserts into partitioned tables that succeed on the master to fail on the slave.

For more information, see Section 5.1.7, "Server SQL Modes".

16.4.1.32 Replication Retries and Timeouts

The global system variable `slave_transaction_retries` affects replication as follows: If the slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because it exceeded the `InnoDB innodb_lock_wait_timeout` value, or the `NDBCLUSTER TransactionDeadlockDetectionTimeout` or `TransactionInactiveTimeout` value, the slave automatically retries the transaction `slave_transaction_retries` times before stopping with an error. The default value is 10. The total retry count can be seen in the output of `SHOW STATUS`; see Section 5.1.6, "Server Status Variables".

16.4.1.33 Replication and TIMESTAMP

Older versions of MySQL (prior to 4.1) differed significantly in several ways in their handling of the `TIMESTAMP` data type from what is supported in MySQL versions 5.1 and newer; these include syntax extensions which are deprecated in MySQL 5.1, and that no longer supported in MySQL 5.5. This can cause problems (including replication failures) when replicating between MySQL Server versions, if you are using columns that are defined using the old `TIMESTAMP(N)` syntax. See Section 2.13.1.1, "Changes Affecting Upgrades to 5.1", for more information about the differences, how they can impact MySQL replication, and what you can do if you encounter such problems.

16.4.1.34 Replication and Time Zones

The same system time zone should be set for both master and slave. Otherwise, statements depending on the local time on the master are not replicated properly, such as statements that use the `NOW()` or `FROM_UNIXTIME()` functions. You can set the time zone in which MySQL server runs by using the `--timezone=timezone_name` option of the `mysqld_safe` script or by setting the `TZ` environment variable. See also Section 16.4.1.15, "Replication and System Functions".

`CONVERT_TZ(...,...,@@session.time_zone)` is properly replicated only if both master and slave are running MySQL 5.0.4 or newer.

16.4.1.35 Replication and Transactions

Mixing transactional and nontransactional statements within the same transaction. In general, you should avoid transactions that update both transactional and nontransactional tables in a replication environment. You should also avoid using any statement that accesses both transactional (or temporary) and nontransactional tables and writes to any of them.

As of MySQL 5.1.44, the server uses these rules for binary logging:

- If the initial statements in a transaction are nontransactional, they are written to the binary log immediately. The remaining statements in the transaction are cached and not written to the binary log until the transaction is committed. (If the transaction is rolled back, the cached statements are written to the binary log only if they make nontransactional changes that cannot be rolled back. Otherwise, they are discarded.)

- For statement-based logging, logging of nontransactional statements is affected by the `binlog_direct_non_transactional_updates` system variable. When this variable is `OFF` (the default), logging is as just described. When this variable is `ON`, logging occurs immediately for nontransactional statements occurring anywhere in the transaction (not just initial nontransactional statements). Other statements are kept in the transaction cache and logged when the transaction commits. `binlog_direct_non_transactional_updates` has no effect for row-format or mixed-format binary logging.

Transactional, nontransactional, and mixed statements.
To apply those rules, the server considers a statement nontransactional if it changes only nontransactional tables, and transactional if it changes only transactional tables. A statement that changes both nontransactional and transactional tables is considered "mixed". Mixed statements, like transactional statements, are cached and logged when the transaction commits.

> **Note**
>
> A mixed statement is unrelated to mixed binary logging format.

Before MySQL 5.1.44, the rules for binary logging are similar to those just described, except that there is no `binlog_direct_non_transactional_updates` system variable to affect logging of transactional

statements. Thus, the server immediately logs only the initial nontransactional statements in a transaction and caches the rest until commit time.

Before MySQL 5.1.31, the *effect* of the rules differs because the definition of transactional statement is different: In these earlier versions, a statement is nontransactional if the first changes it makes change nontransactional tables, transactional if the first changes it makes change transactional tables. "First" applies in the sense that a statement may have several effects if it involves such things as triggers, stored functions, or multiple-table updates. A mixed statement that changes both nontransactional and transactional tables is handled as nontransactional or transactional depending on the type of changes it makes first.

In situations where transactions mix updates to transactional and nontransactional tables, the order of statements in the binary log is correct, and all needed statements are written to the binary log even in case of a `ROLLBACK`. However, when a second connection updates the nontransactional table before the first connection transaction is complete, statements can be logged out of order because the second connection update is written immediately after it is performed, regardless of the state of the transaction being performed by the first connection.

Using different storage engines on master and slave.   It is possible to replicate transactional tables on the master using nontransactional tables on the slave. For example, you can replicate an `InnoDB` master table as a `MyISAM` slave table. However, if you do this, there are problems if the slave is stopped in the middle of a `BEGIN` ... `COMMIT` block because the slave restarts at the beginning of the `BEGIN` block.

Beginning with MySQL 5.1.48, it is also safe to replicate transactions from `MyISAM` tables on the master to transactional tables—such as tables that use the `InnoDB` storage engine—on the slave. In such cases (beginning with MySQL 5.1.48), an `AUTOCOMMIT=1` statement issued on the master is replicated, thus enforcing `AUTOCOMMIT` mode on the slave.

When the storage engine type of the slave is nontransactional, transactions on the master that mix updates of transactional and nontransactional tables should be avoided because they can cause inconsistency of the data between the master transactional table and the slave nontransactional table. That is, such transactions can lead to master storage engine-specific behavior with the possible effect of replication going out of synchrony. MySQL does not issue a warning about this currently, so extra care should be taken when replicating transactional tables from the master to nontransactional tables on the slaves.

Beginning with MySQL Cluster NDB 6.2.14 and MySQL 5.1.24, every transaction (including `autocommit` transactions) is recorded in the binary log as though it starts with a `BEGIN` statement, and ends with either a `COMMIT` or a `ROLLBACK` statement. However, this does *not* apply to nontransactional changes; any statements affecting tables using a nontransactional storage engine such as `MyISAM` are regarded for this purpose as nontransactional, even when `autocommit` is enabled. (Bug #26395)

16.4.1.36 Replication and Triggers

With statement-based replication, triggers executed on the master also execute on the slave. With row-based replication, triggers executed on the master do not execute on the slave. Instead, the row changes on the master resulting from trigger execution are replicated and applied on the slave.

This behavior is by design. If under row-based replication the slave applied the triggers as well as the row changes caused by them, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

If you want triggers to execute on both the master and the slave—perhaps because you have different triggers on the master and slave—you must use statement-based replication. However, to enable slave-side triggers, it is not necessary to use statement-based replication exclusively. It is sufficient to switch to statement-based replication only for those statements where you want this effect, and to use row-based replication the rest of the time.

Before MySQL 5.1.31, a trigger that was defined on a transactional table but that updated a nontransactional table could cause updates on the transactional table to be replicated before they were actually committed on the master, and not be rolled back correctly on the slave if they were rolled back on the master. (Bug #40116) See also Section 16.4.1.35, "Replication and Transactions".

A statement invoking a trigger (or function) that causes an update to an `AUTO_INCREMENT` column is not replicated correctly using statement-based replication. Beginning with MySQL 5.1.40, such statements are marked as unsafe. (Bug #45677)

16.4.1.37 Replication and TRUNCATE TABLE

`TRUNCATE TABLE` is normally regarded as a DML statement, and so would be expected to be logged and replicated using row-based format when the binary logging mode is `ROW` or `MIXED`. However this caused issues when logging or replicating, in `STATEMENT` or `MIXED` mode, tables that used transactional storage engines such as `InnoDB` when the transaction isolation level was `READ COMMITTED` or `READ UNCOMMITTED`, which precludes statement-based logging.

Beginning with MySQL 5.1.32, `TRUNCATE TABLE` is treated for purposes of logging and replication as DDL rather than DML so that it can be logged and replicated as a statement. However, the effects of the statement as applicable to `InnoDB` and other transactional tables on replication slaves still follow the rules described in Section 13.1.34, "TRUNCATE TABLE Syntax" governing such tables. (Bug #36763)

16.4.1.38 Replication and Variables

System variables are not replicated correctly when using `STATEMENT` mode, except for the following variables when they are used with session scope:

- `auto_increment_increment`
- `auto_increment_offset`
- `character_set_client`
- `character_set_connection`
- `character_set_database`
- `character_set_server`
- `collation_connection`
- `collation_database`
- `collation_server`
- `foreign_key_checks`
- `identity`
- `last_insert_id`
- `lc_time_names`
- `pseudo_thread_id`
- `sql_auto_is_null`
- `time_zone`

- `timestamp`

- `unique_checks`

When `MIXED` mode is used, the variables in the preceding list, when used with session scope, cause a switch from statement-based to row-based logging. See Section 5.4.4.3, "Mixed Binary Logging Format".

`sql_mode` is also replicated except for the `NO_DIR_IN_CREATE` mode; the slave always preserves its own value for `NO_DIR_IN_CREATE`, regardless of changes to it on the master. This is true for all replication formats.

However, when `mysqlbinlog` parses a `SET @@sql_mode = ` *mode* statement, the full *mode* value, including `NO_DIR_IN_CREATE`, is passed to the receiving server. For this reason, replication of such a statement may not be safe when `STATEMENT` mode is in use.

The `storage_engine` system variable is not replicated, regardless of the logging mode; this is intended to facilitate replication between different storage engines.

The `read_only` system variable is not replicated. In addition, the enabling this variable has different effects with regard to temporary tables, table locking, and the `SET PASSWORD` statement in different MySQL versions.

The `max_heap_table_size` system variable is not replicated. Increasing the value of this variable on the master without doing so on the slave can lead eventually to `Table is full` errors on the slave when trying to execute `INSERT` statements on a `MEMORY` table on the master that is thus permitted to grow larger than its counterpart on the slave. For more information, see Section 16.4.1.22, "Replication and MEMORY Tables".

In statement-based replication, session variables are not replicated properly when used in statements that update tables. For example, the following sequence of statements will not insert the same data on the master and the slave:

```
SET max_join_size=1000;
INSERT INTO mytable VALUES(@@max_join_size);
```

This does not apply to the common sequence:

```
SET time_zone=...;
INSERT INTO mytable VALUES(CONVERT_TZ(..., ..., @@time_zone));
```

Replication of session variables is not a problem when row-based replication is being used, in which case, session variables are always replicated safely. See Section 16.1.2, "Replication Formats".

In MySQL 5.1.20 and later (and in MySQL 5.0.46 and later in MySQL 5.0, for backward compatibility), the following session variables are written to the binary log and honored by the replication slave when parsing the binary log, regardless of the logging format:

- `sql_mode`

- `foreign_key_checks`

- `unique_checks`

- `character_set_client`

- `collation_connection`

- `collation_database`

- `collation_server`

- `sql_auto_is_null`

> **Important**
>
> Even though session variables relating to character sets and collations are written to the binary log, replication between different character sets is not supported.

It is strongly recommended that you always use the same setting for the `lower_case_table_names` system variable on both master and slave. In particular, when a case-sensitive file system is used, setting this variable to 1 on the slave, but to a different value on the master, can cause two types of problems: Names of databases are not converted to lowercase; in addition, when using row-based replication names of tables are also not converted. Either of these problems can cause replication to fail. This is a known issue, which is fixed in MySQL 5.6.

16.4.1.39 Replication and Views

Views are always replicated to slaves. Views are filtered by their own name, not by the tables they refer to. This means that a view can be replicated to the slave even if the view contains a table that would normally be filtered out by `replication-ignore-table` rules. Care should therefore be taken to ensure that views do not replicate table data that would normally be filtered for security reasons.

Replication from a table to a samed-named view is supported using statement-based logging, but not when using row-based logging. In MySQL 5.1.69 and later, trying to do so when row-based logging is in effect causes an error. (Bug #11752707, Bug #43975)

16.4.2 Replication Compatibility Between MySQL Versions

MySQL supports replication from one release series to the next higher release series. For example, you can replicate from a master running MySQL 5.0 to a slave running MySQL 5.1, from a master running MySQL 5.1 to a slave running MySQL 5.5, and so on.

However, one may encounter difficulties when replicating from an older master to a newer slave if the master uses statements or relies on behavior no longer supported in the version of MySQL used on the slave.

The use of more than two MySQL Server versions is not supported in replication setups involving multiple masters, regardless of the number of master or slave MySQL servers. This restriction applies not only to release series, but to version numbers within the same release series as well. For example, if you are using a chained or circular replication setup, you cannot use MySQL 5.1.31, MySQL 5.1.32, and MySQL 5.1.34 concurrently, although you could use any two of these releases together.

> **Important**
>
> It is strongly recommended to use the most recent release available within a given MySQL release series because replication (and other) capabilities are continually being improved. It is also recommended to upgrade masters and slaves that use early releases of a release series of MySQL to GA (production) releases when the latter become available for that release series.

Replication from newer masters to older slaves may be possible, but is generally not supported. This is due to a number of factors:

- **Binary log format changes.**   The binary log format can change between major releases. While we attempt to maintain backward compatibility, this is not always possible. For example, the binary

log format implemented in MySQL 5.0 changed considerably from that used in previous versions, especially with regard to handling of character sets, `LOAD DATA INFILE`, and time zones. This means that replication from a MySQL 5.0 (or later) master to a MySQL 4.1 (or earlier) slave is generally not supported.

This also has significant implications for upgrading replication servers; see Section 16.4.3, "Upgrading a Replication Setup", for more information.

• **Use of row-based replication.**   Row-based replication was implemented in MySQL 5.1.5, so you cannot replicate using row-based replication from any MySQL 5.1 or later master to a slave older than MySQL 5.1.5.

For more information about row-based replication, see Section 16.1.2, "Replication Formats".

• **SQL incompatibilities.**   You cannot replicate from a newer master to an older slave using statement-based replication if the statements to be replicated use SQL features available on the master but not on the slave.

However, if both the master and the slave support row-based replication, and there are no data definition statements to be replicated that depend on SQL features found on the master but not on the slave, you can use row-based replication to replicate the effects of data modification statements even if the DDL run on the master is not supported on the slave.

For more information on potential replication issues, see Section 16.4.1, "Replication Features and Issues".

16.4.3 Upgrading a Replication Setup

When you upgrade servers that participate in a replication setup, the procedure for upgrading depends on the current server versions and the version to which you are upgrading. This section provides information about how upgrading affects replication. For general information about upgrading MySQL, see Section 2.13.1, "Upgrading MySQL"

When you upgrade a master to 5.1 from an earlier MySQL release series, you should first ensure that all the slaves of this master are using the same 5.1.x release. If this is not the case, you should first upgrade the slaves. To upgrade each slave, shut it down, upgrade it to the appropriate 5.1.x version, restart it, and restart replication. The 5.1 slave is able to read the old relay logs written prior to the upgrade and to execute the statements they contain. Relay logs created by the slave after the upgrade are in 5.1 format.

After the slaves have been upgraded, shut down the master, upgrade it to the same 5.1.x release as the slaves, and restart it. The 5.1 master is able to read the old binary logs written prior to the upgrade and to send them to the 5.1 slaves. The slaves recognize the old format and handle it properly. Binary logs created by the master subsequent to the upgrade are in 5.1 format. These too are recognized by the 5.1 slaves.

In other words, when upgrading to MySQL 5.1, the slaves must be MySQL 5.1 before you can upgrade the master to 5.1. Note that downgrading from 5.1 to older versions does not work so simply: You must ensure that any 5.1 binary log or relay log has been fully processed, so that you can remove it before proceeding with the downgrade.

Downgrading a replication setup to a previous version cannot be done once you have switched from statement-based to row-based replication, and after the first row-based statement has been written to the binary log. See Section 16.1.2, "Replication Formats".

Some upgrades may require that you drop and re-create database objects when you move from one MySQL series to the next. For example, collation changes might require that table indexes be rebuilt. Such operations, if necessary, are detailed at Section 2.13.1.1, "Changes Affecting Upgrades to 5.1". It is safest

to perform these operations separately on the slaves and the master, and to disable replication of these operations from the master to the slave. To achieve this, use the following procedure:

1. Stop all the slaves and upgrade them. Restart them with the `--skip-slave-start` option so that they do not connect to the master. Perform any table repair or rebuilding operations needed to re-create database objects, such as use of `REPAIR TABLE` or `ALTER TABLE`, or dumping and reloading tables or triggers.

2. Disable the binary log on the master. To do this without restarting the master, execute a `SET sql_log_bin = 0` statement. Alternatively, stop the master and restart it without the `--log-bin` option. If you restart the master, you might also want to disallow client connections. For example, if all clients connect using TCP/IP, use the `--skip-networking` option when you restart the master.

3. With the binary log disabled, perform any table repair or rebuilding operations needed to re-create database objects. The binary log must be disabled during this step to prevent these operations from being logged and sent to the slaves later.

4. Re-enable the binary log on the master. If you set `sql_log_bin` to 0 earlier, execute a `SET sql_log_bin = 1` statement. If you restarted the master to disable the binary log, restart it with `--log-bin`, and without `--skip-networking` so that clients and slaves can connect.

5. Restart the slaves, this time without the `--skip-slave-start` option.

16.4.4 Troubleshooting Replication

If you have followed the instructions but your replication setup is not working, the first thing to do is *check the error log for messages*. Many users have lost time by not doing this soon enough after encountering problems.

If you cannot tell from the error log what the problem was, try the following techniques:

- Verify that the master has binary logging enabled by issuing a `SHOW MASTER STATUS` statement. If logging is enabled, `Position` is nonzero. If binary logging is not enabled, verify that you are running the master with the `--log-bin` option.

- Verify that the master and slave both were started with the `--server-id` option and that the ID value is unique on each server.

- Verify that the slave is running. Use `SHOW SLAVE STATUS` to check whether the `Slave_IO_Running` and `Slave_SQL_Running` values are both `Yes`. If not, verify the options that were used when starting the slave server. For example, `--skip-slave-start` prevents the slave threads from starting until you issue a `START SLAVE` statement.

- If the slave is running, check whether it established a connection to the master. Use `SHOW PROCESSLIST`, find the I/O and SQL threads and check their `State` column to see what they display. See Section 16.2.1, "Replication Implementation Details". If the I/O thread state says `Connecting to master`, check the following:

  - Verify the privileges for the user being used for replication on the master.

  - Check that the host name of the master is correct and that you are using the correct port to connect to the master. The port used for replication is the same as used for client network communication (the default is `3306`). For the host name, ensure that the name resolves to the correct IP address.

  - Check that networking has not been disabled on the master or slave. Look for the `skip-networking` option in the configuration file. If present, comment it out or remove it.

- If the master has a firewall or IP filtering configuration, ensure that the network port being used for MySQL is not being filtered.

- Check that you can reach the master by using `ping` or `traceroute`/`tracert` to reach the host.

- If the slave was running previously but has stopped, the reason usually is that some statement that succeeded on the master failed on the slave. This should never happen if you have taken a proper snapshot of the master, and never modified the data on the slave outside of the slave thread. If the slave stops unexpectedly, it is a bug or you have encountered one of the known replication limitations described in Section 16.4.1, "Replication Features and Issues". If it is a bug, see Section 16.4.5, "How to Report Replication Bugs or Problems", for instructions on how to report it.

- If a statement that succeeded on the master refuses to run on the slave, try the following procedure if it is not feasible to do a full database resynchronization by deleting the slave's databases and copying a new snapshot from the master:

  1. Determine whether the affected table on the slave is different from the master table. Try to understand how this happened. Then make the slave's table identical to the master's and run `START SLAVE`.

  2. If the preceding step does not work or does not apply, try to understand whether it would be safe to make the update manually (if needed) and then ignore the next statement from the master.

  3. If you decide that the slave can skip the next statement from the master, issue the following statements:

     ```
     mysql> SET GLOBAL sql_slave_skip_counter = N;
     mysql> START SLAVE;
     ```

     The value of N should be 1 if the next statement from the master does not use `AUTO_INCREMENT` or `LAST_INSERT_ID()`. Otherwise, the value should be 2. The reason for using a value of 2 for statements that use `AUTO_INCREMENT` or `LAST_INSERT_ID()` is that they take two events in the binary log of the master.

     See also Section 13.4.2.6, "SET GLOBAL sql_slave_skip_counter Syntax".

  4. If you are sure that the slave started out perfectly synchronized with the master, and that no one has updated the tables involved outside of the slave thread, then presumably the discrepancy is the result of a bug. If you are running the most recent version of MySQL, please report the problem. If you are running an older version, try upgrading to the latest production release to determine whether the problem persists.

16.4.5 How to Report Replication Bugs or Problems

When you have determined that there is no user error involved, and replication still either does not work at all or is unstable, it is time to send us a bug report. We need to obtain as much information as possible from you to be able to track down the bug. Please spend some time and effort in preparing a good bug report.

If you have a repeatable test case that demonstrates the bug, please enter it into our bugs database using the instructions given in Section 1.7, "How to Report Bugs or Problems". If you have a "phantom" problem (one that you cannot duplicate at will), use the following procedure:

1. Verify that no user error is involved. For example, if you update the slave outside of the slave thread, the data goes out of synchrony, and you can have unique key violations on updates. In this case, the

slave thread stops and waits for you to clean up the tables manually to bring them into synchrony. *This is not a replication problem. It is a problem of outside interference causing replication to fail.*

2. Run the slave with the `--log-slave-updates` and `--log-bin` options. These options cause the slave to log the updates that it receives from the master into its own binary logs.

3. Save all evidence before resetting the replication state. If we have no information or only sketchy information, it becomes difficult or impossible for us to track down the problem. The evidence you should collect is:

   • All binary log files from the master

   • All binary log files from the slave

   • The output of `SHOW MASTER STATUS` from the master at the time you discovered the problem

   • The output of `SHOW SLAVE STATUS` from the slave at the time you discovered the problem

   • Error logs from the master and the slave

4. Use `mysqlbinlog` to examine the binary logs. The following should be helpful to find the problem statement. *log_file* and *log_pos* are the `Master_Log_File` and `Read_Master_Log_Pos` values from `SHOW SLAVE STATUS`.

```
shell> mysqlbinlog --start-position=log_pos log_file | head
```

After you have collected the evidence for the problem, try to isolate it as a separate test case first. Then enter the problem with as much information as possible into our bugs database using the instructions at Section 1.7, "How to Report Bugs or Problems".

Chapter 17 MySQL Cluster NDB 6.1 - 7.1

Table of Contents

This chapter contains information about *MySQL Cluster*, which is a high-availability, high-redundancy version of MySQL adapted for the distributed computing environment. Current releases of MySQL Cluster use versions 6 and 7 of the `NDB` storage engine (also known as `NDBCLUSTER`) to enable running several computers with MySQL servers and other software in a cluster.

Beginning with MySQL 5.1.24, support for the `NDBCLUSTER` storage engine was removed from the standard MySQL server binaries built by MySQL. Instead, users of MySQL Cluster binaries built by MySQL should upgrade to the most recent binary release of MySQL Cluster NDB 7.0 or MySQL Cluster 7.1 for supported platforms—these include RPMs that should work with most Linux distributions. MySQL Cluster users who build from source should be aware that, also beginning with MySQL 5.1.24, `NDBCLUSTER` sources in the standard MySQL 5.1 tree are no longer maintained; these users should use the sources provided for MySQL Cluster NDB 7.0 or later. (Locations where the sources can be obtained are listed later in this section.)

Note

MySQL Cluster NDB 6.1, 6.2, and 6.3 were formerly known as "MySQL Cluster Carrier Grade Edition". Beginning with MySQL Cluster NDB 6.2.15 and MySQL Cluster NDB 6.3.14, this term is no longer applied to the MySQL Cluster software —which is now known simply as "MySQL Cluster"—but rather to a commercial licensing and support package. You can learn more about available options for

> commercial licensing of MySQL Cluster from http://mysql.com/products/database/cluster/features.html, on the MySQL web site.

This chapter contains information about MySQL Cluster in MySQL 5.1 mainline releases through MySQL 5.1.23, MySQL Cluster NDB 6.2 releases through 5.1.51-ndb-6.2.19, MySQL Cluster NDB 6.3 releases through 5.1.73-ndb-6.3.55, MySQL Cluster NDB 7.0 releases through 5.1.73-ndb-7.0.42 and MySQL Cluster NDB 7.1 releases through 5.1.77-ndb-7.1.37. Currently, the MySQL Cluster NDB 7.3 and MySQL Cluster NDB 7.4 release series are both Generally Available (GA). MySQL Cluster NDB 7.2 is a previous GA release series; although this series is still supported, we recommend that new deployments use MySQL Cluster NDB 7.4. For information about MySQL Cluster NDB 7.4, see MySQL Cluster NDB 7.3 and MySQL Cluster NDB 7.4, in the *MySQL 5.6 Manual*. MySQL Cluster NDB 7.5 is also available as a Developer Preview; see MySQL Cluster NDB 7.5.

This chapter also contains historical information about MySQL Cluster NDB 6.1 and MySQL Cluster NDB 6,2, although these release series are no longer in active development, and no longer supported for new deployments. You should upgrade to a MySQL Cluster NDB 7.1 or later release series as soon as possible.

Release notes for the changes in each release of MySQL Cluster are located at MySQL Cluster 7.1 Release Notes.

Supported Platforms.   MySQL Cluster is currently available and supported on a number of platforms. For exact levels of support available for on specific combinations of operating system versions, operating system distributions, and hardware platforms, please refer to http://www.mysql.com/support/supportedplatforms/cluster.html.

Availability.   MySQL Cluster binary and source packages are available for supported platforms from http://dev.mysql.com/downloads/cluster/.

> **Note**
>
> Binary releases and RPMs were not available for MySQL Cluster NDB 6.2 prior to MySQL Cluster NDB 6.2.15.

MySQL Cluster release numbers.   Starting with MySQL Cluster NDB 6.1 and MySQL Cluster NDB 6.2, MySQL Cluster follows a somewhat different release pattern from the mainline MySQL 5.1 Cluster series of releases. In this *Manual* and other MySQL documentation, we identify these and later MySQL Cluster releases employing a version number that begins with "NDB". This version number is that of the NDBCLUSTER storage engine used in the release, and not of the MySQL server version on which the MySQL Cluster release is based.

Version strings used in MySQL Cluster NDB 6.x and 7.x software.   The version string displayed by MySQL Cluster NDB 6.x and 7.x software uses this format:

```
mysql-mysql_server_version-ndb-ndb_engine_version
```

mysql_server_version represents the version of the MySQL Server on which the MySQL Cluster release is based. For all MySQL Cluster NDB 6.x and 7.x releases, this is "5.1". *ndb_engine_version* is the version of the NDB storage engine used by this release of the MySQL Cluster software. You can see this format used in the mysql client, as shown here:

```
shell> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.1.77-ndb-7.1.37 Source distribution
```

```
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT VERSION()\G
*************************** 1. row ***************************
VERSION(): 5.1.77-ndb-7.1.37
1 row in set (0.00 sec)
```

This version string is also displayed in the output of the SHOW command in the ndb_mgm client:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @10.0.10.6  (5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=2    @10.0.10.8  (5.1.77-ndb-7.1.37, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=3    @10.0.10.2  (5.1.77-ndb-7.1.37)

[mysqld(API)]   2 node(s)
id=4    @10.0.10.10  (5.1.77-ndb-7.1.37)
id=5 (not connected, accepting connect from any host)
```

The version string identifies the mainline MySQL version from which the MySQL Cluster release was branched and the version of the NDBCLUSTER storage engine used. For example, the full version string for MySQL Cluster NDB 7.0.5 (the first GA MySQL Cluster NDB 7.0 binary release) was mysql-5.1.32-ndb-7.0.5. From this we can determine the following:

• Since the portion of the version string preceding "-ndb-" is the base MySQL Server version, this means that MySQL Cluster NDB 7.0.5 derives from the MySQL 5.1.32, and contains all feature enhancements and bugfixes from MySQL 5.1 up to and including MySQL 5.1.32.

• Since the portion of the version string following "-ndb-" represents the version number of the NDB (or NDBCLUSTER) storage engine, MySQL Cluster NDB 7.0.5 uses version 7.0.5 of the NDBCLUSTER storage engine.

New MySQL Cluster releases are numbered according to updates in the NDB storage engine, and do not necessarily correspond in a linear fashion with mainline MySQL Server releases. For example, MySQL Cluster NDB 7.0.5 (as previously noted) is based on MySQL 5.1.32, and MySQL Cluster NDB 7.0.6 is based on MySQL 5.1.34 (version string: mysql-5.1.34-ndb-7.0.6).

Compatibility with standard MySQL 5.1 releases.   While many standard MySQL schemas and applications can work using MySQL Cluster, it is also true that unmodified applications and database schemas may be slightly incompatible or have suboptimal performance when run using MySQL Cluster (see Section 17.1.6, "Known Limitations of MySQL Cluster"). Most of these issues can be overcome, but this also means that you are very unlikely to be able to switch an existing application datastore—that currently uses, for example, MyISAM or InnoDB—to use the NDB storage engine without allowing for the possibility of changes in schemas, queries, and applications. Moreover, from MySQL 5.1.24 onwards, the MySQL Server and MySQL Cluster codebases diverge considerably (and NDB storage engine support dropped from subsequent MySQL Server releases), so that the standard mysqld cannot function as a dropin replacement for the version of mysqld that is supplied with MySQL Cluster.

MySQL Cluster development source trees.   MySQL Cluster development trees can also be accessed from https://github.com/mysql/mysql-server.

The MySQL Cluster development sources maintained at https://github.com/mysql/mysql-server are licensed under the GPL. For information about obtaining MySQL sources using Bazaar and building them yourself, see Section 2.11.3, "Installing MySQL Using a Development Source Tree".

Currently, MySQL Cluster NDB 7.3 and MySQL Cluster NDB 7.4 releases are Generally Available (GA). We recommend that new deployments use MySQL Cluster NDB 7.4. MySQL Cluster NDB 7.1 and earlier versions are no longer in active development. For an overview of major features added in MySQL Cluster NDB 7.4, see What is New in MySQL Cluster NDB 7.4. For similar information about MySQL Cluster NDB 7.3, see What is New in MySQL Cluster NDB 7.3. MySQL Cluster NDB 7.2 is a past GA series that is still supported; see What is New in MySQL Cluster. MySQL Cluster NDB 7.5 is also available as a Developer Preview for testing of new features; for more information, see MySQL Cluster NDB 7.5.

This chapter represents a work in progress, and its contents are subject to revision as MySQL Cluster continues to evolve. Additional information regarding MySQL Cluster can be found on the MySQL Web site at http://www.mysql.com/products/cluster/.

Additional Resources.   More information about MySQL Cluster can be found in the following places:

- For answers to some commonly asked questions about MySQL Cluster, see Section A.10, "MySQL 5.1 FAQ: MySQL Cluster".

- The MySQL Cluster mailing list: http://lists.mysql.com/cluster.

- The MySQL Cluster Forum: http://forums.mysql.com/list.php?25.

- Many MySQL Cluster users and developers blog about their experiences with MySQL Cluster, and make feeds of these available through PlanetMySQL.

17.1 MySQL Cluster Overview

MySQL Cluster is a technology that enables clustering of in-memory databases in a shared-nothing system. The shared-nothing architecture enables the system to work with very inexpensive hardware, and with a minimum of specific requirements for hardware or software.

MySQL Cluster is designed not to have any single point of failure. In a shared-nothing system, each component is expected to have its own memory and disk, and the use of shared storage mechanisms such as network shares, network file systems, and SANs is not recommended or supported.

MySQL Cluster integrates the standard MySQL server with an in-memory clustered storage engine called NDB (which stands for "*N*etwork *D*ata*B*ase"). In our documentation, the term NDB refers to the part of the setup that is specific to the storage engine, whereas "MySQL Cluster" refers to the combination of one or more MySQL servers with the NDB storage engine.

A MySQL Cluster consists of a set of computers, known as *hosts*, each running one or more processes. These processes, known as *nodes*, may include MySQL servers (for access to NDB data), data nodes (for storage of the data), one or more management servers, and possibly other specialized data access programs. The relationship of these components in a MySQL Cluster is shown here:

Figure 17.1 MySQL Cluster Components
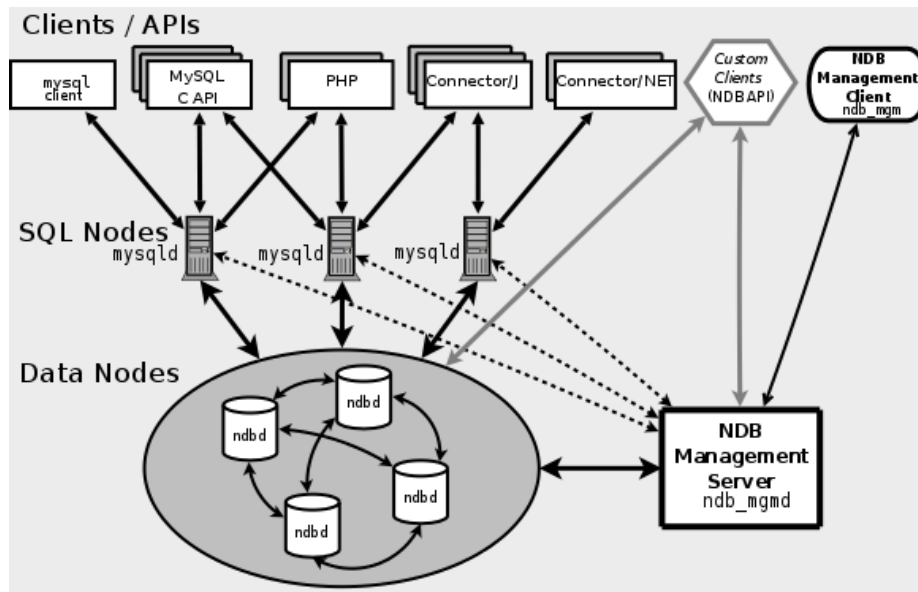
All these programs work together to form a MySQL Cluster (see Section 17.4, "MySQL Cluster Programs". When data is stored by the NDB storage engine, the tables (and table data) are stored in the data nodes. Such tables are directly accessible from all other MySQL servers (SQL nodes) in the cluster. Thus, in a payroll application storing data in a cluster, if one application updates the salary of an employee, all other MySQL servers that query this data can see this change immediately.

Although a MySQL Cluster SQL node uses the mysqld server daemon, it differs in a number of critical respects from the mysqld binary supplied with the MySQL 5.1 distributions, and the two versions of mysqld are not interchangeable.

In addition, a MySQL server that is not connected to a MySQL Cluster cannot use the NDB storage engine and cannot access any MySQL Cluster data.

The data stored in the data nodes for MySQL Cluster can be mirrored; the cluster can handle failures of individual data nodes with no other impact than that a small number of transactions are aborted due to losing the transaction state. Because transactional applications are expected to handle transaction failure, this should not be a source of problems.

Individual nodes can be stopped and restarted, and can then rejoin the system (cluster). Rolling restarts (in which all nodes are restarted in turn) are used in making configuration changes and software upgrades (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster"). In MySQL Cluster NDB 7.0 and later, rolling restarts are also used as part of the process of adding new data nodes online (see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online"). For more information about data nodes, how they are organized in a MySQL Cluster, and how they handle and store MySQL Cluster data, see Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions".

Backing up and restoring MySQL Cluster databases can be done using the NDB-native functionality found in the MySQL Cluster management client and the ndb_restore program included in the MySQL Cluster distribution. For more information, see Section 17.5.3, "Online Backup of MySQL Cluster", and Section 17.4.20, "ndb_restore — Restore a MySQL Cluster Backup". You can also use the standard MySQL functionality provided for this purpose in mysqldump and the MySQL server. See Section 4.5.4, "mysqldump — A Database Backup Program", for more information.

MySQL Cluster nodes can use a number of different transport mechanisms for inter-node communications, including TCP/IP using standard 100 Mbps or faster Ethernet hardware. It is also possible to use the high-

speed *Scalable Coherent Interface* (SCI) protocol with MySQL Cluster, although this is not required to use MySQL Cluster. SCI requires special hardware and software; see Section 17.3.4, "Using High-Speed Interconnects with MySQL Cluster", for more about SCI and using it with MySQL Cluster.

17.1.1 MySQL Cluster Core Concepts

`NDBCLUSTER` (also known as `NDB`) is an in-memory storage engine offering high-availability and data-persistence features.

The `NDBCLUSTER` storage engine can be configured with a range of failover and load-balancing options, but it is easiest to start with the storage engine at the cluster level. MySQL Cluster's `NDB` storage engine contains a complete set of data, dependent only on other data within the cluster itself.

The "Cluster" portion of MySQL Cluster is configured independently of the MySQL servers. In a MySQL Cluster, each part of the cluster is considered to be a *node*.

> **Note**
>
> In many contexts, the term "node" is used to indicate a computer, but when discussing MySQL Cluster it means a *process*. It is possible to run multiple nodes on a single computer; for a computer on which one or more cluster nodes are being run we use the term *cluster host*.

There are three types of cluster nodes, and in a minimal MySQL Cluster configuration, there will be at least three nodes, one of each of these types:

- *Management node*: The role of this type of node is to manage the other nodes within the MySQL Cluster, performing such functions as providing configuration data, starting and stopping nodes, running backup, and so forth. Because this node type manages the configuration of the other nodes, a node of this type should be started first, before any other node. An MGM node is started with the command `ndb_mgmd`.

- *Data node*: This type of node stores cluster data. There are as many data nodes as there are replicas, times the number of fragments (see Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions"). For example, with two replicas, each having two fragments, you need four data nodes. One replica is sufficient for data storage, but provides no redundancy; therefore, it is recommended to have 2 (or more) replicas to provide redundancy, and thus high availability. A data node is started with the command `ndbd` (see Section 17.4.1, "`ndbd` — The MySQL Cluster Data Node Daemon"). In MySQL Cluster NDB 7.0 and later, `ndbmtd` can also be used for the data node process; see Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)", for more information.

  MySQL Cluster tables are normally stored completely in memory rather than on disk (this is why we refer to MySQL Cluster as an *in-memory* database). In MySQL 5.1, MySQL Cluster NDB 6.X, and later, some MySQL Cluster data can be stored on disk; see Section 17.5.12, "MySQL Cluster Disk Data Tables", for more information.

- *SQL node*: This is a node that accesses the cluster data. In the case of MySQL Cluster, an SQL node is a traditional MySQL server that uses the `NDBCLUSTER` storage engine. An SQL node is a `mysqld` process started with the `--ndbcluster` and `--ndb-connectstring` options, which are explained elsewhere in this chapter, possibly with additional MySQL server options as well.

  An SQL node is actually just a specialized type of *API node*, which designates any application which accesses MySQL Cluster data. Another example of an API node is the `ndb_restore` utility that is used to restore a cluster backup. It is possible to write such applications using the NDB API. For basic information about the NDB API, see Getting Started with the NDB API.

⚠️

Important

It is not realistic to expect to employ a three-node setup in a production environment. Such a configuration provides no redundancy; to benefit from MySQL Cluster's high-availability features, you must use multiple data and SQL nodes. The use of multiple management nodes is also highly recommended.

For a brief introduction to the relationships between nodes, node groups, replicas, and partitions in MySQL Cluster, see Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions".

Configuration of a cluster involves configuring each individual node in the cluster and setting up individual communication links between nodes. MySQL Cluster is currently designed with the intention that data nodes are homogeneous in terms of processor power, memory space, and bandwidth. In addition, to provide a single point of configuration, all configuration data for the cluster as a whole is located in one configuration file.

The management server manages the cluster configuration file and the cluster log. Each node in the cluster retrieves the configuration data from the management server, and so requires a way to determine where the management server resides. When interesting events occur in the data nodes, the nodes transfer information about these events to the management server, which then writes the information to the cluster log.

In addition, there can be any number of cluster client processes or applications. These include standard MySQL clients, `NDB`-specific API programs, and management clients. These are described in the next few paragraphs.

Standard MySQL clients. MySQL Cluster can be used with existing MySQL applications written in PHP, Perl, C, C++, Java, Python, Ruby, and so on. Such client applications send SQL statements to and receive responses from MySQL servers acting as MySQL Cluster SQL nodes in much the same way that they interact with standalone MySQL servers.

MySQL clients using a MySQL Cluster as a data source can be modified to take advantage of the ability to connect with multiple MySQL servers to achieve load balancing and failover. For example, Java clients using Connector/J 5.0.6 and later can use `jdbc:mysql:loadbalance://` URLs (improved in Connector/J 5.1.7) to achieve load balancing transparently; for more information about using Connector/J with MySQL Cluster, see Using Connector/J with MySQL Cluster.

NDB client programs. Client programs can be written that access MySQL Cluster data directly from the `NDBCLUSTER` storage engine, bypassing any MySQL Servers that may be connected to the cluster, using the *NDB API*, a high-level C++ API. Such applications may be useful for specialized purposes where an SQL interface to the data is not needed. For more information, see The NDB API.

Beginning with MySQL Cluster NDB 7.1, `NDB`-specific Java applications can also be written for MySQL Cluster, using the *MySQL Cluster Connector for Java*. This MySQL Cluster Connector includes *ClusterJ*, a high-level database API similar to object-relational mapping persistence frameworks such as Hibernate and JPA that connect directly to `NDBCLUSTER`, and so does not require access to a MySQL Server. Support is also provided in MySQL Cluster NDB 7.1 and later for *ClusterJPA*, an OpenJPA implementation for MySQL Cluster that leverages the strengths of ClusterJ and JDBC; ID lookups and other fast operations are performed using ClusterJ (bypassing the MySQL Server), while more complex queries that can benefit from MySQL's query optimizer are sent through the MySQL Server, using JDBC. See Java and MySQL Cluster, and The ClusterJ API and Data Object Model, for more information.

Management clients. These clients connect to the management server and provide commands for starting and stopping nodes gracefully, starting and stopping message tracing (debug versions only), showing node versions and status, starting and stopping backups, and so on. An example of this type of program is the `ndb_mgm` management client supplied with MySQL Cluster (see Section 17.4.5, "`ndb_mgm`

— The MySQL Cluster Management Client"). Such applications can be written using the *MGM API*, a C-language API that communicates directly with one or more MySQL Cluster management servers. For more information, see The MGM API.

Oracle also makes available MySQL Cluster Manager, which provides an advanced command-line interface simplifying many complex MySQL Cluster management tasks, such restarting a MySQL Cluster with a large number of nodes. The MySQL Cluster Manager client also supports commands for getting and setting the values of most node configuration parameters as well as `mysqld` server options and variables relating to MySQL Cluster. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

Event logs.   MySQL Cluster logs events by category (startup, shutdown, errors, checkpoints, and so on), priority, and severity. A complete listing of all reportable events may be found in Section 17.5.6, "Event Reports Generated in MySQL Cluster". Event logs are of the two types listed here:

• *Cluster log*: Keeps a record of all desired reportable events for the cluster as a whole.

• *Node log*: A separate log which is also kept for each individual node.

> **Note**
>
> Under normal circumstances, it is necessary and sufficient to keep and examine only the cluster log. The node logs need be consulted only for application development and debugging purposes.

Checkpoint.   Generally speaking, when data is saved to disk, it is said that a *checkpoint* has been reached. More specific to MySQL Cluster, a checkpoint is a point in time where all committed transactions are stored on disk. With regard to the `NDB` storage engine, there are two types of checkpoints which work together to ensure that a consistent view of the cluster's data is maintained. These are shown in the following list:

• *Local Checkpoint (LCP)*: This is a checkpoint that is specific to a single node; however, LCPs take place for all nodes in the cluster more or less concurrently. An LCP involves saving all of a node's data to disk, and so usually occurs every few minutes. The precise interval varies, and depends upon the amount of data stored by the node, the level of cluster activity, and other factors.

• *Global Checkpoint (GCP)*: A GCP occurs every few seconds, when transactions for all nodes are synchronized and the redo-log is flushed to disk.

For more information about the files and directories created by local checkpoints and global checkpoints, see MySQL Cluster Data Node File System Directory Files.

17.1.2 MySQL Cluster Nodes, Node Groups, Replicas, and Partitions

This section discusses the manner in which MySQL Cluster divides and duplicates data for storage.

A number of concepts central to an understanding of this topic are discussed in the next few paragraphs.

(Data) Node.   An `ndbd` process, which stores a *replica* —that is, a copy of the *partition* (see below) assigned to the node group of which the node is a member.

Each data node should be located on a separate computer. While it is also possible to host multiple `ndbd` processes on a single computer, such a configuration is not supported.

It is common for the terms "node" and "data node" to be used interchangeably when referring to an `ndbd` process; where mentioned, management nodes (`ndb_mgmd` processes) and SQL nodes (`mysqld` processes) are specified as such in this discussion.

Node Group.   A node group consists of one or more nodes, and stores partitions, or sets of *replicas* (see next item).

The number of node groups in a MySQL Cluster is not directly configurable; it is a function of the number of data nodes and of the number of replicas (`NoOfReplicas` configuration parameter), as shown here:

```
[number_of_node_groups] = number_of_data_nodes / NoOfReplicas
```

Thus, a MySQL Cluster with 4 data nodes has 4 node groups if `NoOfReplicas` is set to 1 in the `config.ini` file, 2 node groups if `NoOfReplicas` is set to 2, and 1 node group if `NoOfReplicas` is set to 4. Replicas are discussed later in this section; for more information about `NoOfReplicas`, see Section 17.3.3.6, "Defining MySQL Cluster Data Nodes".

> **Note**
>
> All node groups in a MySQL Cluster must have the same number of data nodes.

Prior to MySQL Cluster NDB 7.0, it was not possible to add new data nodes to a MySQL Cluster without shutting down the cluster completely and reloading all of its data. In MySQL Cluster NDB 7.0 (beginning with MySQL Cluster version NDB 6.4.0), you can add new node groups (and thus new data nodes) to a running MySQL Cluster—see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online", for information about how this can be done.

Partition.   This is a portion of the data stored by the cluster. There are as many cluster partitions as nodes participating in the cluster. Each node is responsible for keeping at least one copy of any partitions assigned to it (that is, at least one replica) available to the cluster.

A replica belongs entirely to a single node; a node can (and usually does) store several replicas.

NDB and user-defined partitioning.   MySQL Cluster normally partitions `NDBCLUSTER` tables automatically. However, in MySQL 5.1 and later MySQL Cluster releases, it is possible to employ user-defined partitioning with `NDBCLUSTER` tables. This is subject to the following limitations:

1. Only the `KEY` and `LINEAR KEY` partitioning schemes are supported in production with `NDB` tables.

2. When using `ndbd`, the maximum number of partitions that may be defined explicitly for any `NDB` table is `8 * [number of node groups]`. (The number of node groups in a MySQL Cluster is determined as discussed previously in this section.)

   When using `ndbmtd`, this maximum is also affected by the number of local query handler threads, which is determined by the value of the `MaxNoOfExecutionThreads` configuration parameter. In such cases, the maximum number of partitions that may be defined explicitly for an `NDB` table is equal to `4 * MaxNoOfExecutionThreads * [number of node groups]`.

   See Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)", for more information.

For more information relating to MySQL Cluster and user-defined partitioning, see Section 17.1.6, "Known Limitations of MySQL Cluster", and Section 18.5.2, "Partitioning Limitations Relating to Storage Engines".

Replica.   This is a copy of a cluster partition. Each node in a node group stores a replica. Also sometimes known as a *partition replica*. The number of replicas is equal to the number of nodes per node group.

The following diagram illustrates a MySQL Cluster with four data nodes, arranged in two node groups of two nodes each; nodes 1 and 2 belong to node group 0, and nodes 3 and 4 belong to node group 1. Note

that only data (`ndbd`) nodes are shown here; although a working cluster requires an `ndb_mgm` process for cluster management and at least one SQL node to access the data stored by the cluster, these have been omitted in the figure for clarity.

Figure 17.2 MySQL Cluster with Two Node Groups
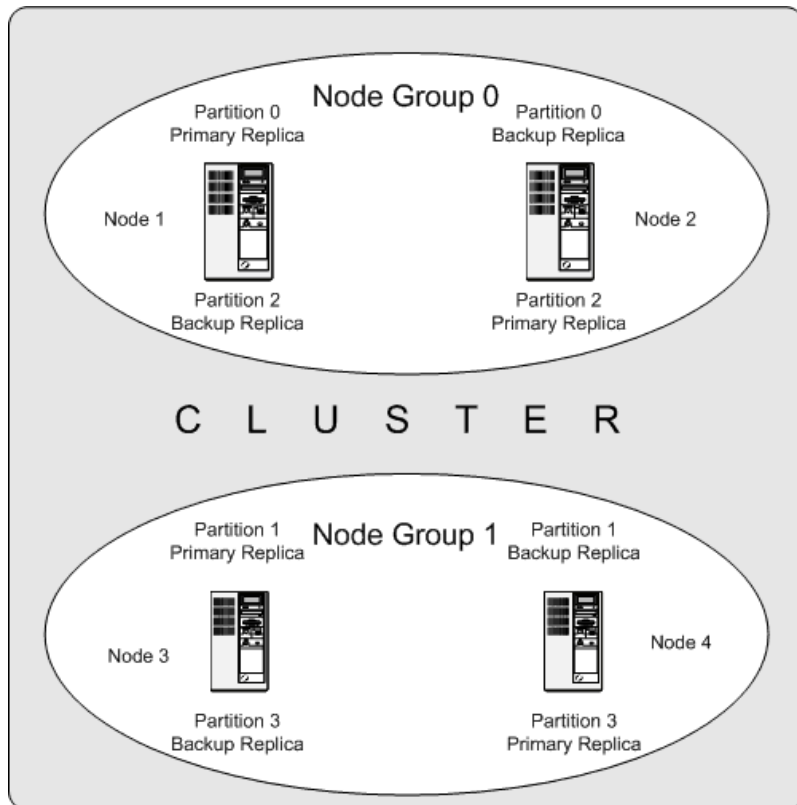
The data stored by the cluster is divided into four partitions, numbered 0, 1, 2, and 3. Each partition is stored—in multiple copies—on the same node group. Partitions are stored on alternate node groups as follows:

- Partition 0 is stored on node group 0; a *primary replica* (primary copy) is stored on node 1, and a *backup replica* (backup copy of the partition) is stored on node 2.

- Partition 1 is stored on the other node group (node group 1); this partition's primary replica is on node 3, and its backup replica is on node 4.

- Partition 2 is stored on node group 0. However, the placing of its two replicas is reversed from that of Partition 0; for Partition 2, the primary replica is stored on node 2, and the backup on node 1.

- Partition 3 is stored on node group 1, and the placement of its two replicas are reversed from those of partition 1. That is, its primary replica is located on node 4, with the backup on node 3.

What this means regarding the continued operation of a MySQL Cluster is this: so long as each node group participating in the cluster has at least one node operating, the cluster has a complete copy of all data and remains viable. This is illustrated in the next diagram.

Figure 17.3 Nodes Required for a 2x2 Cluster
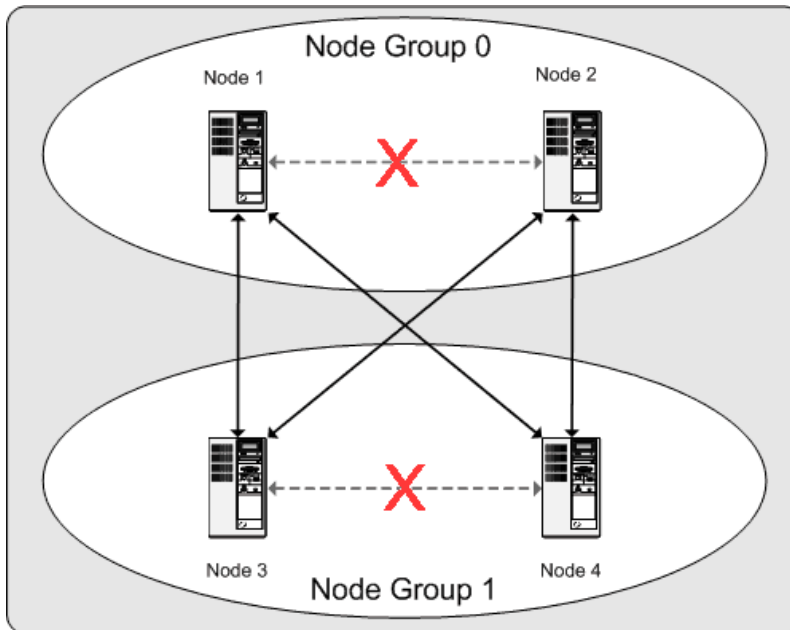
In this example, where the cluster consists of two node groups of two nodes each, any combination of at least one node in node group 0 and at least one node in node group 1 is sufficient to keep the cluster "alive" (indicated by arrows in the diagram). However, if *both* nodes from *either* node group fail, the remaining two nodes are not sufficient (shown by the arrows marked out with an **X**); in either case, the cluster has lost an entire partition and so can no longer provide access to a complete set of all cluster data.

17.1.3 MySQL Cluster Hardware, Software, and Networking Requirements

One of the strengths of MySQL Cluster is that it can be run on commodity hardware and has no unusual requirements in this regard, other than for large amounts of RAM, due to the fact that all live data storage is done in memory. (It is possible to reduce this requirement using Disk Data tables—see Section 17.5.12, "MySQL Cluster Disk Data Tables", for more information about these.) Naturally, multiple and faster CPUs can enhance performance. Memory requirements for other MySQL Cluster processes are relatively small.

The software requirements for MySQL Cluster are also modest. Host operating systems do not require any unusual modules, services, applications, or configuration to support MySQL Cluster. For supported operating systems, a standard installation should be sufficient. The MySQL software requirements are simple: all that is needed is a production release of MySQL Cluster. It is not strictly necessary to compile MySQL yourself merely to be able to use MySQL Cluster. We assume that you are using the binaries appropriate to your platform, available from the MySQL Cluster software downloads page at http://dev.mysql.com/downloads/cluster/.

For communication between nodes, MySQL Cluster supports TCP/IP networking in any standard topology, and the minimum expected for each host is a standard 100 Mbps Ethernet card, plus a switch, hub, or router to provide network connectivity for the cluster as a whole. We strongly recommend that a MySQL Cluster be run on its own subnet which is not shared with machines not forming part of the cluster for the following reasons:

- **Security.** Communications between MySQL Cluster nodes are not encrypted or shielded in any way. The only means of protecting transmissions within a MySQL Cluster is to run your MySQL Cluster on a protected network. If you intend to use MySQL Cluster for Web applications, the cluster should definitely reside behind your firewall and not in your network's De-Militarized Zone (DMZ) or elsewhere.

See Section 17.5.11.1, "MySQL Cluster Security and Networking Issues", for more information.

- **Efficiency.**   Setting up a MySQL Cluster on a private or protected network enables the cluster to make exclusive use of bandwidth between cluster hosts. Using a separate switch for your MySQL Cluster not only helps protect against unauthorized access to MySQL Cluster data, it also ensures that MySQL Cluster nodes are shielded from interference caused by transmissions between other computers on the network. For enhanced reliability, you can use dual switches and dual cards to remove the network as a single point of failure; many device drivers support failover for such communication links.

Network communication and latency.   MySQL Cluster requires communication between data nodes and API nodes (including SQL nodes), as well as between data nodes and other data nodes, to execute queries and updates. Communication latency between these processes can directly affect the observed performance and latency of user queries. In addition, to maintain consistency and service despite the silent failure of nodes, MySQL Cluster uses heartbeating and timeout mechanisms which treat an extended loss of communication from a node as node failure. This can lead to reduced redundancy. Recall that, to maintain data consistency, a MySQL Cluster shuts down when the last node in a node group fails. Thus, to avoid increasing the risk of a forced shutdown, breaks in communication between nodes should be avoided wherever possible.

The failure of a data or API node results in the abort of all uncommitted transactions involving the failed node. Data node recovery requires synchronization of the failed node's data from a surviving data node, and re-establishment of disk-based redo and checkpoint logs, before the data node returns to service. This recovery can take some time, during which the Cluster operates with reduced redundancy.

Heartbeating relies on timely generation of heartbeat signals by all nodes. This may not be possible if the node is overloaded, has insufficient machine CPU due to sharing with other programs, or is experiencing delays due to swapping. If heartbeat generation is sufficiently delayed, other nodes treat the node that is slow to respond as failed.

This treatment of a slow node as a failed one may or may not be desirable in some circumstances, depending on the impact of the node's slowed operation on the rest of the cluster. When setting timeout values such as `HeartbeatIntervalDbDb` and `HeartbeatIntervalDbApi` for MySQL Cluster, care must be taken care to achieve quick detection, failover, and return to service, while avoiding potentially expensive false positives.

Where communication latencies between data nodes are expected to be higher than would be expected in a LAN environment (on the order of 100 μs), timeout parameters must be increased to ensure that any allowed periods of latency periods are well within configured timeouts. Increasing timeouts in this way has a corresponding effect on the worst-case time to detect failure and therefore time to service recovery.

LAN environments can typically be configured with stable low latency, and such that they can provide redundancy with fast failover. Individual link failures can be recovered from with minimal and controlled latency visible at the TCP level (where MySQL Cluster normally operates). WAN environments may offer a range of latencies, as well as redundancy with slower failover times. Individual link failures may require route changes to propagate before end-to-end connectivity is restored. At the TCP level this can appear as large latencies on individual channels. The worst-case observed TCP latency in these scenarios is related to the worst-case time for the IP layer to reroute around the failures.

SCI support.   It is also possible to use the high-speed Scalable Coherent Interface (SCI) with MySQL Cluster, but this is not a requirement. See Section 17.3.4, "Using High-Speed Interconnects with MySQL Cluster", for more about this protocol and its use with MySQL Cluster.

17.1.4 MySQL Cluster Development History

In this section, we discuss changes in the implementation of MySQL Cluster in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x, as compared to earlier MySQL Cluster releases.

There are a number of significant changes in the implementation of the `NDBCLUSTER` storage engine in mainline MySQL 5.1 releases up to and including MySQL 5.1.23 as compared to that in MySQL 5.0; MySQL Cluster NDB 6.x and 7.x make further changes and improvements in MySQL Cluster in addition to these. The changes and features most likely to be of interest are shown in the following tables:

MySQL Cluster NDB 7.2
Distribution of MySQL users and privileges across MySQL Cluster SQL nodes
Distributed pushed-down joins, with greatly improved performance for many joins that can thus be pushed down and executed in parallel on the data nodes.
Improved default values for data node configuration parameters.

MySQL Cluster NDB 7.1
Production-level support for MySQL Cluster on Microsoft Windows platforms.
`ndbinfo` meta-information database
MySQL Cluster Connector for Java, including ClusterJ and OpenJPA (ClusterJPA) support
Native support for default column values

MySQL Cluster NDB 7.0
Multi-threaded data nodes (`ndbmtd` data node daemon)
Online addition of data nodes; online data redistribution
MySQL on Windows (alpha; source releases only)
Configuration cache
Backup snapshots (`START BACKUP ... SNAPSHOTSTART`, `START BACKUP ... SNAPSHOTEND` commands)
IPv6 support for geo-replication
Protected DDL operations
Dynamic buffering for NDB transporters
Increased flexibility in determining arbitration handling, using a new `Arbitration` data node configuration parameter
NDB API counters and associated status variables, which make it possible to observe the API-level effects of SQL statements on `NDB` tables from the `mysql` client.

MySQL Cluster NDB 6.3
Conflict detection and resolution for multi-master replication
Compressed backups and local checkpoints
Support for `OPTIMIZE TABLE`
Parallel data node recovery
Enhanced transaction coordinator selection
Improved SQL statement performance metrics
Transaction batching
`ndb_restore` attribute promotion
Support for `epoll` (Linux only)

MySQL Cluster NDB 6.3
Distribution awareness
`NDB` thread locks; realtime extensions for multiple CPUs

MySQL Cluster NDB 6.2
Improved backup status reporting (`BackupReportFrequency`, `REPORT BackupStatus`)
Multiple connections per SQL node
Data access with `NdbRecord` (NDB API)
`REPORT MemoryUsage` command
Memory allocation improvements
Management client connection control
Micro-GCPs
Online `ADD COLUMN`; improved online index creation

MySQL Cluster NDB 6.1
Greater number of cluster nodes
Disabling of arbitration
Additional `DUMP` commands
Faster Disk Data backups
Batched slave updates

MySQL 5.1 (through 5.1.23)
MySQL Cluster Replication
Disk Data storage
Variable-size columns
User-defined partitioning
Autodiscovery of table schema changes
Online adding and dropping of indexes

17.1.4.1 What is New in MySQL Cluster NDB 7.2.0

The following improvements to MySQL Cluster were made in MySQL Cluster NDB 7.2.0.

- **Distribution of MySQL users and privileges.**   Automatic distribution of MySQL users and privileges across all SQL nodes in a given MySQL Cluster is now supported. To enable this support, you must first import an SQL script `share/mysql/ndb_dist_priv.sql` that is included with the MySQL Cluster NDB 7.2 distribution. This script creates several stored procedures which you can use to enable privilege distribution and perform related tasks.

  When a new MySQL Server joins a MySQL Cluster where privilege distribution is in effect, it also participates in the privilege distribution automatically.

  Once privilege distribution is enabled, all changes to the grant tables made on any `mysqld` attached to the cluster are immediately available on any other attached MySQL Servers. This is true whether the changes are made using `CREATE USER`, `GRANT`, or any of the other statements described elsewhere in

this Manual (see Section 13.7.1, "Account Management Statements".) This includes privileges relating to stored routines and views; however, automatic distribution of the views or stored routines themselves is not currently supported.

For more information, see Section 17.5.14, "Distributed MySQL Privileges for MySQL Cluster".

- **Distributed pushed-down joins.** Many joins can now be pushed down to the NDB kernel for processing on MySQL Cluster data nodes. Previously, a join was handled in MySQL Cluster by means of repeated accesses of `NDB` by the SQL node; however, when pushed-down joins are enabled, a pushable join is sent in its entirety to the data nodes, where it can be distributed among the data nodes and executed in parallel on multiple copies of the data, with a single, merged result being returned to `mysqld`. This can reduce greatly the number of round trips between an SQL node and the data nodes required to handle such a join, leading to greatly improved performance of join processing.

  It is possible to determine when joins can be pushed down to the data nodes by examining the join with `EXPLAIN`. A number of new system status variables (`Ndb_pushed_queries_defined`, `Ndb_pushed_queries_dropped`, `Ndb_pushed_queries_executed`, and `Ndb_pushed_reads`) and additions to the `counters` table (in the `ndbinfo` information database) can also be helpful in determining when and how well joins are being pushed down.

  More information and examples are available in the description of the `ndb_join_pushdown` server system variable. See also the description of the status variables referenced in the previous paragraph, as well as Section 17.5.10.7, "The ndbinfo counters Table".

- **Improved default values for data node configuration parameters.** In order to provide more resiliency to environmental issues and better handling of some potential failure scenarios, and to perform more reliably with increases in memory and other resource requirements brought about by recent improvements in join handling by `NDB`, the default values for a number of MySQL Cluster data node configuration parameters have been changed. The parameters and changes are described in the following list:

  - `HeartbeatIntervalDbDb`: Default increased from 1500 ms to 5000 ms.

  - `ArbitrationTimeout`: Default increased from 3000 ms to 7500 ms.

  - `TimeBetweenEpochsTimeout`: Now effectively disabled by default (default changed from 4000 ms to 0).

  - `SharedGlobalMemory`: Default increased from 20 MB to 128 MB.

  - `MaxParallelScansPerFragment`: Default increased from 32 to 256.

  In addition, the value computed for `MaxNoOfLocalScans` when this parameter is not set in `config.ini` has been increased by a factor of 4.

MySQL Cluster NDB 7.2.1 and later MySQL Cluster NDB 7.2 releases are based on MySQL Server 5.5 and are not covered here. See MySQL Cluster NDB 7.2.

17.1.4.2 What is New in MySQL Cluster NDB 7.1

The following improvements to MySQL Cluster have been made in MySQL Cluster NDB 7.1.

- **MySQL Cluster information database (ndbinfo).** The `ndbinfo` information database makes it possible to obtain real-time characteristics of a MySQL Cluster by issuing queries from the `mysql` client or other MySQL client applications. `ndbinfo` provides metadata specific to MySQL Cluster similarly to how the `INFORMATION_SCHEMA` database provides metadata for the standard MySQL Server. This

eliminates much of the need to read log files, issue `REPORT` or `DUMP` commands in the `ndb_mgm` client, or parse the output of `ndb_config` in order to get configuration and status information from a running MySQL Cluster.

For more information, see Section 17.5.10, "The ndbinfo MySQL Cluster Information Database".

- **Java connectors for MySQL Cluster.**   The MySQL Cluster distribution now includes 2 new Java user APIs, ClusterJ and ClusterJPA. ClusterJ is an object-relational interface in a manner similar to that of Java persistence frameworks such as Hibernate. Cluster JPA is a reimplementation of OpenJPA. ClusterJ uses a backend library (NdbJTie) that provides access to the `NDB` storage engine without using a MySQL Server connection or JDBC. ClusterJPA also uses NdbJTie when it improves performance, but can also process complex queries using JDBC and a MySQL Server connection, where it can take advantage of the MySQL query optimizer.

  ClusterJ and Cluster JPA can also be made to work with recent MySQL Cluster NDB 7.0 releases although the necessary library and JAR files are included only in MySQL Cluster NDB 7.1.1 and later.

  For more information about using ClusterJ and ClusterJPA, see MySQL Cluster Connector for Java.

- **New CHANGE MASTER TO option for circular replication.**   Beginning with MySQL Cluster NDB 7.1.0, the `CHANGE MASTER TO` statement supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. (Log rotation and log deletion events are preserved.)

  See Section 13.4.2.1, "CHANGE MASTER TO Syntax", as well as Section 13.7.5.36, "SHOW SLAVE STATUS Syntax", for more information.

- **Native support for default column values.**   Starting with MySQL Cluster NDB 7.1.4, default values for table columns are stored in the NDB kernel rather than by the MySQL server as was done previously. This means that inserts on tables having column value defaults can be smaller and faster than before, because less data must be sent from SQL nodes to `NDBCLUSTER`.

  Tables created using previous MySQL Cluster releases can still be used in MySQL Cluster 7.1.4 and later; however, they do not support native default values until they are upgraded. You can upgrade a table with non-native default values to support native default values using an offline `ALTER TABLE` statement.

- **MySQL Cluster on Windows (Production).**   Beginning with MySQL Cluster NDB 7.1.3, MySQL Cluster is available for production use on Microsoft Windows operating systems; MySQL Cluster NDB 7.1 binaries for Windows can be obtained from http://dev.mysql.com/downloads/cluster/.

  Features and behavior are generally comparable to those found on previously supported platforms such as Linux and Solaris. However, you must install the binaries manually.

  Beginning with MySQL Cluster NDB 7.1.5, MySQL Cluster processes can be run as Windows services.

  If you wish to build MySQL Cluster from source on Windows, you must configure the build using the `WITH_NDBCLUSTER_STORAGE_ENGINE` option. For more information, see Section 2.11.7, "Installing MySQL from Source on Windows".

- **--nowait-nodes option for management servers.**   It is now possible to configure a cluster with two management servers, but to start the cluster using only one of them by starting the management node daemon with the `--nowait-nodes` option. The other management server can then be started at a later time to join the running MySQL Cluster.

- **Improved lock handling for primary key lookups on BLOB tables.**   A MySQL Cluster table stores all but the first 256 bytes of any `BLOB` or `TEXT` column values in a separate `BLOB` table; when executing

queries against such tables, a shared lock is obtained. Prior to MySQL Cluster NDB 7.1.1, when the query used a primary key lookup and took place within a transaction, the lock was held for the duration of the transaction, even after no more data was being read from the `NDB` table. Now in such cases, the lock is released when all `BLOB` data associated with the table has been read. (Bug #49190)

> **Note**
>
> A shared lock is also taken for unique key lookups; it is still the case that this lock is held for the duration of the transaction.

- **Heartbeat thread policy and priority.**   Beginning with MySQL Cluster NDB 7.1.2, a new configuration parameter `HeartbeatThreadPriority` makes it possible to set the policy and the priority for the heartbeat thread on management and API nodes.

- **Improved access to partitioning information.**   The `ndb_desc` utility now provides additional information about the partitioning of data stored in MySQL Cluster. Beginning with MySQL Cluster NDB 7.1.2, the `--blob-info` option causes this program to include partition information for `BLOB` tables in its output. Also beginning with MySQL Cluster NDB 7.1.2, the `--extra-node-info` option causes `ndb_desc` to include information about data distribution (that is, which table fragments are stored on which data nodes). Each of these options also requires the use of the `--extra-partition-info` option.

  Information about partition-to-node mappings can also be obtained using the `Table::getFragmentNodes()` method, also added in MySQL Cluster NDB 7.1.2.

- **Replication attribute promotion and demotion.**   Beginning with MySQL Cluster NDB 7.1.3, MySQL Cluster Replication supports attribute promotion and demotion when replicating between columns of different but similar types on the master and the slave. For example, it is possible to promote an `INT` column on the master to a `BIGINT` column on the slave, and to demote a `TEXT` column to a `VARCHAR` column.

  The implementation of type demotion distinguishes between lossy and non-lossy type conversions, and their use on the slave can be controlled by setting the `slave_type_conversions` global server system variable.

  For more information, see Attribute promotion and demotion (MySQL Cluster).

- **Change in ndbinfo database.**   The experimental `pools` table was removed from `ndbinfo` in MySQL Cluster NDB 7.1.3. Applications which used this table can and should be rewritten to use other `ndbinfo` tables.

- **Configuration caching control.**   Beginning with MySQL Cluster NDB 7.1.4, it is possible to disable the management server's configuration cache using the `--config-cache` option, which forces `ndb_mgmd` to read its configuration data from the `config.ini` configuration file every time it starts. For more information about configuration caching and this option, see Section 17.3.3, "MySQL Cluster Configuration Files". See also Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon".

- **Incompatible change in NDB API event reporting.**   Beginning with MySQL Cluster NDB 7.1.4, DDL events are no longer reported on `Event` objects by default. Instead the desired level of event reporting (`EventReport` value) must be set explicitly using `Event::setReport()`.

- **Number of table attributes.**   Beginning with MySQL Cluster NDB 7.1.4, the maximum number of attributes (columns plus indexes) per table has been increased from 128 to 512.

- **InnoDB support in commercial binaries.**   Beginning with MySQL Cluster NDB 7.1.4b, all commercial binary releases of MySQL Cluster provide support for the `InnoDB` storage engine.

- **Heartbeat ordering.**   Beginning with MySQL Cluster NDB 7.1.5, it is possible to set a specific order for transmission of heartbeats between data nodes, using the `HeartbeatOrder` data node configuration parameter introduced in this version. This parameter can be useful in situations where multiple data nodes are running on the same host and a temporary disruption in connectivity between hosts would otherwise cause the loss of a node group (and thus failure of the cluster).

- **Relaxed ndb_restore column comparison rules.**   When restoring data, ndb_restore compares the attributes of a column for equality with the definition of the column in the target table. However, not all of these attributes need to be the same for `ndb_restore` to be meaningful, safe and useful. Beginning with MySQL Cluster NDB 7.1.5, `ndb_restore` automatically ignores differences in certain column attributes which do not necessarily have to match between the version of the column in a backup and the version of that column in the MySQL Cluster to which the column data is being restored. These attributes include the following:

  - `COLUMN_FORMAT` setting (`FIXED`, `DYNAMIC`, or `DEFAULT`)

  - `STORAGE` setting (`MEMORY` or `DISK`)

  - The default value

  - The distribution key

  In such cases, `ndb_restore` reports any such differences to minimize any chance of user error.

- **Storage of user data in anyValue.**   When writing NDB events to the binary log, MySQL Cluster uses `OperationOptions::anyValue` to store the server ID. Beginning with MySQL Cluster NDB 7.1.6, it is possible to store user data from an NDB API application in part of the `anyValue` when `mysqld` has been started with the `--server-id-bits` option set to a nondefault value. Also beginning with MySQL Cluster NDB 7.1.6, it is possible to view this data in the output of mysqlbinlog, for which its own `--server-id-bits` option is added.

- **--add-drop-trigger option for mysqldump.**   Beginning with MySQL Cluster NDB 7.1.8, this option can be used to force all `CREATE TRIGGER` statements in `mysqldump` output to be preceded by a `DROP TRIGGER IF EXISTS` statement.

- **Forcing node shutdown and restart.**   In MySQL Cluster NDB 7.1.8 and later, it is possible using the `ndb_mgm` management client or the MGM API to force a data node shutdown or restart even if this would force the shutdown or restart of the entire cluster. In the management client, this is implemented through the addition of the `-f` (force) option to the `STOP` and `RESTART` commands. For more information, see Section 17.5.2, "Commands in the MySQL Cluster Management Client". The MGM API also adds two new methods for forcing such a node shutdown or restart; see ndb_mgm_stop4(), and ndb_mgm_restart4(), for more information about these methods.

- **Disk Data usage statistics (diskpagebuffer table).**   MySQL Cluster 7.1.9 introduces a new table in the `ndbinfo` information database. The `diskpagebuffer` table provides real-time data on disk page buffer usage. These statistics can be used to monitor performance of MySQL Cluster Disk Data read and write operations, and can prove useful in the tuning of Disk Data parameters such as `DiskPageBufferMemory`.

- **InnoDB Plugin support.**   Beginning with MySQL Cluster NDB 7.1.9, the MySQL Server supplied with MySQL Cluster supports the `InnoDB` Plugin. For more information about enabling the plugin if you are building MySQL Cluster from source, see Section 17.2, "MySQL Cluster Installation and Upgrades".

> **Note**
>
> Due to a packaging issue, the `InnoDB` plugin was not included in RPMs for MySQL Cluster NDB 7.1.9; this issue was corrected in MySQL Cluster NDB 7.1.9a. (Bug #58283)

- **TimeBetweenEpochsTimeout and GCP stop control.**   Beginning with MySQL Cluster NDB 7.1.10, it is possible to disable GCP stops by setting `TimeBetweenEpochsTimeout` to 0. In addition, a warning is written to the cluster log whenever the time required for a GCP save exceeds 60 seconds or the time required for a GCP commit exceeds 10 seconds. This warning includes a report of the current value of `TimeBetweenEpochsTimeout`. For more information, see Disk Data and GCP Stop errors.

- **Skipping corrupted tables in NDB native backups.**   Beginning with MySQL Cluster NDB 7.1.10, you can cause `ndb_restore` to ignore tables that are corrupted due to missing blob parts tables by using the `--skip-broken-objects` option. When this option is used, such tables are skipped, and the restoration of any remaining uncorrupted tables in the backup continues.

- **BLOB read and write batching.**   Beginning with MySQL Cluster NDB 7.1.10, it possible to control batching of `BLOB` read and write operations. For SQL nodes, this can be done using the `--ndb-blob-read-batch-bytes` and `--ndb-blob-write-batch-bytes` options for `mysqld`. In NDB API applications, you can control batching of `BLOB` reads and writes using the `NdbTransaction` methods `setMaxPendingBlobReadBytes()`, `getMaxPendingBlobReadBytes()`, `setMaxPendingBlobWriteBytes()`, and `getMaxPendingBlobWriteBytes()`.

- **Restoring from a NDB native backup to a differently-named database.**   MySQL Cluster NDB 7.1.11 adds a new `--rewrite-database` option to `ndb_restore`, which makes it possible to restore to a database having a different name from that of the database in the backup. The option can be used multiple times, and it is possible to restore from more than one source database in the backup to a single target database (although no protection against table or other object name collision is provided).

    See Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup", for more information.

- **Selective over-commit handling.**   Beginning with MySQL Cluster NDB 7.1.10, it is possible to exercise more direct control over uncommitted operations from transactions aborted due to timeouts flushing redo logs to disk. This is implemented using three configuration parameters added in this version of MySQL Cluster: the data node configuration parameters `RedoOverCommitCounter` and `RedoOverCommitLimit`, and the API node configuration parameter `DefaultOperationRedoProblemAction`.

    When an attempt to flush a given redo log takes longer than `RedoOverCommitLimit` seconds, and this occurs `RedoOverCommitLimit` times or more, the transactions contained within the redo log are aborted. Any operations left uncommitted as a result are either aborted or re-tried, according to the value of `DefaultOperationRedoProblemAction`.

    For more information, see Redo log over-commit handling

- **INFORMATION_SCHEMA improvements.**   Beginning with MySQL Cluster NDB 7.1.11, Beginning with MySQL Cluster NDB 7.0.22, `INFORMATION_SCHEMA` provides disk usage information for MySQL Cluster Disk Data tables. Previously, `INFORMATION_SCHEMA.TABLES` showed only the space usage for the in-memory data part of the table. Now, it also shows the space allocated for and used by the disk_part data of that table as well.

    In addition, the `INFORMATION_SCHEMA.PARTITIONS` table (which did not show any statistics for `NDB` tables) now shows correct values in this table's `TABLE_ROWS`, `AVG_ROW_LENGTH`, `DATA_LENGTH`, `MAX_DATA_LENGTH`, and `DATA_FREE` columns, for each partition.

- **ndb_restore attribute demotion.**   Beginning with MySQL Cluster NDB 7.1.11, it is possible to enable attribute demotion when restoring a MySQL Cluster from a native backup running `ndb_restore` with a new `--lossy-conversions` option.

  In general,the rules governing demotion are the same as for MySQL replication, although there are some exceptions that you may need to take into account being employing this option. See Replication of Columns Having Different Data Types, for information about type conversions currently supported by attribute promotion and demotion in MySQL Cluster.

- **Improved multi-threaded order index building.**   Previously, it was not possible to enable multi-threaded building of ordered indexes during initial restarts. In MySQL Cluster NDB 7.1.11, this can now be done, using the new `TwoPassInitialNodeRestartCopy` data node configuration parameter.

- **Configuration version information in ndbinfo.nodes.**   You can see which version or versions of the MySQL Cluster configuration file are in effect on the data nodes by checking the `config_generation` column which is added to the `nodes` table in MySQL Cluster NDB 7.1.13.

- **Configuration version information in ndbinfo.nodes.**   You can see which version or versions of the MySQL Cluster configuration file are in effect on the data nodes by checking the `config_generation` column which is added to the `nodes` table in MySQL Cluster NDB 7.1.13.

- **Improvements in adding data nodes online.**   Begining with MySQL Cluster NDB 7.0.24, it is possible to add data nodes online to a running MySQL Cluster without performing a rolling restart of the cluster or starting data node processes with the `--nowait-nodes` option. This can be done by setting `Nodegroup = 65536` in the `config.ini` file for any data nodes that should be started at a later time, when first starting the cluster. The amount of time the cluster waits before doing this can be controlled using the `StartNoNodeGroupTimeout` data node configuration parameter.

- **Unique key updates in replication.**   It is possible in MySQL Cluster NDB 7.1.14 and later to employ operations that update unique keys when replicating `NDB` tables. Previously this could lead to duplicate key errors when trying to execute the binary log (due to the fact that row events in the binary log were ordered according to the partitioning of the base table, and could differ in order within the epoch for that in which they were executed).

  > **Important**
  >
  > Master and slave tables must both be using the `NDB` storage engine for this to work.

- Starting with MySQL Cluster NDB 7.1.17, the NDB kernel implements a number of statistical counters relating to actions performed by or affecting `Ndb` objects. Such events include starting, closing, and aborting transactions; operations using primary keys or unique keys; table, range, and pruned scans; blocking of threads by incompleted operations; and data and events sent and received by MySQL Cluster nodes. NDB API statistics counters are incremented inside the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes. A MySQL Server running as an SQL node in the cluster can access the values of these counters as system status variables, as seen in the output of `SHOW STATUS`, or in the results of queries against the `SESSION_STATUS` or `GLOBAL_STATUS` table in the `INFORMATION_SCHEMA` database. By comparing the values of these status variables before and after the execution of statements affecting `NDB` tables, you can observe the corresponding actions taken on the NDB API level. This can be highly useful when monitoring and tuning MySQL Cluster.

  For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables". See also MySQL Cluster Status Variables, for information about the individual status variables.

- **Version 2 binary log row events.**   New versions of the `WRITE_ROW`, `UPDATE_ROW`, and `DELETE_ROW` events have been implemented in MySQL Cluster NDB 7.1.16, extending them with

additional information intended to support future enhancements; these are referred to as "Version 2" binary log events.

Version 2 log events are not backward compatible, and cannot be read by older slaves. A new `mysqld` option `--log-bin-use-v1-row-events` can be employed to force use of Version 1 events when writing the binary log. This can be used during upgrades to make a newer `mysqld` generate Version 1 binary log row events that can be read by older slaves.

- **Circular replication: Primary wins first conflict detection.** Two new conflict detection functions `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` can be useful in "active-active" circular replication scenarios with two MySQL Clusters. For each case, we designate one cluster as primary and one as secondary, and implement a "primary always wins" rule for determining whether to accept conflicting changes. When using `NDB$EPOCH()`, conflicting rows on the secondary are realigned with those on the primary; when using `NDB$EPOCH_TRANS()`, it is transactions containing rows in conflict (and any transactions which depend on them) on the secondary that are realigned.

  When using `NDB$EPOCH_TRANS()` as the conflict detection function, the binary log must be written using Version 2 binary logging row events; that is, the `mysqld` processes on both the primary and the secondary must be started with `--log-bin-use-v1-row-events=0`. In addition, the secondary's binary log must include transaction IDs for all rows, that is, by setting `--ndb-log-transaction-id=1`.

  You can monitor conflict detection and resolution performed using these functions by reading a number of related server status variables, including `Ndb_conflict_fn_epoch`, `Ndb_conflict_fn_epoch_trans`, and `Ndb_conflict_trans_row_conflict_count` (among others). See MySQL Cluster Status Variables.

  For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- **Fail-fast data node capability.** Beginning with MySQL Cluster NDB 7.1.17, it is possible to enable fail-fast behavior for data nodes by enabling the `CrashOnCorruptedTuple` configuration parameter introduced in this version (disabled by default). Doing so causes data nodes to fail whenever they detect a corrupted tuple.

- **Rows per partition limit removed.** Previously it was possible to store a maximum of 46137488 rows in a single MySQL Cluster partition—that is, per data node. Beginning with MySQL Cluster NDB 7.0.36 and MySQL Cluster NDB 7.1.25, this limitation has been lifted, and there is no longer any practical upper limit to this number. (Bug #13844405, Bug #14000373)

MySQL Cluster NDB 7.1 is also supported by MySQL Cluster Manager, which provides an advanced command-line interface that can simplify many complex MySQL Cluster management tasks. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

17.1.4.3 What is New in MySQL Cluster NDB 7.0

The following list provides an overview of significant feature additions and changes made in MySQL Cluster NDB 7.0. For more detailed information about all feature changes and bugfixes made in MySQL Cluster NDB 7.0, see http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-7-0.html.

> **Important**
>
> Early development versions of MySQL Cluster NDB 7.0 were known as "MySQL Cluster NDB 6.4", and the first four releases in this series were identified as MySQL Cluster NDB 6.4.0 through 6.4.3. Any information relating to these MySQL Cluster NDB 6.4.x releases appearing in this documentation apply to MySQL Cluster NDB 7.0.

> MySQL Cluster NDB 7.0.4 is the fifth MySQL Cluster NDB 7.0 release; it is the successor to MySQL Cluster NDB 6.4.3.

- **MySQL Cluster on Windows (alpha).**   MySQL Cluster NDB 7.0 is available on an experimental basis for Windows operating systems (for production use on Windows, you should use MySQL Cluster NDB 7.1.3 or later). Features and behavior comparable to those found on platforms that are already supported —such as Linux and Solaris—are planned for MySQL Cluster on Windows. In MySQL Cluster NDB 7.0, you must build from source (Windows binaries are available for MySQL Cluster NDB 7.1 releases). To enable MySQL Cluster support on Windows when building from source, you must configure the build using the `WITH_NDBCLUSTER_STORAGE_ENGINE` option. For more information, see Section 2.11.7, "Installing MySQL from Source on Windows".

- **Ability to add nodes and node groups online.**   Beginning with MySQL Cluster NDB 6.4.0, it is possible to add new node groups (and thus new data nodes) to a running MySQL Cluster without shutting down and reloading the cluster. As part of enabling this feature, a new command `CREATE NODEGROUP` has been added to the cluster management client and the functionality of the `ALTER ONLINE TABLE ... REORGANIZE PARTITION` SQL statement has been extended. For more information, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

- **Data node multi-threading support.**   Beginning with MySQL Cluster NDB 6.4.0, a multi-threaded version of the data node daemon, named `ndbmtd`, is available for use on data node hosts with multiple CPU cores. This binary is built automatically when compiling with MySQL Cluster support; no additional options other than those needed to provide MySQL Cluster support are needed when configuring the build. In most respects, `ndbmtd` functions in the same way as `ndbd`, and can use the same command-line options and configuration parameters. In addition, the new `MaxNoOfExecutionThreads` configuration parameter can be used to determine the number of data node process threads for `ndbmtd`. For more information, see Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)".

> **Note**
>
> Disk Data tables are not yet supported for use with `ndbmtd`.

- **Configuration cache.**   Formerly, MySQL Cluster configuration was stateless—that is, configuration information was reloaded from the cluster's global configuration file (usually `config.ini`) each time `ndb_mgmd` was started. Beginning with MySQL Cluster NDB 6.4.0, the cluster's configuration is cached internally, and the global configuration file is no longer automatically re-read when the management server is restarted. This behavior can be controlled using the management server options `--configdir`, `--initial`, and `--reload`. In MySQL Cluster NDB 7.0.15 and later, the configuration cache can be disabled using the `--config-cache` option. For more information about these changes, see Section 17.3.3, "MySQL Cluster Configuration Files". For more information about the new management server options, see Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon".

- **Detection of NDB API client connection errors.**   In MySQL Cluster NDB 7.0 (6.4.0 and later releases), the NDB API's `Ndb_cluster_connection` class adds the `get_latest_error()` and `get_latest_error_msg()` methods for catching and diagnosing problems with NDB API client connections.

- **Snapshot options for backups.**   Beginning with MySQL Cluster NDB 6.4.0, you can determine when performing a cluster backup whether the backup matches the state of the data when the backup was started or when it was completed, using the new options `SNAPSHOTSTART` and `SNAPSHOTEND` for the management client's `START BACKUP` command. See Section 17.5.3.2, "Using The MySQL Cluster Management Client to Create a Backup", for more information.

- **Dynamic NDB transporter send buffer memory allocation.**   Previously, the NDB kernel used a fixed-size send buffer for every data node in the cluster, which was allocated when the node started. Because the size of this buffer could not be changed after the cluster was started, it was necessary to make it large enough in advance to accommodate the maximum possible load on any transporter socket. However, this was an inefficient use of memory, since much of it often went unused. Beginning with MySQL Cluster NDB 6.4.0, send buffer memory is allocated dynamically from a memory pool shared between all transporters, which means that the size of the send buffer can be adjusted as necessary. This change is reflected by the addition of the configuration parameters `TotalSendBufferMemory`, `ReservedSendBufferMemory`, and `OverLoadLimit`, as well as a change in how the existing `SendBufferMemory` configuration parameter is used. For more information, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

- **Robust DDL operations.**   Beginning with MySQL Cluster NDB 6.4.0, DDL operations (such as `CREATE TABLE` or `ALTER TABLE`) are protected from data node failures; in the event of a data node failure, such operations are now rolled back gracefully. Previously, if a data node failed while trying to perform a DDL operation, the MySQL Cluster data dictionary became locked and no further DDL statements could be executed without restarting the cluster.

- **IPv6 support in MySQL Cluster Replication.**   Beginning with MySQL Cluster NDB 6.4.1, IPv6 networking is supported between MySQL Cluster SQL nodes, which makes it possible to replicate between instances of MySQL Cluster using IPv6 addresses. However, IPv6 is supported only for direct connections between MySQL servers; all connections *within* an individual MySQL Cluster must use IPv4. For more information, see Section 17.6.3, "Known Issues in MySQL Cluster Replication".

- **Restoring specific databases, tables, or columns from a MySQL Cluster backup.**   It is now possible to exercise more fine-grained control when restoring a MySQL Cluster from backup using `ndb_restore`. Beginning with MySQL Cluster NDB 6.4.3, you can choose to restore only specified tables or databases, or exclude specific tables or databases from being restored, using the new `ndb_restore` options `--include-tables`, `--include-databases`, `--exclude-tables`, and `--exclude-databases`. Beginning with MySQL Cluster NDB 7.0.7, it is also possible to restore to a table having fewer columns than the original using the `--exclude-missing-columns` option. For more information about all of these options, see Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup".

- **Improved Disk Data file system configuration.**   As of MySQL Cluster NDB 6.4.3, you can specify default locations for MySQL Cluster Disk Data data files and undo log files using the data node configuration parameters `FileSystemPathDD`, `FileSystemPathDataFiles`, and `FileSystemPathUndoFiles`. This eliminates the need to use symbolic links to place Disk Data files separately from other files in data node file systems to improve Disk Data performance. For more information, see Disk Data file system parameters.

- **Automatic creation of Disk Data log file groups and tablespaces.**   Beginning with MySQL Cluster NDB 6.4.3, using the data node configuration parameters `InitialLogFileGroup` and `InitialTablespace`, you can cause the creation of a MySQL Cluster Disk Data log file group, tablespace, or both, when the cluster is first started. When using these parameters, no SQL statements are required to create these Disk Data objects. For more information, see *Disk Data object creation parameters*.

- **Improved internal message passing and record handling.**   MySQL Cluster NDB 7.0 contains 2 changes that optimize the use of network connections by addressing the size and number of messages passed between data nodes, and between data nodes and API nodes, which can increase MySQL Cluster and application performance:

  - **Packed reads.**   Formerly, each read request signal contained a list of columns to be retrieved, each of these column identifiers using 4 bytes within the message. This meant that the message size increased as the number of columns being fetched increased. In addition, in the response from the

data node, each column result was packed to a 4-byte boundary, which resulted in wasted space. In MySQL Cluster NDB 7.0, messaging for read operations is optimized in both directions, using a bitmap in the read request to specify the columns to be fetched. Where many fields are requested, this can result in a significant message size reduction as compared with the old method. In addition, the 4-byte packing in responses is no longer used, which means that smaller fields consume less space.

- **Long signal transactions.**   This enhancement reduces the number of messages and signals that are sent to data nodes for complex requests. Prior to MySQL Cluster NDB 7.0, there was a 100 byte limit on the size of the request signal, which meant that complex requests had to be split up between multiple messages prior to transmission, then reassembled on the receiving end. In addition to actual payload data, each message required its own operating system and protocol overhead such as header information. This often wasted network bandwidth and data node CPU. The maximum size of the message is now 32 KB, which is sufficient to accommodate most queries.

Both of these optimizations are internal to the NDB API, and so is transparent to applications; this is true whether an application uses the NDB API directly or does so indirectly through an SQL node.

- **Configuration parameter data dumps.**   Starting with MySQL Cluster NDB 7.0.6, the `ndb_config` utility supports a `--configinfo` option that causes it to dump a list of all configuration parameters supported by the cluster, along with brief descriptions, information about the parameters' default and permitted values, and the sections of the `config.ini` file in which the parameters apply. An additional `--xml` switch causes `ndb_config` to use XML rather than plain text output. Using `ndb_config --configinfo` or `ndb_config --configinfo --xml` requires no access to a running MySQL Cluster, any other programs, or any files. For more information and examples, see Section 17.4.7, "`ndb_config` — Extract MySQL Cluster Configuration Information".

- **Per-table reporting of free space on disk.**   The `INFORMATION_SCHEMA.FILES` table shows information about used and free space in MySQL Cluster Disk Data data files, but this information is not applicable to individual tables. In MySQL Cluster NDB 7.0.8 and later, the `ndb_desc` utility provides two additional columns in its output that show the amount of space allocated on disk for a given `NDB` table as well the amount of space that remains available for additional storage of disk-based column data for that table. For more information, see Section 17.4.10, "`ndb_desc` — Describe NDB Tables".

- **Improved restart times.**   Optimizations in redo log handling and other file system operations introduced in MySQL Cluster NDB 7.0.9 have the potential to reduce considerably the time required for restarts. While actual performance benefits observed in production setups will naturally vary depending on database size, hardware, and other conditions, our own preliminary testing has shown that these improvements can yield startup times that are faster than those typical of previous MySQL Cluster NDB 7.0 releases by a factor of 50 or more.

- **Native support for default column values.**   Starting with MySQL Cluster NDB 7.0.15, default values for table columns are stored in the NDB kernel rather than by the MySQL server as was done previously. This means that inserts on tables having column value defaults can be smaller and faster than before, because less data must be sent from SQL nodes to `NDBCLUSTER`.

Tables created using previous MySQL Cluster releases can still be used in MySQL Cluster 7.0.15 and later; however, they do not support native default values until they are upgraded. You can upgrade a table with non-native default values to support native default values using an offline `ALTER TABLE` statement.

- **--nowait-nodes option for management servers.**   Starting with MySQL Cluster NDB 7.0.10, it is possible to configure a cluster with two management servers, but to start the cluster using only one of them by starting the management node daemon with the `--nowait-nodes` option. The other management server can then be started at a later time to join the running MySQL Cluster.

- **Increased flexibility in online upgrade procedure.** Previously, when performing an upgrade of a running MySQL cluster, the order in which the types of cluster nodes had to be upgraded was very strict. However, beginning with MySQL Cluster NDB 7.0.10, MySQL Cluster supports online upgrading of API nodes (including MySQL servers running as SQL nodes) online upgrading management nodes, data nodes, or both.

  > **Important**
  >
  > Before attempting to use this new upgrade functionality, see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster", for additional information, especially if you are planning an online upgrade to MySQL Cluster NDB 7.0 from MySQL Cluster NDB 6.3.

- **New CHANGE MASTER TO option for circular replication.** Beginning with MySQL Cluster NDB 7.0.11, the `CHANGE MASTER TO` statement supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. (Log rotation and log deletion events are preserved.)

  See Section 13.4.2.1, "CHANGE MASTER TO Syntax", as well as Section 13.7.5.36, "SHOW SLAVE STATUS Syntax", for more information.

- **New replication conflict resolution strategy.** Beginning with MySQL Cluster NDB 7.0.11, the function `NDB$MAX_DELETE_WIN()` is available to implement "greatest timestamp, delete wins" conflict resolution. See NDB$MAX_DELETE_WIN(column_name), for more information.

- **Improved lock handling for primary key lookups on BLOB tables.** A MySQL Cluster table stores all but the first 256 bytes of any `BLOB` or `TEXT` column values in a separate `BLOB` table; when executing queries against such tables, a shared lock is obtained. Prior to MySQL Cluster NDB 7.0.12, when the query used a primary key lookup and took place within a transaction, the lock was held for the duration of the transaction, even after no more data was being read from the `NDB` table. Now in such cases, the lock is released when all `BLOB` data associated with the table has been read. (Bug #49190)

  > **Note**
  >
  > A shared lock is also taken for unique key lookups; it is still the case that this lock is held for the duration of the transaction.

- **Heartbeat thread policy and priority.** Beginning with MySQL Cluster NDB 7.0.13, a new configuration parameter `HeartbeatThreadPriority` makes it possible to set the policy and the priority for the heartbeat thread on management and API nodes.

- **Improved access to partitioning information.** The `ndb_desc` utility now provides additional information about the partitioning of data stored in MySQL Cluster. Beginning with MySQL Cluster NDB 7.0.13, the `--blob-info` option causes this program to include partition information for `BLOB` tables in its output. Beginning with MySQL Cluster NDB 7.0.14, the `--extra-node-info` option causes `ndb_desc` to include information about data distribution (that is, which table fragments are stored on which data nodes). Each of these options also requires the use of the `--extra-partition-info` option.

  Information about partition-to-node mappings can also be obtained using the `Table::getFragmentNodes()` method, also added in MySQL Cluster NDB 7.0.14.

- **Replication attribute promotion and demotion.** Beginning with MySQL Cluster NDB 7.0.14, MySQL Cluster Replication supports attribute promotion and demotion when replicating between columns of different but similar types on the master and the slave. For example, it is possible to promote an `INT` column on the master to a `BIGINT` column on the slave, and to demote a `TEXT` column to a `VARCHAR` column.

The implementation of type demotion distinguishes between lossy and non-lossy type conversions, and their use on the slave can be controlled by setting the `slave_type_conversions` global server system variable.

For more information, see Attribute promotion and demotion (MySQL Cluster).

- **Incompatible change in NDB API event reporting.**   Beginning with MySQL Cluster NDB 7.0.15, DDL events are no longer reported on `Event` objects by default. Instead such event reporting must be enabled explicitly using the `Event::setReport()` method. For more information, see Event::setReport(), and The Event::EventReport Type.

- **Number of table attributes.**   Beginning with MySQL Cluster NDB 7.0.15, the maximum number of attributes (columns plus indexes) per table has been increased from 128 to 512.

- **Heartbeat ordering.**   Beginning with MySQL Cluster NDB 7.0.16, it is possible to set a specific order for transmission of heartbeats between data nodes, using the `HeartbeatOrder` data node configuration parameter introduced in this version. This parameter can be useful in situations where multiple data nodes are running on the same host and a temporary disruption in connectivity between hosts would otherwise cause the loss of a node group (and thus failure of the cluster).

- **Relaxed ndb_restore column comparison rules.**   When restoring data, ndb_restore compares the attributes of a column for equality with the definition of the column in the target table. However, not all of these attributes need to be the same for `ndb_restore` to be meaningful, safe and useful. Beginning with MySQL Cluster NDB 7.0.16, `ndb_restore` automatically ignores differences in certain column attributes which do not necessarily have to match between the version of the column in a backup and the version of that column in the MySQL Cluster to which the column data is being restored. These attributes include the following:

  - `COLUMN_FORMAT` setting (`FIXED`, `DYNAMIC`, or `DEFAULT`)

  - `STORAGE` setting (`MEMORY` or `DISK`)

  - The default value

  - The distribution key

  In such cases, `ndb_restore` reports any such differences to minimize any chance of user error.

- **Storage of user data in anyValue.**   When writing NDB events to the binary log, MySQL Cluster uses `OperationOptions::anyValue` to store the server ID. Beginning with MySQL Cluster NDB 7.0.17, it is possible to store user data from an NDB API application in part of the `anyValue` when `mysqld` has been started with the `--server-id-bits` option set to a nondefault value. Also beginning with MySQL Cluster NDB 7.0.17, it is possible to view this data in the output of mysqlbinlog, for which its own `--server-id-bits` option is added.

- **--add-drop-trigger option for mysqldump.**   Beginning with MySQL Cluster NDB 7.0.19, this option can be used to force all `CREATE TRIGGER` statements in `mysqldump` output to be preceded by a `DROP TRIGGER IF EXISTS` statement.

- **Forcing node shutdown and restart.**   In MySQL Cluster NDB 7.0.19 and later, it is possible using the `ndb_mgm` management client or the MGM API to force a data node shutdown or restart even if this would force the shutdown or restart of the entire cluster. In the management client, this is implemented through the addition of the `-f` (force) option to the `STOP` and `RESTART` commands. For more information, see Section 17.5.2, "Commands in the MySQL Cluster Management Client". The MGM API also adds two new methods for forcing such a node shutdown or restart; see ndb_mgm_stop4(), and ndb_mgm_restart4(), for more information about these methods.

- **TimeBetweenEpochsTimeout and GCP stop control.**   Beginning with MySQL Cluster NDB 7.0.21, it is possible to disable GCP stops by setting `TimeBetweenEpochsTimeout` to 0. In addition, a warning is written to the cluster log whenever the time required for a GCP save exceeds 60 seconds or the time required for a GCP commit exceeds 10 seconds. This warning includes a report of the current value of `TimeBetweenEpochsTimeout`. For more information, see Disk Data and GCP Stop errors.

- **Skipping corrupted tables in NDB native backups.**   Beginning with MySQL Cluster NDB 7.0.21, you can cause `ndb_restore` to ignore tables that are corrupted due to missing blob parts tables by using the `--skip-broken-objects` option. When this option is used, such tables are skipped, and the restoration of any remaining uncorrupted tables in the backup continues.

- **BLOB read and write batching.**   Beginning with MySQL Cluster NDB 7.0.21, it possible to control batching of `BLOB` read and write operations. For SQL nodes, this can be done using the `--ndb-blob-read-batch-bytes` and `--ndb-blob-write-batch-bytes` options for `mysqld`. In NDB API applications, you can control batching of `BLOB` reads and writes using the `NdbTransaction` methods `setMaxPendingBlobReadBytes()`, `getMaxPendingBlobReadBytes()`, `setMaxPendingBlobWriteBytes()`, and `getMaxPendingBlobWriteBytes()`.

- **Restoring from a NDB native backup to a differently-named database.**   MySQL Cluster NDB 7.0.22 adds a new `--rewrite-database` option to `ndb_restore`, which makes it possible to restore to a database having a different name from that of the database in the backup. The option can be used multiple times, and it is possible to restore from more than one source database in the backup to a single target database (although no protection against table or other object name collision is provided).

  See Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup", for more information.

- **INFORMATION_SCHEMA inprovements.**   Beginning with MySQL Cluster NDB 7.0.22, `INFORMATION_SCHEMA` provides disk usage information for MySQL Cluster Disk Data tables. Previously, `INFORMATION_SCHEMA.TABLES` showed only the space usage for the in-memory data part of the table. Now, it also shows the space allocated for and used by the disk_part data of that table as well.

  In addition, the `INFORMATION_SCHEMA.PARTITIONS` table (which did not show any statistics for `NDB` tables) now shows correct values in this table's `TABLE_ROWS`, `AVG_ROW_LENGTH`, `DATA_LENGTH`, `MAX_DATA_LENGTH`, and `DATA_FREE` columns, for each partition.

- **Configuration version information in ndbinfo.nodes.**   You can see which version or versions of the MySQL Cluster configuration file are in effect on the data nodes by checking the `config_generation` column which is added to the `nodes` table in MySQL Cluster NDB 7.0.24.

- **Improvements in adding data nodes online.**   Beginning with MySQL Cluster NDB 7.0.24, it is possible to add data nodes online to a running MySQL Cluster without performing a rolling restart of the cluster or starting data node processes with the `--nowait-nodes` option. This can be done by setting `Nodegroup = 65536` in the `config.ini` file for any data nodes that should be started at a later time, when first starting the cluster. The amount of time the cluster waits before doing this can be controlled using the `StartNoNodeGroupTimeout` data node configuration parameter.

- **Unique key updates in replication.**   It is possible in MySQL Cluster NDB 7.0.25 and later to employ operations that update unique keys when replicating `NDB` tables. Previously this could lead to duplicate key errors when trying to execute the binary log (due to the fact that row events in the binary log were ordered according to the partitioning of the base table, and could differ in order within the epoch for that in which they were executed).

  > **⚠ Important**
  >
  > Master and slave tables must both be using the `NDB` storage engine for this to work.

- Starting with MySQL Cluster NDB 7.0.22, the NDB kernel implements a number of statistical counters relating to actions performed by or affecting `Ndb` objects. Such events include starting, closing, and aborting transactions; operations using primary keys or unique keys; table, range, and pruned scans; blocking of threads by incompleted operations; and data and events sent and received by MySQL Cluster nodes. NDB API statistics counters are incremented inside the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes. A MySQL Server running as an SQL node in the cluster can access the values of these counters as system status variables, as seen in the output of `SHOW STATUS`, or in the results of queries against the `SESSION_STATUS` or `GLOBAL_STATUS` table in the `INFORMATION_SCHEMA` database. By comparing the values of these status variables before and after the execution of statements affecting `NDB` tables, you can observe the corresponding actions taken on the NDB API level. This can be highly useful when monitoring and tuning MySQL Cluster.

  For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables". See also MySQL Cluster Status Variables, for information about the individual status variables.

- **Version 2 binary log row events.** New versions of the `WRITE_ROW`, `UPDATE_ROW`, and `DELETE_ROW` events have been implemented in MySQL Cluster NDB 7.0.27, extending them with additional information intended to support future enhancements; these are referred to as "Version 2" binary log events.

  Version 2 log events are not backward compatible, and cannot be read by older slaves. A new `mysqld` option `--log-bin-use-v1-row-events` can be employed to force use of Version 1 events when writing the binary log. This can be used during upgrades to make a newer `mysqld` generate Version 1 binary log row events that can be read by older slaves.

- **Fail-fast data node capability.** Beginning with MySQL Cluster NDB 7.0.28, it is possible to enable fail-fast behavior for data nodes by enabling the `CrashOnCorruptedTuple` configuration parameter introduced in this version (disabled by default). Doing so causes data nodes to fail whenever they detect a corrupted tuple.

- **Rows per partition limit removed.** Previously it was possible to store a maximum of 46137488 rows in a single MySQL Cluster partition—that is, per data node. Beginning with MySQL Cluster NDB 7.0.36, this limitation has been lifted, and there is no longer any practical upper limit to this number.

17.1.4.4 What is New in MySQL Cluster NDB 6.3

The following list provides an overview of significant feature additions and changes first made in MySQL Cluster NDB 6.3. For more detailed information about all feature changes and bugfixes made in MySQL Cluster NDB 6.3, see http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-6-3.html.

- **Conflict detection and resolution.** It is now possible to detect and resolve conflicts that arise in multi-master replication scenarios, such as circular replication, when different masters may try to update the same row on the slave with different data. Both "greatest timestamp wins" and "same timestamp wins" scenarios are supported. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- **Recovery of one master, many slaves replication setups.** Recovery of multi-way replication setups ("one master, many slaves") is now supported using the `--ndb-log-orig` server option and changes in the `mysql.ndb_binlog_index` table. See Section 17.6.4, "MySQL Cluster Replication Schema and Tables", for more information.

- **Enhanced selection options for transaction coordinator.** New values and behaviors are introduced for `--ndb_optimized_node_selection`, enabling greater flexibility when an SQL node chooses a transaction coordinator. For more information, see the description of `ndb_optimized_node_selection` in MySQL Cluster System Variables.

- **Replication heartbeats.** Replication heartbeats facilitate the task of monitoring and detecting failures in master-slave connections in real time. This feature is implemented using a new `MASTER_HEARTBEAT_PERIOD = value` clause for the `CHANGE MASTER TO` statement and the addition of two status variables `Slave_heartbeat_period` and `Slave_received_heartbeats`. For more information, see Section 13.4.2.1, "CHANGE MASTER TO Syntax".

- **NDB thread locks.** It is possible to lock `NDB` execution threads and maintenance threads (such as file system and other operating system threads) to specific CPUs on multiprocessor data node hosts, and to leverage real-time scheduling.

- **Improved performance of updates using primary keys or unique keys.** The number of unnecessary reads when performing a primary key or unique key update has been greatly reduced. Since it is seldom necessary to read a record prior to an update, this can yield a considerable improvement in performance. In addition, primary key columns are no longer written to when not needed during update operations.

- **Batching improvements.** Support of batched `DELETE` and `UPDATE` operations has been significantly improved. Batching of `UPDATE WHERE...` and multiple `DELETE` operations is also now implemented.

- **Improved SQL statement performance metrics.** The `Ndb_execute_count` system status variable measures the number of round trips made by SQL statements to the `NDB` kernel, providing an improved metric for determining efficiency with which statements are executed. For more information, see *MySQL Cluster Status Variables:* `Ndb_execute_count`.

- **Compressed LCPs and backups.** Compressed local checkpoints and backups can save 50% or more of the disk space used by uncompressed LCPs and backups. These can be enabled using the two new data node configuration parameters `CompressedLCP` and `CompressedBackup`, respectively.

- **OPTIMIZE TABLE support with NDBCLUSTER tables.** `OPTIMIZE TABLE` is supported for dynamic columns of in-memory `NDB` tables. In such cases, it is no longer necessary to drop (and possibly to re-create) a table, or to perform a rolling restart, in order to recover memory from deleted rows for general re-use by Cluster. The performance of `OPTIMIZE` on Cluster tables can be tuned by adjusting the value of the `ndb_optimization_delay` system variable, which controls the number of milliseconds to wait between processing batches of rows by `OPTIMIZE TABLE`. In addition, `OPTIMIZE TABLE` on an `NDBCLUSTER` table can be interrupted by, for example, killing the SQL thread performing the `OPTIMIZE` operation.

- **Batching of transactions.** It is possible to cause statements occurring within the same transaction to be run as a batch by setting the session variable `transaction_allow_batching` to `1` or `ON`. To use this feature, `autocommit` must be set to `0` or `OFF`. Batch sizes can be controlled using the `--ndb-batch-size` option for `mysqld`. For additional information, see MySQL Server Options for MySQL Cluster, and MySQL Cluster System Variables.

- **Attribute promotion with ndb_restore.** It is possible using `ndb_restore` to restore data reliably from a column of a given type to a column that uses a "larger" type. This is sometimes referred to as *attribute promotion*. For example, MySQL Cluster backup data that originated in a `SMALLINT` column can be restored to a `MEDIUMINT`, `INT`, or `BIGINT` column. See Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup", for more information.

- **Parallel data node recovery.** Recovery of multiple data nodes can now be done in parallel, rather than sequentially. In other words, several data nodes can be restored concurrently, which can often result in much faster recovery times than when they are restored one at a time.

- **Increased local checkpoint efficiency.** Only 2 local checkpoints are stored, rather than 3, lowering disk space requirements and the size and number of redo log files.

- **NDBCLUSTER table persistence control.** Persistence of `NDB` tables can be controlled using the session variables `ndb_table_temporary` and `ndb_table_no_logging`. `ndb_table_no_logging` causes `NDB` tables not to be checkpointed to disk; `ndb_table_temporary` does the same, and in addition, no schema files are created. See Section 17.3.2.5, "MySQL Cluster mysqld Option and Variable Reference".

- **Epoll support (Linux only).** *Epoll* is an improved method for handling file descriptors, which is more efficient than scanning to determine whether a file descriptor has data to be read. (The term *epoll* is specific to Linux and equivalent functionality is known by other names on other platforms such as Solaris and FreeBSD.) Currently, MySQL Cluster supports this functionality on Linux only.

- **Distribution awareness (SQL nodes).** In MySQL Cluster NDB 6.3, SQL nodes can take advantage of distribution awareness. Here we provide a brief example showing how to design a table to make a given class of queries distrubtion-aware. Suppose an `NDBCLUSTER` table `t1` has the following schema:

```
CREATE TABLE t1 (
    userid INT NOT NULL,
    serviceid INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    data VARCHAR(255)
)   ENGINE=NDBCLUSTER;
```

Suppose further that most of the queries to be used in our application test values of the `userid` column of this table. The form of such a query looks something like this:

```
SELECT columns FROM t1
    WHERE userid relation value;
```

In this query, `relation` represents some relational operator, such as `=`, `<`, `>`, and so on. Queries using `IN` and a list of values can also be used:

```
SELECT columns FROM t1
    WHERE userid IN value_list;
```

To make use of distribution awareness, we need to make the `userid` column part of the table's primary key, then explicitly partition the table with this column being used as the partitioning key. (Recall that for a partitioned table having one or more unique keys, all columns of the table's partitioning key must also be part of all of the unique keys—for more information and examples, see Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys".) In other words, the table schema should be equivalent to the following `CREATE TABLE` statement:

```
CREATE TABLE t1 (
    userid INT NOT NULL,
    serviceid INT NOT NULL AUTO_INCREMENT,
    data VARCHAR(255),
    PRIMARY KEY p (userid,serviceid)
)   ENGINE=NDBCLUSTER
    PARTITION BY KEY(userid);
```

When the table is partitioned in this way, all rows having the same `userid` value are found on the same node group, and the MySQL Server can immediately select the optimal node to use as the transaction coordinator.

- **Realtime extensions for multiple CPUs.** When running MySQL Cluster data nodes on hosts with multiple processors, the realtime extensions make it possible to give priority to the data node process and control on which CPU cores it should operate. This can be done using the data node configuration parameters `RealtimeScheduler`, `SchedulerExecutionTimer`, and `SchedulerSpinTimer`. Doing

so properly can significantly lower response times and make them much more predictable response. For more information about using these parameters, see Defining Data Nodes: Realtime Performance Parameters

- **Fully automatic database discovery.**   It is no longer a requirement for database autodiscovery that an SQL node already be connected to the cluster at the time that a database is created on another SQL node, or for a `CREATE DATABASE` or `CREATE SCHEMA` statement to be issued on the new SQL node after it joins the cluster.

- **Detection of NDB API client connection errors.**   Beginning with MySQL Cluster NDB 6.3.20, the NDB API's `Ndb_cluster_connection` class adds the `get_latest_error()` and `get_latest_error_msg()` methods for catching and diagnosing problems with NDB API client connections.

- **Restoring specific databases, tables, or columns from a MySQL Cluster backup.**   It is now possible to exercise more fine-grained control when restoring a MySQL Cluster from backup using `ndb_restore`. Beginning with MySQL Cluster NDB 6.3.22, you can choose to restore only specified tables or databases, or exclude specific tables or databases from being restored, using the new `ndb_restore` options `--include-tables`, `--include-databases`, `--exclude-tables`, and `--exclude-databases`. Beginning with MySQL Cluster NDB 6.3.26, it is also possible to restore to a table having fewer columns than the original using the `--exclude-missing-columns` option. For more information about all of these options, see Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup".

- **Improved Disk Data file system configuration.**   As of MySQL Cluster NDB 6.3.22, you can specify default locations for MySQL Cluster Disk Data data files and undo log files using the data node configuration parameters `FileSystemPathDD`, `FileSystemPathDataFiles`, and `FileSystemPathUndoFiles`. This eliminates the need to use symbolic links to place Disk Data files separately from other files in data node file systems to improve Disk Data performance. For more information, see Disk Data file system parameters.

- **Automatic creation of Disk Data log file groups and tablespaces.**   Beginning with MySQL Cluster NDB 6.3.22, using the data node configuration parameters `InitialLogFileGroup` and `InitialTablespace`, you can cause the creation of a MySQL Cluster Disk Data log file group, tablespace, or both, when the cluster is first started. When using these parameters, no SQL statements are required to create these Disk Data objects. For more information, see *Disk Data object creation parameters*.

- **Configuration parameter data dumps.**   Starting with MySQL Cluster NDB 6.3.25, the `ndb_config` utility supports a `--configinfo` option that causes it to dump a list of all configuration parameters supported by the cluster, along with brief descriptions, information about the parameters' default and permitted values, and the sections of the `config.ini` file in which the parameters apply. An additional `--xml` switch causes `ndb_config` to use XML rather than plain text output. Using `ndb_config --configinfo` or `ndb_config --configinfo --xml` requires no access to a running MySQL Cluster, any other programs, or any files. For more information and examples, see Section 17.4.7, "`ndb_config` — Extract MySQL Cluster Configuration Information".

- **Per-table reporting of free space on disk.**   The `INFORMATION_SCHEMA.FILES` table shows information about used and free space in MySQL Cluster Disk Data data files, but this information is not applicable to individual tables. In MySQL Cluster NDB 6.3.27 and later, the `ndb_desc` utility provides two additional columns in its output that show the amount of space allocated on disk for a given `NDB` table as well the amount of space that remains available for additional storage of disk-based column data for that table. For more information, see Section 17.4.10, "`ndb_desc` — Describe NDB Tables".

- **Improved restart times.**   Optimizations in redo log handling and other file system operations introduced in MySQL Cluster NDB 6.3.28 have the potential to reduce considerably the time required for

restarts. While actual performance benefits observed in production setups will naturally vary depending on database size, hardware, and other conditions, our own preliminary testing has shown that these improvements can yield startup times that are faster than those typical of previous MySQL Cluster NDB 6.3 releases by a factor of 50 or more.

- **Increased flexibility in online upgrade procedure.**   Previously, when performing an upgrade of a running MySQL cluster, the order in which the types of cluster nodes had to be upgraded was very strict. However, beginning with MySQL Cluster NDB 6.3.29, MySQL Cluster supports online upgrading of API nodes (including MySQL servers running as SQL nodes) before upgrading management nodes, data nodes, or both.

  > **Important**
  >
  > Before attempting to use this new upgrade functionality, see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster", for additional information, especially if you are planning an online upgrade from MySQL Cluster NDB 6.3 to MySQL Cluster NDB 7.0.

- **New replication conflict resolution strategy.**   Beginning with MySQL Cluster NDB 6.3.31, the function `NDB$MAX_DELETE_WIN()` is available to implement "greatest timestamp, delete wins" conflict resolution. See NDB$MAX_DELETE_WIN(column_name), for more information.

- **New CHANGE MASTER TO option for circular replication.**   Beginning with MySQL Cluster NDB 6.3.31, the `CHANGE MASTER TO` statement supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. (Log rotation and log deletion events are preserved.)

  See Section 13.4.2.1, "CHANGE MASTER TO Syntax", as well as Section 13.7.5.36, "SHOW SLAVE STATUS Syntax", for more information.

- **Heartbeat thread policy and priority.**   Beginning with MySQL Cluster NDB 6.3.32, a new configuration parameter `HeartbeatThreadPriority` makes it possible to set the policy and the priority for the heartbeat thread on management and API nodes.

- **Improved access to partitioning information.**   The `ndb_desc` utility now provides additional information about the partitioning of data stored in MySQL Cluster. Beginning with MySQL Cluster NDB 6.3.32, the `--blob-info` option causes this program to include partition information for `BLOB` tables in its output. Beginning with MySQL Cluster NDB 6.3.33, the `--extra-node-info` option causes `ndb_desc` to include information about data distribution (that is, which table fragments are stored on which data nodes). Each of these options also requires the use of the `--extra-partition-info` option.

  Information about partition-to-node mappings can also be obtained using the `Table::getFragmentNodes()` method, also added in MySQL Cluster NDB 6.3.33.

- **Replication attribute promotion and demotion.**   Beginning with MySQL Cluster NDB 6.3.33, MySQL Cluster Replication supports attribute promotion and demotion when replicating between columns of different but similar types on the master and the slave. For example, it is possible to promote an `INT` column on the master to a `BIGINT` column on the slave, and to demote a `TEXT` column to a `VARCHAR` column.

  The implementation of type demotion distinguishes between lossy and non-lossy type conversions, and their use on the slave can be controlled by setting the `slave_type_conversions` global server system variable.

  For more information, see Attribute promotion and demotion (MySQL Cluster).

- **Incompatible change in NDB API event reporting.** Beginning with MySQL Cluster NDB 6.3.34, DDL events are no longer reported on `Event` objects by default. Instead such event reporting must be enabled explicitly using the `Event::setReport()` method. For more information, see Event::setReport(), and The Event::EventReport Type.

- **Heartbeat ordering.** Beginning with MySQL Cluster NDB 6.3.35, it is possible to set a specific order for transmission of heartbeats between data nodes, using the `HeartbeatOrder` data node configuration parameter introduced in this version. This parameter can be useful in situations where multiple data nodes are running on the same host and a temporary disruption in connectivity between hosts would otherwise cause the loss of a node group (and thus failure of the cluster).

- **Relaxed ndb_restore column comparison rules.** When restoring data, ndb_restore compares the attributes of a column for equality with the definition of the column in the target table. However, not all of these attributes need to be the same for `ndb_restore` to be meaningful, safe and useful. Beginning with MySQL Cluster NDB 6.3.35, `ndb_restore` automatically ignores differences in certain column attributes which do not necessarily have to match between the version of the column in a backup and the version of that column in the MySQL Cluster to which the column data is being restored. These attributes include the following:

  - `COLUMN_FORMAT` setting (`FIXED`, `DYNAMIC`, or `DEFAULT`)

  - `STORAGE` setting (`MEMORY` or `DISK`)

  - The default value

  - The distribution key

  In such cases, `ndb_restore` reports any such differences to minimize any chance of user error.

- **--add-drop-trigger option for mysqldump.** Beginning with MySQL Cluster NDB 6.3.38, this option can be used to force all `CREATE TRIGGER` statements in `mysqldump` output to be preceded by a `DROP TRIGGER IF EXISTS` statement.

- **Skipping corrupted tables in NDB native backups.** Beginning with MySQL Cluster NDB 6.3.40, you can cause `ndb_restore` to ignore tables that are corrupted due to missing blob parts tables by using the `--skip-broken-objects` option. When this option is used, such tables are skipped, and the restoration of any remaining uncorrupted tables in the backup continues.

- **Restoring from a NDB native backup to a differently-named database.** MySQL Cluster NDB 6.3.41 adds a new `--rewrite-database` option to `ndb_restore`, which makes it possible to restore to a database having a different name from that of the database in the backup. The option can be used multiple times, and it is possible to restore from more than one source database in the backup to a single target database (although no protection against table or other object name collision is provided).

  See Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup", for more information.

17.1.4.5 What is New in MySQL Cluster NDB 6.2

The following list provides an overview of significant feature additions and changes made in MySQL Cluster NDB 6.2. All of the changes in this list are also available in MySQL Cluster NDB 6.3. For more detailed information about all feature changes and bugfixes made in MySQL Cluster NDB 6.2, see http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-6-2.html.

- **Enhanced backup status reporting.** Backup status reporting has been improved, aided in part by the introduction of a `BackupReportFrequency` configuration parameter.

- **Multiple cluster connections per SQL node.**   A single MySQL server acting as a MySQL Cluster SQL node can employ multiple connections to the cluster using the `--ndb-cluster-connection-pool` startup option for `mysqld`. This option is described in *MySQL Cluster-Related Command Options for* `mysqld:` `--ndb-cluster-connection-pool` *option*.

- **New data access interface.**   The `NdbRecord` interface provides a new and simplified data handler for use in NDB API applications.

- **New reporting commands.**   The new management client `REPORT BackupStatus` and `REPORT MemoryUsage` commands provide better access to information about the status of MySQL Cluster backups and how much memory is being used by MySQL Cluster for data and index storage. See Section 17.5.2, "Commands in the MySQL Cluster Management Client", for more information about the `REPORT` commands. In addition, in-progress status reporting is provided by the `ndb_restore` utility; see Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup".

- **Improved memory allocation and configuration.**   Memory is now allocated by the `NDB` kernel to tables on a page-by-page basis, which significantly reduces the memory overhead required for maintaining `NDBCLUSTER` tables. In addition, the `MaxAllocate` configuration parameter now makes it possible to set the maximum size of the allocation unit used for table memory.

- **Choice of fixed-width or variable-width columns.**   You can control whether fixed-width or variable-width storage is used for a given column of an `NDB` table by employing of the `COLUMN_FORMAT` specifier as part of the column's definition in a `CREATE TABLE` or `ALTER TABLE` statement. In addition, the ability to control whether a given column of an `NDB` table is stored in memory or on disk, using the `STORAGE` specifier as part of the column's definition in a `CREATE TABLE` or `ALTER TABLE` statement. For more information, see Section 13.1.17, "CREATE TABLE Syntax", and Section 13.1.7, "ALTER TABLE Syntax".

- **Controlling management client connections.**   The `--bind-address` cluster management server startup option makes it possible to restrict management client connections to `ndb_mgmd` to a single host (IP address or host name) and port, which can make MySQL Cluster management operations more secure. For more information about this option, see Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon".

- **Micro-GCPs.**   Due to a change in the protocol for handling of global checkpoints (GCPs handled in this manner sometimes being referred to as "micro-GCPs"), it is now possible to control how often the GCI number is updated, and how often global checkpoints are written to disk, using the `TimeBetweenEpochs` and `TimeBetweenEpochsTimeout` configuration parameters. This improves the reliability and performance of MySQL Cluster Replication.

- **Core online schema change support.**   Support for the online `ALTER TABLE` operations `ADD COLUMN`, `ADD INDEX`, and `DROP INDEX` is available. When the `ONLINE` keyword is used, the `ALTER TABLE` is noncopying, which means that indexes do not have to be re-created, which provides these benefits:

  - Single user mode is no longer required for `ALTER TABLE` operations that can be performed online.

  - Transactions can continue during `ALTER TABLE` operations that can be performed online.

  - Tables being altered online are not locked against access by other SQL nodes.

    However, such tables are locked against other operations on the *same* SQL node for the duration of the `ALTER TABLE`. We are working to overcome this limitation in a future MySQL Cluster release.

  Online `CREATE INDEX` and `DROP INDEX` statements are also supported. Online changes can be suppressed using the `OFFLINE` key word. See Section 13.1.7.2, "ALTER TABLE Online Operations

in MySQL Cluster", Section 13.1.13, "CREATE INDEX Syntax", and Section 13.1.24, "DROP INDEX Syntax", for more detailed information.

- **mysql.ndb_binlog_index improvements.** More information has been added to the `mysql.ndb_binlog_index` table so that it is possible to determine which originating epochs have been applied inside an epoch. This is particularly useful for 3-way replication. See Section 17.6.4, "MySQL Cluster Replication Schema and Tables", for more information.

- **Epoch lag control.** The `MaxBufferedEpochs` data node configuration parameter provides a means to control the maximum number of unprocessed epochs by which a subscribing node can lag. Subscribers which exceed this number are disconnected and forced to reconnect.

- **Fully automatic database discovery.** It is no longer a requirement for database autodiscovery that an SQL node already be connected to the cluster at the time that a database is created on another SQL node, or for a `CREATE DATABASE` or `CREATE SCHEMA` statement to be issued on the new SQL node after it joins the cluster.

- **Multiple data node processes per host.**
  In earlier MySQL Cluster release series, we did not support MySQL Cluster deployments in production where more than one `ndbd` process was run on a single physical machine. However, beginning with MySQL Cluster NDB 6.2.0, you can use multiple data node processes on a single host.

  > **Note**
  >
  > A multi-threaded version of `ndbd` tailored for use on hosts with multiple CPUs or cores was introduced in MySQL Cluster NDB 7.0. See Section 17.1.4.3, "What is New in MySQL Cluster NDB 7.0", and Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)", for more information.

- **Improved Disk Data file system configuration.** As of MySQL Cluster NDB 6.2.17, you can specify default locations for MySQL Cluster Disk Data data files and undo log files using the data node configuration parameters `FileSystemPathDD`, `FileSystemPathDataFiles`, and `FileSystemPathUndoFiles`. This eliminates the need to use symbolic links to place Disk Data files separately from other files in data node file systems to improve Disk Data performance. For more information, see Disk Data file system parameters.

- **Automatic creation of Disk Data log file groups and tablespaces.** Beginning with MySQL Cluster NDB 6.2.17, using the data node configuration parameters `InitialLogFileGroup` and `InitialTablespace`, you can cause the creation of a MySQL Cluster Disk Data log file group, tablespace, or both, when the cluster is first started. When using these parameters, no SQL statements are required to create these Disk Data objects.

- **Improved access to partitioning information.** The `ndb_desc` utility now provides additional information about the partitioning of data stored in MySQL Cluster. Beginning with MySQL Cluster NDB 6.2.19, the `--extra-node-info` option causes `ndb_desc` to include information about data distribution (that is, which table fragments are stored on which data nodes). This option also requires the use of the `--extra-partition-info` option.

  Information about partition-to-node mappings can also be obtained using the `Table::getFragmentNodes()` method, also added in MySQL Cluster NDB 6.2.19.

- **New CHANGE MASTER TO option for circular replication.** Beginning with MySQL Cluster NDB 6.2.19, the `CHANGE MASTER TO` statement supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. (Log rotation and log deletion events are preserved.)

See Section 13.4.2.1, "CHANGE MASTER TO Syntax", as well as Section 13.7.5.36, "SHOW SLAVE STATUS Syntax", for more information.

17.1.4.6 What is New in MySQL Cluster NDB 6.1

The following list provides an overview of significant feature additions and changes made in MySQL Cluster NDB 6.1. All of the changes in this list are also available in MySQL Cluster NDB 6.2 and 6.3 releases. For detailed information about all changes made in MySQL Cluster NDB 6.1, see http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-6-1.html.

- **Increased number of cluster nodes.** The maximum number of all nodes in a MySQL Cluster has been increased to 255. For more information, see Section 17.1.6.10, "Limitations Relating to Multiple MySQL Cluster Nodes".

- **Disabling arbitration.** It is now possible to disable arbitration by setting `ArbitrationRank=0` on all cluster management and SQL nodes. For more information, see *Defining the Management Server: `ArbitrationRank`* and *Defining SQL and Other API Nodes: `ArbitrationRank`*.

- **Additional DUMP commands.** New management client `DUMP` commands provide help with tracking transactions, scan operations, and locks. See Section 17.5.2, "Commands in the MySQL Cluster Management Client", and MySQL Cluster Management Client DUMP Commands, for more information.

- **Faster Disk Data backups.** Improvements in backups of Disk Data tables can yield a 10 to 15% increase in backup speed of Disk Data tables.

- **Batched slave updates.** Batching of updates on cluster replication slaves, enabled using the `--slave-allow-batching` option for `mysqld`, increases replication efficiency. For more information, see Section 17.6.6, "Starting MySQL Cluster Replication (Single Replication Channel)".

17.1.4.7 What is New in MySQL Cluster 5.1

A number of features for MySQL Cluster were implemented in MySQL 5.1 through MySQL 5.1.23, when support for MySQL Cluster was moved to MySQL Cluster NDB. All of the features in the following list are also available in all MySQL Cluster NDB (6.1 and later) releases.

- **Integration of MySQL Cluster into MySQL Replication.** MySQL Cluster Replication makes it possible to replicate from one MySQL Cluster to another. Updates on any SQL node (MySQL server) in the cluster acting as the master are replicated to the slave cluster; the state of the slave side remains consistent with the cluster acting as the master. This is sometimes referred to as *asynchronous replication* between clusters, providing *geographic redundancy*. It is also possible to replicate from a MySQL Cluster acting as the master to a standalone MySQL server acting as the slave, or from a standalone MySQL master server to a slave cluster; in either of these cases, the standalone MySQL server uses a storage engine other than `NDBCLUSTER`. Multi-master replication setups such as circular replication are also supported.

  See Section 17.6, "MySQL Cluster Replication".

- **Support for storage of rows on disk.** Storage of `NDBCLUSTER` table data on disk is now supported. Indexed columns, including the primary key hash index, must still be stored in RAM; however, all other columns can be stored on disk.

  See Section 17.5.12, "MySQL Cluster Disk Data Tables".

- **Variable-size columns.** In MySQL 5.0, an `NDBCLUSTER` table column defined as `VARCHAR(255)` used 260 bytes of storage independent of what was stored in any particular record. In MySQL 5.1 Cluster tables, only the portion of the column actually taken up by the record is stored. This makes

possible a significant reduction in space requirements for such columns as compared to previous release series—by a factor of up to 5 in many cases.

- **User-defined partitioning.**   Users can define partitions based on columns that are part of the primary key. It is possible to partition `NDB` tables based on `KEY` and `LINEAR KEY` schemes. This feature is also available for many other MySQL storage engines, which support additional partitioning types that are not available with `NDBCLUSTER` tables.

  For additional general information about user-defined partitioning in MySQL 5.1, see Chapter 18, *Partitioning*. Specifics of partitioning types are discussed in Section 18.2, "Partitioning Types".

  The MySQL Server can also determine whether it is possible to "prune away" some of the partitions from the `WHERE` clause, which can greatly speed up some queries. See Section 18.4, "Partition Pruning", for information about designing tables and queries to take advantage of partition pruning.

- **Autodiscovery of table schema changes.**   In MySQL 5.0, it was necessary to issue a `FLUSH TABLES` statement or a "dummy" `SELECT` for new `NDBCLUSTER` tables or changes made to schemas of existing `NDBCLUSTER` tables on one SQL node to be visible on the cluster's other SQL nodes. In MySQL 5.1, this is no longer necessary; new Cluster tables and changes in the definitions of existing `NDBCLUSTER` tables made on one SQL node are immediately visible to all SQL nodes connected to the cluster.

  > **Note**
  >
  > When creating a new database, it is still necessary in MySQL 5.1 to issue a `CREATE DATABASE` or `CREATE SCHEMA` statement on each SQL node in the cluster.

- **Distribution awareness (NDB API).**   *Distribution awareness* is a mechanism by which the best data node is automatically selected to be queried for information. (Conceptually, it is similar in some ways to partition pruning (see Section 18.4, "Partition Pruning"). To take advantage of distribution awareness, you should do the following:

  1. Determine which table column is most likely to be used for finding matching records.

  2. Make this column part of the table's primary key.

  3. Explicitly partition the table by `KEY`, using this column as the table' partitioning key.

  Following these steps causes records with the same value for the partitioning column to be stored on the same partition (that is, in the same node group). When reading data, transactions are begun on the data node actually having the desired rows instead of this node being determined by the usual round-robin mechanism.

  > **Important**
  >
  > To see a measureable impact on performance, the cluster must have at least four data nodes, since, with only two data nodes, both data nodes have exactly the same data.

  Using distribution awareness can yield performance increase of as great as 45% when using four data nodes, and possibly more when using a greater number of data nodes.

  > **Note**
  >
  > In mainline MySQL 5.1 releases, distribution awareness was supported only when using the NDB API; support was added for SQL and API nodes in MySQL

> Cluster NDB 6.3 (see Section 17.1.4.4, "What is New in MySQL Cluster NDB 6.3", which includes an example showing how to create a table to take advantage of distribution awareness).

- **Online adding and dropping of indexes.**   For `ALTER TABLE` statements, `ADD INDEX` and `DROP INDEX` operations for dynamic (variable-width) columns on `NDB` tables are now performed as online operations (no table copying). This is also true for `CREATE INDEX` and `DROP INDEX`. As a result, these operations are now performed much more quickly than previously.

  For more information, see Section 13.1.7.2, "ALTER TABLE Online Operations in MySQL Cluster", Section 13.1.13, "CREATE INDEX Syntax", and Section 13.1.24, "DROP INDEX Syntax".

See Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x", for more information.

17.1.5 MySQL Server Using InnoDB Compared with MySQL Cluster

MySQL Server offers a number of choices in storage engines. Since both `NDBCLUSTER` and `InnoDB` can serve as transactional MySQL storage engines, users of MySQL Server sometimes become interested in MySQL Cluster. They see `NDB` as a possible alternative or upgrade to the default `InnoDB` storage engine in MySQL 5.5. While `NDB` and `InnoDB` share common characteristics, there are differences in architecture and implementation, so that some existing MySQL Server applications and usage scenarios can be a good fit for MySQL Cluster, but not all of them.

In this section, we discuss and compare some characteristics of the `NDB` storage engine used by MySQL Cluster with `InnoDB` used in MySQL 5.1 and MySQL 5.5. The next few sections provide a technical comparison. In many instances, decisions about when and where to use MySQL Cluster must be made on a case-by-case basis, taking all factors into consideration. While it is beyond the scope of this documentation to provide specifics for every conceivable usage scenario, we also attempt to offer some very general guidance on the relative suitability of some common types of applications for `NDB` as opposed to `InnoDB` backends.

While it is possible to use `InnoDB` tables with MySQL Cluster, such tables are not clustered. MySQL Cluster NDB 7.1 releases use a `mysqld` based on MySQL 5.1 which includes `InnoDB` 1.0; MySQL Cluster NDB 7.2.1 and later are based on MySQL Server 5.5, which includes support for `InnoDB` 1.1. It is also not possible to use programs or libraries from a MySQL Cluster NDB 6.x or MySQL Cluster NDB 7.x distribution with MySQL Server 5.1 or MySQL Server 5.5, or the reverse.

While it is also true that some types of common business applications can be run either on MySQL Cluster or on MySQL Server (most likely using the `InnoDB` storage engine), there are some important architectural and implementation differences. Section 17.1.5.1, "Differences Between the NDB and InnoDB Storage Engines", provides a summary of the these differences. Due to the differences, some usage scenarios are clearly more suitable for one engine or the other; see Section 17.1.5.2, "NDB and InnoDB Workloads". This in turn has an impact on the types of applications that better suited for use with `NDB` or `InnoDB`. See Section 17.1.5.3, "NDB and InnoDB Feature Usage Summary", for a comparison of the relative suitability of each for use in common types of database applications.

For information about the relative characteristics of the `NDB` and `MEMORY` storage engines, see When to Use MEMORY or MySQL Cluster.

See Chapter 14, *Storage Engines*, for additional information about MySQL storage engines.

17.1.5.1 Differences Between the NDB and InnoDB Storage Engines

The MySQL Cluster `NDB` storage engine is implemented using a distributed, shared-nothing architecture, which causes it to behave differently from `InnoDB` in a number of ways. For those unaccustomed to

working with `NDB`, unexpected behaviors can arise due to its distributed nature with regard to transactions, foreign keys, joins, and other characteristics. These are shown in the following table:

Feature	`InnoDB`	MySQL Cluster
MySQL Server Version	`InnoDB` 1.1: 5.5 `InnoDB` 1.0: 5.1	MySQL Cluster NDB 6.3, 7.0, 7.1: 5.1 MySQL Cluster NDB 7.2: 5.5 MySQL Cluster NDB 7.3: 5.6
`InnoDB` Availability	`InnoDB` 1.1 plugin	*NDB 6.3, 7.0*: `InnoDB` storage engine *NDB 7.1*: `InnoDB` 1.0 plugin support (MySQL Cluster NDB 7.1.9a and later) *NDB 7.2*: `InnoDB` 1.1 (MySQL Cluster NDB 7.2.1 and later)
Storage Limits	64TB	3TB (Practical upper limit based on 48 data nodes with 64GB RAM each; can be increased with disk-based data and BLOBs)
Foreign Keys	Yes	Prior to MySQL Cluster NDB 7.3: No. (Ignored, as with `MyISAM`) Available in MySQL Cluster NDB 7.3 and later.
Transactions	All standard types	`READ COMMITTED`
MVCC	Yes	No
Data Compression	Yes	No (MySQL Cluster checkpoint and backup files can be compressed)
Large Row Support (> 14K)	Supported for `VARBINARY`, `VARCHAR`, `BLOB`, and `TEXT` columns	Supported for `BLOB` and `TEXT` columns only (Using these types to store very large amounts of data can lower MySQL Cluster performance)
Replication Support	Asynchronous and semisynchronous replication using MySQL Replication	Automatic synchronous replication within a MySQL Cluster. Asynchronous replication between MySQL Clusters, using MySQL Replication
Scaleout for Read Operations	Yes (MySQL Replication)	Yes (Automatic partitioning in MySQL Cluster; MySQL Replication)

Feature	**InnoDB**	**MySQL Cluster**
Scaleout for Write Operations	Requires application-level partitioning (sharding)	Yes (Automatic partitioning in MySQL Cluster is transparent to applications)
High Availability (HA)	Requires additional software	Yes (Designed for 99.999% uptime)
Node Failure Recovery and Failover	Requires additional software	Automatic (Key element in MySQL Cluster architecture)
Time for Node Failure Recovery	30 seconds or longer	Typically < 1 second
Real-Time Performance	No	Yes
In-Memory Tables	No	Yes (Some data can optionally be stored on disk; both in-memory and disk data storage are durable)
NoSQL Access to Storage Engine	Native memcached interface in development (see the MySQL Dev Zone article *MySQL Cluster 7.2 (DMR2): NoSQL, Key/Value, Memcached*)	Yes Multiple APIs, including C++, HTTP/REST, Java and JPA (MySQL Cluster NDB 7.1 and later); Memcached (MySQL Cluster NDB 7.2 and later); Node.js under development (MySQL Cluster NDB 7.3)
Concurrent and Parallel Writes	Not supported	Up to 48 writers, optimized for concurrent writes
Conflict Detection and Resolution (Multiple Replication Masters)	No	Yes
Hash Indexes	No	Yes
Online Addition of Nodes	Read-only replicas using MySQL Replication	Yes (all node types)
Online Upgrades	No	Yes
Online Schema Modifications	No.	Yes.

17.1.5.2 NDB and InnoDB Workloads

MySQL Cluster has a range of unique attributes that make it ideal to serve applications requiring high availability, fast failover, high throughput, and low latency. Due to its distributed architecture and multi-node implementation, MySQL Cluster also has specific constraints that may keep some workloads from performing well. A number of major differences in behavior between the `NDB` and `InnoDB` storage engines with regard to some common types of database-driven application workloads are shown in the following table::

Workload	**InnoDB**	**MySQL Cluster (NDB)**
High-Volume OLTP Applications	Yes	Yes

Workload	`InnoDB`	MySQL Cluster (`NDB`)
DSS Applications (data marts, analytics)	Yes	Limited (Join operations across OLTP datasets not exceeding 3TB in size)
Custom Applications	Yes	Yes
Packaged Applications	Yes	Limited (should be mostly primary key access). **Note** MySQL Cluster NDB 7.3 supports foreign keys.
In-Network Telecoms Applications (HLR, HSS, SDP)	No	Yes
Session Management and Caching	Yes	Yes
E-Commerce Applications	Yes	Yes
User Profile Management, AAA Protocol	Yes	Yes

17.1.5.3 NDB and InnoDB Feature Usage Summary

When comparing application feature requirements to the capabilities of `InnoDB` with `NDB`, some are clearly more compatible with one storage engine than the other.

The following table lists supported application features according to the storage engine to which each feature is typically better suited.

Preferred application requirements for `InnoDB`	Preferred application requirements for `NDB`
• Foreign keys **Note** MySQL Cluster NDB 7.3 supports foreign keys. • Full table scans • Very large databases, rows, or transactions • Transactions other than `READ COMMITTED`	• Write scaling • 99.999% uptime • Online addition of nodes and online schema operations • Multiple SQL and NoSQL APIs (see MySQL Cluster APIs: Overview and Concepts) • Real-time performance • Limited use of `BLOB` columns

17.1.6 Known Limitations of MySQL Cluster

In the sections that follow, we discuss known limitations in current releases of MySQL Cluster as compared with the features available when using the `MyISAM` and `InnoDB` storage engines. If you check the "Cluster" category in the MySQL bugs database at http://bugs.mysql.com, you can find known bugs in the following

categories under "MySQL Server:" in the MySQL bugs database at http://bugs.mysql.com, which we intend to correct in upcoming releases of MySQL Cluster:

• MySQL Cluster

• Cluster Direct API (NDBAPI)

• Cluster Disk Data

• Cluster Replication

• ClusterJ

This information is intended to be complete with respect to the conditions just set forth. You can report any discrepancies that you encounter to the MySQL bugs database using the instructions given in Section 1.7, "How to Report Bugs or Problems". If we do not plan to fix the problem in MySQL Cluster NDB 7.1, we will add it to the list.

See Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x" for a list of issues in MySQL Cluster in MySQL 5.0 that have been resolved in the current version.

> **Note**
>
> Limitations and other issues specific to MySQL Cluster Replication are described in Section 17.6.3, "Known Issues in MySQL Cluster Replication".

17.1.6.1 Noncompliance with SQL Syntax in MySQL Cluster

Some SQL statements relating to certain MySQL features produce errors when used with `NDB` tables, as described in the following list:

• **Temporary tables.**   Temporary tables are not supported. Trying either to create a temporary table that uses the `NDB` storage engine or to alter an existing temporary table to use `NDB` fails with the error `Table storage engine 'ndbcluster' does not support the create option 'TEMPORARY'`.

• **Indexes and keys in NDB tables.**   Keys and indexes on MySQL Cluster tables are subject to the following limitations:

  • **Column width.**   Attempting to create an index on an `NDB` table column whose width is greater than 3072 bytes succeeds, but only the first 3072 bytes are actually used for the index. In such cases, a warning `Specified key was too long; max key length is 3072 bytes` is issued, and a `SHOW CREATE TABLE` statement shows the length of the index as 3072.

  • **TEXT and BLOB columns.**   You cannot create indexes on `NDB` table columns that use any of the `TEXT` or `BLOB` data types.

  • **FULLTEXT indexes.**   The `NDB` storage engine does not support `FULLTEXT` indexes, which are possible for `MyISAM` tables only.

    However, you can create indexes on `VARCHAR` columns of `NDB` tables.

  • **USING HASH keys and NULL.**   Using nullable columns in unique keys and primary keys means that queries using these columns are handled as full table scans. To work around this issue, make the column `NOT NULL`, or re-create the index without the `USING HASH` option.

  • **Prefixes.**   There are no prefix indexes; only entire columns can be indexed. (The size of an `NDB` column index is always the same as the width of the column in bytes, up to and including 3072 bytes,

as described earlier in this section. Also see Section 17.1.6.6, "Unsupported or Missing Features in MySQL Cluster", for additional information.)

- **BIT columns.** A `BIT` column cannot be a primary key, unique key, or index, nor can it be part of a composite primary key, unique key, or index.

- **AUTO_INCREMENT columns.** Like other MySQL storage engines, the `NDB` storage engine can handle a maximum of one `AUTO_INCREMENT` column per table, and this column must be indexed. However, in the case of a MySQL Cluster table with no explicit primary key, an `AUTO_INCREMENT` column is automatically defined and used as a "hidden" primary key. For this reason, you cannot create an `NDB` table having an `AUTO_INCREMENT` column and no explicit primary key.

- **MySQL Cluster and geometry data types.**
  Geometry data types (`WKT` and `WKB`) are supported in `NDB` tables in MySQL 5.1 (including MySQL Cluster NDB 6.X and 7.X through 7.1). However, spatial indexes are not supported.

- **Character sets and binary log files.** Currently, the `ndb_apply_status` and `ndb_binlog_index` tables are created using the `latin1` (ASCII) character set. Because names of binary logs are recorded in this table, binary log files named using non-Latin characters are not referenced correctly in these tables. This is a known issue, which we are working to fix. (Bug #50226)

  To work around this problem, use only Latin-1 characters when naming binary log files or setting any the `--basedir`, `--log-bin`, or `--log-bin-index` options.

- **Creating NDB tables with user-defined partitioning.** Support for user-defined partitioning for MySQL Cluster is restricted to [`LINEAR`] `KEY` partitioning. Beginning with MySQL 5.1.12, using any other partitioning type with `ENGINE=NDB` or `ENGINE=NDBCLUSTER` in a `CREATE TABLE` statement results in an error.

  It is possible to override this restriction, but doing so is not supported for use in production settings. For details, see User-defined partitioning and the NDB storage engine (MySQL Cluster).

  Default partitioning scheme. As of MySQL 5.1.6, all MySQL Cluster tables are by default partitioned by `KEY` using the table's primary key as the partitioning key. If no primary key is explicitly set for the table, the "hidden" primary key automatically created by the `NDBCLUSTER` storage engine is used instead. For additional discussion of these and related issues, see Section 18.2.4, "KEY Partitioning".

  Beginning with MySQL Cluster NDB 6.2.18, MySQL Cluster NDB 6.3.25, and MySQL Cluster NDB 7.0.6, `CREATE TABLE` and `ALTER TABLE` statements that would cause a user-partitioned `NDBCLUSTER` table not to meet either or both of the following two requirements are not permitted, and fail with an error (Bug #40709):

  1. The table must have an explicit primary key.

  2. All columns listed in the table's partitioning expression must be part of the primary key.

  Exception. If a user-partitioned `NDBCLUSTER` table is created using an empty column-list (that is, using `PARTITION BY [LINEAR] KEY()`), then no explicit primary key is required.

  Maximum number of partitions for NDBCLUSTER tables. The maximum number of partitions that can defined for a `NDBCLUSTER` table when employing user-defined partitioning is 8 per node group. (See Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions", for more information about MySQL Cluster node groups.

  DROP PARTITION not supported. It is not possible to drop partitions from `NDB` tables using `ALTER TABLE ... DROP PARTITION`. The other partitioning extensions to `ALTER TABLE`—ADD

PARTITION, REORGANIZE PARTITION, and COALESCE PARTITION—are supported for Cluster tables, but use copying and so are not optimized. See Section 18.3.1, "Management of RANGE and LIST Partitions" and Section 13.1.7, "ALTER TABLE Syntax".

- **Row-based replication.**
  When using row-based replication with MySQL Cluster, binary logging cannot be disabled. That is, the NDB storage engine ignores the value of sql_log_bin. (Bug #16680)

17.1.6.2 Limits and Differences of MySQL Cluster from Standard MySQL Limits

In this section, we list limits found in MySQL Cluster that either differ from limits found in, or that are not found in, standard MySQL.

Memory usage and recovery.   Memory consumed when data is inserted into an NDB table is not automatically recovered when deleted, as it is with other storage engines. Instead, the following rules hold true:

- A DELETE statement on an NDB table makes the memory formerly used by the deleted rows available for re-use by inserts on the same table only. However, this memory can be made available for general re-use by performing a rolling restart of the cluster. See Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster".

  Beginning with MySQL Cluster NDB 6.3.7, this limitation can be overcome using OPTIMIZE TABLE. See Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x", for more information.

- A DROP TABLE or TRUNCATE TABLE operation on an NDB table frees the memory that was used by this table for re-use by any NDB table, either by the same table or by another NDB table.

  > **Note**
  >
  > Recall that TRUNCATE TABLE drops and re-creates the table. See Section 13.1.34, "TRUNCATE TABLE Syntax".

- **Limits imposed by the cluster's configuration.**
  A number of hard limits exist which are configurable, but available main memory in the cluster sets limits. See the complete list of configuration parameters in Section 17.3.3, "MySQL Cluster Configuration Files". Most configuration parameters can be upgraded online. These hard limits include:

  - Database memory size and index memory size (DataMemory and IndexMemory, respectively).

    DataMemory is allocated as 32KB pages. As each DataMemory page is used, it is assigned to a specific table; once allocated, this memory cannot be freed except by dropping the table.

    See Section 17.3.3.6, "Defining MySQL Cluster Data Nodes", for more information.

  - The maximum number of operations that can be performed per transaction is set using the configuration parameters MaxNoOfConcurrentOperations and MaxNoOfLocalOperations.

    > **Note**
    >
    > Bulk loading, TRUNCATE TABLE, and ALTER TABLE are handled as special cases by running multiple transactions, and so are not subject to this limitation.

  - Different limits related to tables and indexes. For example, the maximum number of ordered indexes in the cluster is determined by MaxNoOfOrderedIndexes, and the maximum number of ordered indexes per table is 16.

- **Node and data object maximums.**   The following limits apply to numbers of cluster nodes and metadata objects:

  - The maximum number of data nodes is 48.

    A data node must have a node ID in the range of 1 to 48, inclusive. (Previous to MySQL Cluster NDB 6.1.1, management and API nodes were restricted to the range 1 to 63 inclusive as a node ID; starting with MySQL Cluster NDB 6.1.1, management and API nodes may use node IDs in the range 1 to 255, inclusive.)

  - Prior to MySQL Cluster NDB 6.1.1, the total maximum number of nodes in a MySQL Cluster was 63. Beginning with MySQL Cluster NDB 6.1.1, the total maximum number of nodes in a MySQL Cluster is 255. In either case, this number includes all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers.

  - The maximum number of metadata objects in current versions of MySQL Cluster is 20320. This limit is hard-coded.

  See Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x", for more information.

17.1.6.3 Limits Relating to Transaction Handling in MySQL Cluster

A number of limitations exist in MySQL Cluster with regard to the handling of transactions. These include the following:

- **Transaction isolation level.**   The `NDBCLUSTER` storage engine supports only the `READ COMMITTED` transaction isolation level. (`InnoDB`, for example, supports `READ COMMITTED`, `READ UNCOMMITTED`, `REPEATABLE READ`, and `SERIALIZABLE`.) You should keep in mind that `NDB` implements `READ COMMITTED` on a per-row basis; when a read request arrives at the data node storing the row, what is returned is the last committed version of the row at that time.

  Uncommitted data is never returned, but when a transaction modifying a number of rows commits concurrently with a transaction reading the same rows, the transaction performing the read can observe "before" values, "after" values, or both, for different rows among these, due to the fact that a given row read request can be processed either before or after the commit of the other transaction.

  To ensure that a given transaction reads only before or after values, you can impose row locks using `SELECT ... LOCK IN SHARE MODE`. In such cases, the lock is held until the owning transaction is committed. Using row locks can also cause the following issues:

  - Increased frequency of lock wait timeout errors, and reduced concurrency

  - Increased transaction processing overhead due to reads requiring a commit phase

  - Possibility of exhausting the available number of concurrent locks, which is limited by `MaxNoOfConcurrentOperations`

  `NDB` uses `READ COMMITTED` for all reads unless a modifier such as `LOCK IN SHARE MODE` or `FOR UPDATE` is used. `LOCK IN SHARE MODE` causes shared row locks to be used; `FOR UPDATE` causes exclusive row locks to be used. Unique key reads have their locks upgraded automatically by `NDB` to ensure a self-consistent read; `BLOB` reads also employ extra locking for consistency.

  See Section 17.5.3.4, "MySQL Cluster Backup Troubleshooting", for information on how MySQL Cluster's implementation of transaction isolation level can affect backup and restoration of `NDB` databases.

- **Transactions and BLOB or TEXT columns.**   `NDBCLUSTER` stores only part of a column value that uses any of MySQL's `BLOB` or `TEXT` data types in the table visible to MySQL; the remainder of the `BLOB` or `TEXT` is stored in a separate internal table that is not accessible to MySQL. This gives rise to two related issues of which you should be aware whenever executing `SELECT` statements on tables that contain columns of these types:

  1. For any `SELECT` from a MySQL Cluster table: If the `SELECT` includes a `BLOB` or `TEXT` column, the `READ COMMITTED` transaction isolation level is converted to a read with read lock. This is done to guarantee consistency.

  2. Prior to MySQL Cluster NDB 7.0.12, for any `SELECT` which used a primary key lookup or unique key lookup to retrieve any columns that used any of the `BLOB` or `TEXT` data types and that was executed within a transaction, a shared read lock was held on the table for the duration of the transaction—that is, until the transaction was either committed or aborted.

     In MySQL Cluster NDB 7.0.12 and later, for primary key lookups, the lock is released as soon as all `BLOB` or `TEXT` data has been read. (Bug #49190) However, for unique key lookups, the shared lock continues to be held for the lifetime of the transaction.

     This issue does not occur for queries that use index or table scans, even against `NDB` tables having `BLOB` or `TEXT` columns.

     For example, consider the table `t` defined by the following `CREATE TABLE` statement:

     ```
     CREATE TABLE t (
         a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
         b INT NOT NULL,
         c INT NOT NULL,
         d TEXT,
         INDEX i(b),
         UNIQUE KEY u(c)
     ) ENGINE = NDB,
     ```

     Either of the following queries on `t` causes a shared read lock, because the first query uses a primary key lookup and the second uses a unique key lookup:

     ```
     SELECT * FROM t WHERE a = 1;

     SELECT * FROM t WHERE c = 1;
     ```

     However, none of the four queries shown here causes a shared read lock:

     ```
     SELECT * FROM t WHERE b = 1;

     SELECT * FROM t WHERE d = '1';

     SELECT * FROM t;

     SELECT b,c WHERE a = 1;
     ```

     This is because, of these four queries, the first uses an index scan, the second and third use table scans, and the fourth, while using a primary key lookup, does not retrieve the value of any `BLOB` or `TEXT` columns.

     You can help minimize issues with shared read locks by avoiding queries that use unique key lookups (or primary key lookups in MySQL Cluster NDB 7.0.11 and earlier) that retrieve `BLOB` or

`TEXT` columns, or, in cases where such queries are not avoidable, by committing transactions as soon as possible afterward.

- **Rollbacks.** There are no partial transactions, and no partial rollbacks of transactions. A duplicate key or similar error causes the entire transaction to be rolled back.

  This behavior differs from that of other transactional storage engines such as `InnoDB` that may roll back individual statements.

- **Transactions and memory usage.**
  As noted elsewhere in this chapter, MySQL Cluster does not handle large transactions well; it is better to perform a number of small transactions with a few operations each than to attempt a single large transaction containing a great many operations. Among other considerations, large transactions require very large amounts of memory. Because of this, the transactional behavior of a number of MySQL statements is effected as described in the following list:

  - `TRUNCATE TABLE` is not transactional when used on `NDB` tables. If a `TRUNCATE TABLE` fails to empty the table, then it must be re-run until it is successful.

  - `DELETE FROM` (even with no `WHERE` clause) *is* transactional. For tables containing a great many rows, you may find that performance is improved by using several `DELETE FROM ... LIMIT ...` statements to "chunk" the delete operation. If your objective is to empty the table, then you may wish to use `TRUNCATE TABLE` instead.

  - **LOAD DATA statements.** `LOAD DATA INFILE` is not transactional when used on `NDB` tables.

    > ⚠️ **Important**
    >
    > When executing a `LOAD DATA INFILE` statement, the `NDB` engine performs commits at irregular intervals that enable better utilization of the communication network. It is not possible to know ahead of time when such commits take place.

    `LOAD DATA FROM MASTER` is not supported in MySQL Cluster.

  - **ALTER TABLE and transactions.** When copying an `NDB` table as part of an `ALTER TABLE`, the creation of the copy is nontransactional. (In any case, this operation is rolled back when the copy is deleted.)

- **Transactions and the COUNT() function.** When using MySQL Cluster Replication, it is not possible to guarantee the transactional consistency of the `COUNT()` function on the slave. In other words, when performing on the master a series of statements (`INSERT`, `DELETE`, or both) that changes the number of rows in a table within a single transaction, executing `SELECT COUNT(*) FROM table` queries on the slave may yield intermediate results. This is due to the fact that `SELECT COUNT(...)` may perform dirty reads, and is not a bug in the `NDB` storage engine. (See Bug #31321 for more information.)

17.1.6.4 MySQL Cluster Error Handling

Starting, stopping, or restarting a node may give rise to temporary errors causing some transactions to fail. These include the following cases:

- **Temporary errors.** When first starting a node, it is possible that you may see Error 1204 `Temporary failure, distribution changed` and similar temporary errors.

- **Errors due to node failure.** The stopping or failure of any data node can result in a number of different node failure errors. (However, there should be no aborted transactions when performing a planned shutdown of the cluster.)

In either of these cases, any errors that are generated must be handled within the application. This should be done by retrying the transaction.

See also

17.1.6.5 Limits Associated with Database Objects in MySQL Cluster

Some database objects such as tables and indexes have different limitations when using the `NDBCLUSTER` storage engine:

- **Database and table names.**   When using the `NDB` storage engine, the maximum allowed length both for database names and for table names is 63 characters.

- **Table names containing special characters.**   `NDB` tables whose names contain characters other than letters, numbers, dashes, and underscores and which are created on one SQL node were not always discovered correctly by other SQL nodes. (Bug #31470)

  > **Note**
  >
  > This issue was fixed in MySQL 5.1.23, MySQL Cluster NDB 6.2.7, and MySQL Cluster NDB 6.3.4.

- **Number of database objects.**   The maximum number of *all* `NDB` database objects in a single MySQL Cluster—including databases, tables, and indexes—is limited to 20320.

- **Attributes per table.**   Prior to MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, the maximum number of attributes (that is, columns and indexes) per table is limited to 128.

  Beginning with MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, this limit is increased to 512.

- **Attributes per key.**   The maximum number of attributes per key is 32.

- **Row size.**   Prior to MySQL Cluster NDB 7.0, the maximum permitted size of any one row was 8052 bytes; in MySQL Cluster NDB 7.0 and later, this is 14000 bytes. Each `BLOB` or `TEXT` column contributes 256 + 8 = 264 bytes to this total.

- **BIT column storage per table.**   The maximum combined width for all `BIT` columns used in a given `NDB` table is 4096.

17.1.6.6 Unsupported or Missing Features in MySQL Cluster

A number of features supported by other storage engines are not supported for `NDB` tables. Trying to use any of these features in MySQL Cluster does not cause errors in or of itself; however, errors may occur in applications that expects the features to be supported or enforced. Statements referencing such features, even if effectively ignored by `NDB`, must be syntactically and otherwise valid.

- **Foreign key constraints.**   Prior to MySQL Cluster NDB 7.3, the foreign key construct is ignored, just as it is by `MyISAM` tables. Foreign keys are supported in MySQL Cluster NDB 7.3 and later.

- **Index prefixes.**   Prefixes on indexes are not supported for `NDB` tables. If a prefix is used as part of an index specification in a statement such as `CREATE TABLE`, `ALTER TABLE`, or `CREATE INDEX`, the prefix is not created by `NDB`.

  A statement containing an index prefix, and creating or modifying an `NDB` table, must still be syntactically valid. For example, the following statement always fails with Error 1089 `Incorrect prefix key; the used key part isn't a string, the used length is longer than the key`

`part, or the storage engine doesn't support unique prefix keys`, regardless of storage engine:

```
CREATE TABLE t1 (
    c1 INT NOT NULL,
    c2 VARCHAR(100),
    INDEX i1 (c2(500))
);
```

This happens on account of the SQL syntax rule that no index may have a prefix larger than itself.

- **OPTIMIZE operations.**   `OPTIMIZE` operations are not supported.

  Beginning with MySQL Cluster NDB 6.3.7, this limitation has been lifted. See Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x", for more information.

- **LOAD TABLE ... FROM MASTER.**   `LOAD TABLE FROM MASTER` is not supported.

- **Savepoints and rollbacks.**   Savepoints and rollbacks to savepoints are ignored as in `MyISAM`.

- **Durability of commits.**   There are no durable commits on disk. Commits are replicated, but there is no guarantee that logs are flushed to disk on commit.

- **Replication.**   Statement-based replication is not supported. Use `--binlog-format=ROW` (or `--binlog-format=MIXED`) when setting up cluster replication. See Section 17.6, "MySQL Cluster Replication", for more information.

> **Note**
>
> See Section 17.1.6.3, "Limits Relating to Transaction Handling in MySQL Cluster", for more information relating to limitations on transaction handling in `NDB`.

17.1.6.7 Limitations Relating to Performance in MySQL Cluster

The following performance issues are specific to or especially pronounced in MySQL Cluster:

- **Range scans.**   There are query performance issues due to sequential access to the `NDB` storage engine; it is also relatively more expensive to do many range scans than it is with either `MyISAM` or `InnoDB`.

- **Reliability of Records in range.**   The `Records in range` statistic is available but is not completely tested or officially supported. This may result in nonoptimal query plans in some cases. If necessary, you can employ `USE INDEX` or `FORCE INDEX` to alter the execution plan. See Section 8.9.3, "Index Hints", for more information on how to do this.

- **Unique hash indexes.**   Unique hash indexes created with `USING HASH` cannot be used for accessing a table if `NULL` is given as part of the key.

17.1.6.8 Issues Exclusive to MySQL Cluster

The following are limitations specific to the `NDBCLUSTER` storage engine:

- **Machine architecture.**   All machines used in the cluster must have the same architecture. That is, all machines hosting nodes must be either big-endian or little-endian, and you cannot use a mixture of both. For example, you cannot have a management node running on a PowerPC which directs a data node

that is running on an x86 machine. This restriction does not apply to machines simply running `mysql` or other clients that may be accessing the cluster's SQL nodes.

- **Binary logging.**
  MySQL Cluster has the following limitations or restrictions with regard to binary logging:

  - `sql_log_bin` has no effect on data operations; however, it is supported for schema operations.

  - MySQL Cluster cannot produce a binary log for tables having `BLOB` columns but no primary key.

  - Only the following schema operations are logged in a cluster binary log which is *not* on the `mysqld` executing the statement:

    - `CREATE TABLE`

    - `ALTER TABLE`

    - `DROP TABLE`

    - `CREATE DATABASE` / `CREATE SCHEMA`

    - `DROP DATABASE` / `DROP SCHEMA`

    - `CREATE TABLESPACE`

    - `ALTER TABLESPACE`

    - `DROP TABLESPACE`

    - `CREATE LOGFILE GROUP`

    - `ALTER LOGFILE GROUP`

    - `DROP LOGFILE GROUP`

  See also Section 17.1.6.10, "Limitations Relating to Multiple MySQL Cluster Nodes".

17.1.6.9 Limitations Relating to MySQL Cluster Disk Data Storage

Disk Data object maximums and minimums.   Disk data objects are subject to the following maximums and minimums:

- Maximum number of tablespaces: 2^{32} (4294967296)

- Maximum number of data files per tablespace: 2^{16} (65536)

- Maximum data file size: The theoretical limit is 64G; however, in MySQL 5.1 (including MySQL Cluster NDB 6.X and 7.X through 7.1), the practical upper limit is 32G. This is equivalent to 32768 extents of 1M each.

  Since a MySQL Cluster Disk Data table can use at most 1 tablespace, this means that the theoretical upper limit to the amount of data (in bytes) that can be stored on disk by a single `NDB` table is 32G * 65536 = 2251799813685248, or approximately 2 petabytes.

- The theoretical maximum number of extents per tablespace data file is 2^{16} (65536); however, for practical purposes, the recommended maximum number of extents per data file is 2^{15} (32768).

  The minimum and maximum possible sizes of extents for tablespace data files are 32K and 2G, respectively. See Section 13.1.18, "CREATE TABLESPACE Syntax", for more information.

Disk Data tables and diskless mode. Use of Disk Data tables is not supported when running the cluster in diskless mode. Beginning with MySQL 5.1.12, it is prohibited altogether. (Bug #20008)

17.1.6.10 Limitations Relating to Multiple MySQL Cluster Nodes

Multiple SQL nodes.
The following are issues relating to the use of multiple MySQL servers as MySQL Cluster SQL nodes, and are specific to the `NDBCLUSTER` storage engine:

- **No distributed table locks.** A `LOCK TABLES` works only for the SQL node on which the lock is issued; no other SQL node in the cluster "sees" this lock. This is also true for a lock issued by any statement that locks tables as part of its operations. (See next item for an example.)

- **ALTER TABLE operations.** `ALTER TABLE` is not fully locking when running multiple MySQL servers (SQL nodes). (As discussed in the previous item, MySQL Cluster does not support distributed table locks.)

Multiple management nodes.
When using multiple management servers:

- If any of the management servers are running on the same host, you must give nodes explicit IDs in connection strings because automatic allocation of node IDs does not work across multiple management servers on the same host. This is not required if every management server resides on a different host.

- In MySQL Cluster NDB 7.0.7 and earlier, you must take extreme care to have the same configurations for all management servers; no special checks for consistency are performed.

  Beginning with MySQL Cluster NDB 7.0.8, a management server when first starting checks for any other management server in the same MySQL Cluster, and upon successful connection to the other management server uses its configuration data. This means that the management server `--reload` and `--initial` startup options are ignored unless the management server is the only one running. It also means that, when performing a rolling restart of a MySQL Cluster with multiple management nodes, the management server reads its own configuration file if (and only if) it is the only management server running in this MySQL Cluster. See Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster", for more information.

Multiple network addresses. Multiple network addresses per data node are not supported. Use of these is liable to cause problems: In the event of a data node failure, an SQL node waits for confirmation that the data node went down but never receives it because another route to that data node remains open. This can effectively make the cluster inoperable.

> **Note**
>
> It is possible to use multiple network hardware *interfaces* (such as Ethernet cards) for a single data node, but these must be bound to the same address. This also means that it not possible to use more than one `[tcp]` section per connection in the `config.ini` file. See Section 17.3.3.9, "MySQL Cluster TCP/IP Connections", for more information.

17.1.6.11 Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x

A number of limitations and related issues existing in earlier versions of MySQL Cluster have been resolved:

- **Variable-length column support.** The `NDBCLUSTER` storage engine now supports variable-length column types for in-memory tables.

Previously, for example, any Cluster table having one or more `VARCHAR` fields which contained only relatively small values, much more memory and disk space were required when using the `NDBCLUSTER` storage engine than would have been the case for the same table and data using the `MyISAM` engine. In other words, in the case of a `VARCHAR` column, such a column required the same amount of storage as a `CHAR` column of the same size. In MySQL 5.1, this is no longer the case for in-memory tables, where storage requirements for variable-length column types such as `VARCHAR` and `BINARY` are comparable to those for these column types when used in `MyISAM` tables (see Section 11.7, "Data Type Storage Requirements").

> **Important**
>
> For MySQL Cluster Disk Data tables, the fixed-width limitation continues to apply. See Section 17.5.12, "MySQL Cluster Disk Data Tables".

- **Replication with MySQL Cluster.**   It is now possible to use MySQL replication with Cluster databases. For details, see Section 17.6, "MySQL Cluster Replication".

  Circular Replication.   Circular replication is also supported with MySQL Cluster, beginning with MySQL 5.1.18. See Section 17.6.10, "MySQL Cluster Replication: Multi-Master and Circular Replication".

- **auto_increment_increment and auto_increment_offset.**   The `auto_increment_increment` and `auto_increment_offset` server system variables are supported for Cluster replication beginning with MySQL 5.1.20, MySQL Cluster NDB 6.2.5, and MySQL Cluster 6.3.2.

- **Database autodiscovery and online schema changes.**   Autodiscovery of databases is now supported for multiple MySQL servers accessing the same MySQL Cluster. Formerly, autodiscovery in MySQL Cluster 5.1 and MySQL Cluster NDB 6.x releases required that a given `mysqld` was already running and connected to the cluster at the time that the database was created on a different `mysqld`—in other words, when a `mysqld` process connected to the cluster after a database named *db_name* was created, it was necessary to issue a `CREATE DATABASE` *db_name* or `CREATE SCHEMA` *db_name* statement on the "new" MySQL server when it first accessed that MySQL Cluster. Beginning with MySQL Cluster NDB 6.2.16 and MySQL Cluster NDB 6.3.18, such a `CREATE` statement is no longer required. (Bug #39612)

  This also means that online schema changes in `NDB` tables are now possible. That is, the result of operations such as `ALTER TABLE` and `CREATE INDEX` performed on one SQL node in the cluster are now visible to the cluster's other SQL nodes without any additional action being taken.

- **Backup and restore between architectures.**   Beginning with MySQL 5.1.10, it is possible to perform a Cluster backup and restore between different architectures. Previously—for example—you could not back up a cluster running on a big-endian platform and then restore from that backup to a cluster running on a little-endian system. (Bug #19255)

- **Character set directory.**   Beginning with MySQL 5.1.10, it is possible to install MySQL with Cluster support to a nondefault location and change the search path for font description files using either the `--basedir` or `--character-sets-dir` options. (Previously, `ndbd` in MySQL 5.1 searched only the default path—typically `/usr/local/mysql/share/mysql/charsets`—for character sets.)

- **Multiple management servers.**   In MySQL 5.1 (including all MySQL Cluster NDB 6.x and later versions), it is no longer necessary, when running multiple management servers, to restart all the cluster's data nodes to enable the management nodes to see one another.

  Also, when using multiple management servers and starting concurrently several API nodes (possibly including one or more SQL nodes) whose connection strings listed the management servers in different

order, it was possible for 2 API nodes to be assigned the same node ID. This issue is resolved in MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3. (Bug #42973)

If any of the management servers are running on the same host, you must give nodes explicit IDs in connection strings because automatic allocation of node IDs does not work across multiple management servers on the same host. This is not required if every management server resides on a different host.

- **Multiple data node processes per host.**   Beginning with MySQL Cluster NDB 6.2.0, you can use multiple data node processes on a single host. (In MySQL Cluster NDB 6.1, MySQL 5.1, and earlier release series, we did not support production MySQL Cluster deployments in which more than one `ndbd` process was run on a single physical machine.)

  In addition, MySQL Cluster NDB 7.0 introduces support for multi-threaded data nodes (`ndbmtd`). See Section 17.1.4.3, "What is New in MySQL Cluster NDB 7.0", and Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)", for more information.

- **Identifiers.**   Formerly (in MySQL 5.0 and earlier), database names, table names and attribute names could not be as long for `NDB` tables as tables using other storage engines, because attribute names were truncated internally. In MySQL 5.1 and later, names of MySQL Cluster databases, tables, and table columns follow the same rules regarding length as they do for any other storage engine.

- **Length of CREATE TABLE statements.**   `CREATE TABLE` statements may be no more than 4096 characters in length. *This limitation affects MySQL 5.1.6, 5.1.7, and 5.1.8 only*. (See Bug #17813)

- **IGNORE and REPLACE functionality.**   In MySQL 5.1.7 and earlier, `INSERT IGNORE`, `UPDATE IGNORE`, and `REPLACE` were supported only for primary keys, but not for unique keys. It was possible to work around this issue by removing the constraint, then dropping the unique index, performing any inserts, and then adding the unique index again.

  This limitation was removed for `INSERT IGNORE` and `REPLACE` in MySQL 5.1.8. (See Bug #17431.)

- **AUTO_INCREMENT columns.**   In MySQL 5.1.10 and earlier versions, the maximum number of tables having `AUTO_INCREMENT` columns—including those belonging to hidden primary keys—was 2048.

  This limitation was lifted in MySQL 5.1.11.

- **Maximum number of cluster nodes.**   Prior to MySQL Cluster NDB 6.1.1, the total maximum number of nodes in a MySQL Cluster was 63, including all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers.

  Starting with MySQL Cluster NDB 6.1.1, the total maximum number of nodes in a MySQL Cluster is 255, including all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers. The total number of data nodes and management nodes beginning with this version is 63, of which up to 48 can be data nodes.

  > **Note**
  >
  > The limitation that a data node cannot have a node ID greater than 49 continues to apply.

- **Recovery of memory from deleted rows.**   Beginning with MySQL Cluster NDB 6.3.7, memory can be reclaimed from an `NDB` table for reuse with any `NDB` table by employing `OPTIMIZE TABLE`, subject to the following limitations:

  - Only in-memory tables are supported; the `OPTIMIZE TABLE` statement still has no effect on MySQL Cluster Disk Data tables.

- Only variable-length columns (such as those declared as `VARCHAR`, `TEXT`, or `BLOB`) are supported.

  However, you can force columns defined using fixed-length data types (such as `CHAR`) to be dynamic using the `ROW_FORMAT` or `COLUMN_FORMAT` option with a `CREATE TABLE` or `ALTER TABLE` statement.

  See Section 13.1.17, "CREATE TABLE Syntax", and Section 13.1.7, "ALTER TABLE Syntax", for information on these options.

  You can regulate the effects of `OPTIMIZE` on performance by adjusting the value of the global system variable `ndb_optimization_delay`, which sets the number of milliseconds to wait between batches of rows being processed by `OPTIMIZE`. The default value is 10 milliseconds. It is possible to set a lower value (to a minimum of `0`), but not recommended. The maximum is 100000 milliseconds (that is, 100 seconds).

- **Implicit Rollbacks.**   Prior to MySQL Cluster NDB 6.2.17 and MySQL Cluster NDB 6.3.19, MySQL Cluster did not automatically roll back a transaction that was aborted by a duplicate key or similar error, and subsequent statements raised `ERROR 1296 (HY000): Got error 4350 'Transaction already aborted' from NDBCLUSTER`. In such cases, it was necessary to issue an explicit `ROLLBACK` statement first, and then to retry the entire transaction.

  Beginning with MySQL Cluster NDB 6.2.17 and MySQL Cluster NDB 6.3.19, this limitation has been removed; now, an error which causes a transaction to be aborted generates an implicit rollback of the entire transaction. This is logged with the warning `Storage engine NDB does not support rollback for this statement. Transaction rolled back and must be restarted`. A statement subsequent to this starts a new transaction. (Bug #32656)

  > **Note**
  >
  > The `NDBCLUSTER` storage engine does not support partial transactions or partial rollbacks of transactions in any version of MySQL Cluster.

- **Number of tables.**   Previously, the maximum number of `NDBCLUSTER` tables in a single MySQL Cluster was 1792, but this is no longer the case in MySQL 5.1 and later MySQL Cluster releases. However, the number of tables is still included in the total maximum number of `NDBCLUSTER` database objects (20320). (See Section 17.1.6.5, "Limits Associated with Database Objects in MySQL Cluster".)

- **DDL operations.**   Beginning with MySQL Cluster NDB 6.4.0, DDL operations (such as `CREATE TABLE` or `ALTER TABLE`) are protected from data node failures. Previously, if a data node failed while trying to perform one of these, the data dictionary became locked and no further DDL statements could be executed without restarting the cluster (Bug #36718).

- **Adding and dropping of data nodes.**   In MySQL Cluster NDB 6.3 and previous versions of MySQL Cluster, the online adding or dropping of data nodes was not possible; such operations required a complete shutdown and restart of the entire cluster. In MySQL Cluster NDB 7.0 (beginning with MySQL Cluster NDB 6.4.0) and later MySQL Cluster release series, it is possible to add new data nodes to a running MySQL Cluster by performing a rolling restart, so that the cluster and the data stored in it remain available to applications.

  When planning to increase the number of data nodes in the cluster online in MySQL Cluster NDB 7.0 or MySQL Cluster NDB 7.1, you should be aware of and take into account the following issues:

  - New data nodes can be added online to a MySQL Cluster only as part of a new node group.

  - New data nodes can be added online, but cannot yet be dropped online. Reducing the number of data nodes still requires a system restart of the cluster.

- As in previous MySQL Cluster releases, it is not possible to change online either the number of replicas (`NoOfReplicas` configuration parameter) or the number of data nodes per node group. These changes require a system restart.

- Redistribution of existing cluster data using the new data nodes is not automatic; however, this can be accomplished using simple SQL statements in the `mysql` client or other MySQL client application once the nodes have been added. During this procedure, it is not possible to perform DDL operations, although DML operations can continue as normal.

  The distribution of new cluster data (that is, data stored in the cluster *after* the new nodes have been added) uses the new nodes without manual intervention.

  For more information, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

- **Native support for default column values.**   Starting with MySQL Cluster NDB 7.1.0, default values for table columns are stored by `NDBCLUSTER`, rather than by the MySQL server as was previously the case. Because less data must be sent from an SQL node to the data nodes, inserts on tables having column value defaults can be performed more efficiently than before.

  Tables created using previous MySQL Cluster releases can still be used in MySQL Cluster 7.1.0 and later, although they do not support native default values and continue to use defaults supplied by the MySQL server until they are upgraded. This can be done by means of an offline `ALTER TABLE` statement.

  > **Important**
  >
  > You cannot set or change a table column's default value using an online `ALTER TABLE` operation

- **InnoDB plugin support.**   Previously, `InnoDB` support in MySQL Cluster was limited to the version built in to the MySQl Server. Beginning with MySQL Cluster NDB 7.1.9, MySQL Cluster also provides support for the `InnoDB` Plugin. See Section 17.2, "MySQL Cluster Installation and Upgrades", for information about enabling `InnoDB` storage engine and plugin support with MySQL Cluster.

- **Distribution of MySQL users and privileges.**   Previously, MySQL users and privileges created on one SQL node were unique to that SQL node, due to the fact that the MySQL grant tables were restricted to using the `MyISAM` storage engine. Beginning with MySQL Cluster NDB 7.2.0, it is possible, following installation of the MySQL Cluster software and setup of the desired users and privileges on one SQL node, to convert the grant tables to use `NDB` and thus to distribute the users and privileges across all SQL nodes connected to the cluster. You can do this by loading and making use of a set of stored procedures defined in an SQL script supplied with the MySQL Cluster distribution. For more information, see Section 17.5.14, "Distributed MySQL Privileges for MySQL Cluster".

- **Number of rows per partition.**   Previously, a single MySQL Cluster partition could hold a maximum of 46137488 rows. This limitation was removed in MySQL Cluster NDB 7.0.36 and MySQL Cluster NDB 7.1.25. (Bug #13844405, Bug #14000373)

  If you are still using a previous MySQL Cluster release, you can work around this limitation by taking advantage of the fact that the number of partitions is the same as the number of data nodes in the cluster (see Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions"). This means that, by increasing the number of data nodes, you can increase the available space for storing data.

In MySQL Cluster NDB 7.0 and later, you can increase the number of data nodes in the cluster while the cluster remains in operation. See Section 17.5.13, "Adding MySQL Cluster Data Nodes Online", for more information.

It is also possible to increase the number of partitions for `NDB` tables by using explicit `KEY` or `LINEAR KEY` partitioning (see Section 18.2.4, "KEY Partitioning").

17.2 MySQL Cluster Installation and Upgrades

This section describes the basics for planning, installing, configuring, and running a MySQL Cluster. Whereas the examples in Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1" provide more in-depth information on a variety of clustering options and configuration, the result of following the guidelines and procedures outlined here should be a usable MySQL Cluster which meets the *minimum* requirements for availability and safeguarding of data.

For information about upgrading or downgrading a MySQL Cluster between release versions, see Section 17.2.7, "Upgrading and Downgrading MySQL Cluster".

This section covers hardware and software requirements; networking issues; installation of MySQL Cluster; configuration issues; starting, stopping, and restarting the cluster; loading of a sample database; and performing queries.

Assumptions. The following sections make a number of assumptions regarding the cluster's physical and network configuration. These assumptions are discussed in the next few paragraphs.

Cluster nodes and host computers. The cluster consists of four nodes, each on a separate host computer, and each with a fixed network address on a typical Ethernet network as shown here:

Node	IP Address
Management node (`mgmd`)	192.168.0.10
SQL node (`mysqld`)	192.168.0.20
Data node "A" (`ndbd`)	192.168.0.30
Data node "B" (`ndbd`)	192.168.0.40

This may be made clearer by the following diagram:

Figure 17.4 MySQL Cluster Multi-Computer Setup
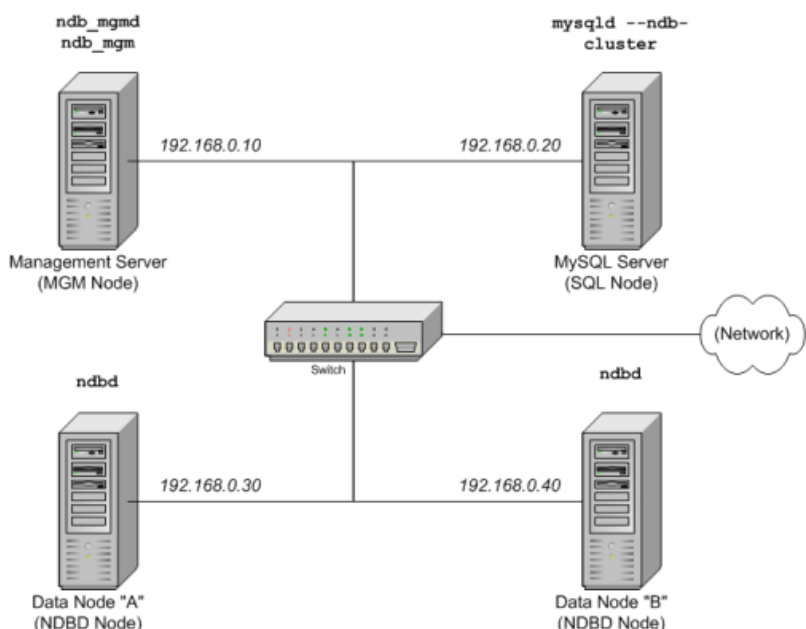
Network addressing.   In the interest of simplicity (and reliability), this *How-To* uses only numeric IP addresses. However, if DNS resolution is available on your network, it is possible to use host names in lieu of IP addresses in configuring Cluster. Alternatively, you can use the `hosts` file (typically `/etc/hosts` for Linux and other Unix-like operating systems, `C:\WINDOWS\system32\drivers\etc\hosts` on Windows, or your operating system's equivalent) for providing a means to do host lookup if such is available.

Potential hosts file issues.   A common problem when trying to use host names for Cluster nodes arises because of the way in which some operating systems (including some Linux distributions) set up the system's own host name in the `/etc/hosts` during installation. Consider two machines with the host names `ndb1` and `ndb2`, both in the `cluster` network domain. Red Hat Linux (including some derivatives such as CentOS and Fedora) places the following entries in these machines' `/etc/hosts` files:

```
#  ndb1 /etc/hosts:
127.0.0.1   ndb1.cluster ndb1 localhost.localdomain localhost
```

```
#  ndb2 /etc/hosts:
127.0.0.1   ndb2.cluster ndb2 localhost.localdomain localhost
```

SUSE Linux (including OpenSUSE) places these entries in the machines' `/etc/hosts` files:

```
#  ndb1 /etc/hosts:
127.0.0.1        localhost
127.0.0.2        ndb1.cluster ndb1
```

```
#  ndb2 /etc/hosts:
127.0.0.1        localhost
127.0.0.2        ndb2.cluster ndb2
```

In both instances, `ndb1` routes `ndb1.cluster` to a loopback IP address, but gets a public IP address from DNS for `ndb2.cluster`, while `ndb2` routes `ndb2.cluster` to a loopback address and obtains a public address for `ndb1.cluster`. The result is that each data node connects to the management server,

but cannot tell when any other data nodes have connected, and so the data nodes appear to hang while starting.

> **Caution**
>
> You cannot mix `localhost` and other host names or IP addresses in `config.ini`. For these reasons, the solution in such cases (other than to use IP addresses for *all* `config.ini HostName` entries) is to remove the fully qualified host names from `/etc/hosts` and use these in `config.ini` for all cluster hosts.

Host computer type.   Each host computer in our installation scenario is an Intel-based desktop PC running a supported operating system installed to disk in a standard configuration, and running no unnecessary services. The core operating system with standard TCP/IP networking capabilities should be sufficient. Also for the sake of simplicity, we also assume that the file systems on all hosts are set up identically. In the event that they are not, you should adapt these instructions accordingly.

Network hardware.   Standard 100 Mbps or 1 gigabit Ethernet cards are installed on each machine, along with the proper drivers for the cards, and that all four hosts are connected through a standard-issue Ethernet networking appliance such as a switch. (All machines should use network cards with the same throughput. That is, all four machines in the cluster should have 100 Mbps cards *or* all four machines should have 1 Gbps cards.) MySQL Cluster works in a 100 Mbps network; however, gigabit Ethernet provides better performance.

> **Important**
>
> MySQL Cluster is *not* intended for use in a network for which throughput is less than 100 Mbps or which experiences a high degree of latency. For this reason (among others), attempting to run a MySQL Cluster over a wide area network such as the Internet is not likely to be successful, and is not supported in production.

Sample data.   We use the `world` database which is available for download from the MySQL Web site (see http://dev.mysql.com/doc/index-other.html). We assume that each machine has sufficient memory for running the operating system, required MySQL Cluster processes, and (on the data nodes) storing the database.

For general information about installing MySQL, see Chapter 2, *Installing and Upgrading MySQL*. For information about installation of MySQL Cluster on Linux and other Unix-like operating systems, see Section 17.2.1, "Installing MySQL Cluster on Linux". For information about installation of MySQL Cluster on Windows operating systems, see Section 17.2.2, "Installing MySQL Cluster on Windows".

For general information about MySQL Cluster hardware, software, and networking requirements, see Section 17.1.3, "MySQL Cluster Hardware, Software, and Networking Requirements".

17.2.1 Installing MySQL Cluster on Linux

This section covers installation of MySQL Cluster on Linux and other Unix-like operating systems. While the next few sections refer to a Linux operating system, the instructions and procedures given there should be easily adaptable to other supported Unix-like platforms.

Beginning with MySQL Cluster NDB 7.1.3, MySQL Cluster is also supported for production use on Windows operating systems; for installation and setup instructions specific to Windows, see Section 17.2.2, "Installing MySQL Cluster on Windows".

Each MySQL Cluster host computer must have the correct executable programs installed. A host running an SQL node must have installed on it a MySQL Server binary (`mysqld`). Management nodes require the

management server daemon (`ndb_mgmd`); data nodes require the data node daemon (`ndbd`; in MySQL Cluster NDB 7.0 and later, you can use `ndbmtd` instead. It is not necessary to install the MySQL Server binary on management node hosts and data node hosts. It is recommended that you also install the management client (`ndb_mgm`) on the management server host.

Installation of MySQL Cluster on Linux can be done using precompiled binaries from Oracle (downloaded as a .tar.gz archive), with RPM packages (also available from Oracle), or from source code. All three of these installation methods are described in the section that follow.

Regardless of the method used, it is still necessary following installation of the MySQL Cluster binaries to create configuration files for all cluster nodes, before you can start the cluster. See Section 17.2.3, "Initial Configuration of MySQL Cluster".

17.2.1.1 Installing a MySQL Cluster Binary Release on Linux

This section covers the steps necessary to install the correct executables for each type of Cluster node from precompiled binaries supplied by Oracle.

For setting up a cluster using precompiled binaries, the first step in the installation process for each cluster host is to download the latest MySQL Cluster NDB 6.3, MySQL Cluster NDB 7.0, or MySQL Cluster NDB 7.1 binary archive (`mysql-cluster-gpl-6.3.55-linux-i686-glibc23.tar.gz`, `mysql-cluster-gpl-7.0.42-linux-i686-glibc23.tar.gz`, or `mysql-cluster-gpl-7.1.37-linux-i686-glibc23.tar.gz`, respectively) from the MySQL Cluster downloads area. We assume that you have placed this file in each machine's `/var/tmp` directory. (If you do require a custom binary, see Section 2.11.3, "Installing MySQL Using a Development Source Tree".)

> **Note**
>
> After completing the installation, do not yet start any of the binaries. We show you how to do so following the configuration of the nodes (see Section 17.2.3, "Initial Configuration of MySQL Cluster").

SQL nodes.   On each of the machines designated to host SQL nodes, perform the following steps as the system `root` user:

1. Check your `/etc/passwd` and `/etc/group` files (or use whatever tools are provided by your operating system for managing users and groups) to see whether there is already a `mysql` group and `mysql` user on the system. Some OS distributions create these as part of the operating system installation process. If they are not already present, create a new `mysql` user group, and then add a `mysql` user to this group:

   ```
   shell> groupadd mysql
   shell> useradd -g mysql -s /bin/false mysql
   ```

   The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix, or they may have different names such as `adduser` and `addgroup`.

2. Change location to the directory containing the downloaded file, unpack the archive, and create a symbolic link named `mysql` to the `mysql` directory. Note that the actual file and directory names vary according to the MySQL Cluster version number.

   ```
   shell> cd /var/tmp
   shell> tar -C /usr/local -xzvf mysql-cluster-gpl-7.1.37-linux-i686-glibc23.tar.gz
   shell> ln -s /usr/local/mysql-cluster-gpl-7.1.37-linux-i686-glibc23 /usr/local/mysql
   ```

3. Change location to the `mysql` directory and run the supplied script for creating the system databases:

```
shell> cd mysql
shell> scripts/mysql_install_db --user=mysql
```

4. Set the necessary permissions for the MySQL server and data directories:

```
shell> chown -R root .
shell> chown -R mysql data
shell> chgrp -R mysql .
```

5. Copy the MySQL startup script to the appropriate directory, make it executable, and set it to start when the operating system is booted up:

```
shell> cp support-files/mysql.server /etc/rc.d/init.d/
shell> chmod +x /etc/rc.d/init.d/mysql.server
shell> chkconfig --add mysql.server
```

(The startup scripts directory may vary depending on your operating system and version—for example, in some Linux distributions, it is `/etc/init.d`.)

Here we use Red Hat's `chkconfig` for creating links to the startup scripts; use whatever means is appropriate for this purpose on your platform, such as `update-rc.d` on Debian.

Remember that the preceding steps must be repeated on each machine where an SQL node is to reside.

Data nodes. Installation of the data nodes does not require the `mysqld` binary. Only the MySQL Cluster data node executable `ndbd` (single-threaded) or `ndbmtd` (multi-threaded) is required. These binaries can also be found in the `.tar.gz` archive. Again, we assume that you have placed this archive in `/var/tmp`.

As system `root` (that is, after using `sudo`, `su root`, or your system's equivalent for temporarily assuming the system administrator account's privileges), perform the following steps to install the data node binaries on the data node hosts:

1. Change location to the `/var/tmp` directory, and extract the `ndbd` and `ndbmtd` binaries from the archive into a suitable directory such as `/usr/local/bin`:

```
shell> cd /var/tmp
shell> tar -zxvf mysql-5.1.77-ndb-7.1.37-linux-i686-glibc23.tar.gz
shell> cd mysql-5.1.77-ndb-7.1.37-linux-i686-glibc23
shell> cp bin/ndbd /usr/local/bin/ndbd
shell> cp bin/ndbmtd /usr/local/bin/ndbmtd
```

(You can safely delete the directory created by unpacking the downloaded archive, and the files it contains, from `/var/tmp` once `ndb_mgm` and `ndb_mgmd` have been copied to the executables directory.)

2. Change location to the directory into which you copied the files, and then make both of them executable:

```
shell> cd /usr/local/bin
shell> chmod +x ndb*
```

The preceding steps should be repeated on each data node host.

Although only one of the data node executables is required to run a MySQL Cluster data node, we have shown you how to install both `ndbd` and `ndbmtd` in the preceding instructions. We recommend that you do

this when installing or upgrading MySQL Cluster, even if you plan to use only one of them, since this will save time and trouble in the event that you later decide to change from one to the other.

> **Note**
>
> The data directory on each machine hosting a data node is `/usr/local/mysql/data`. This piece of information is essential when configuring the management node. (See Section 17.2.3, "Initial Configuration of MySQL Cluster".)

Management nodes. Installation of the management node does not require the `mysqld` binary. Only the MySQL Cluster management server (`ndb_mgmd`) is required; you most likely want to install the management client (`ndb_mgm`) as well. Both of these binaries also be found in the `.tar.gz` archive. Again, we assume that you have placed this archive in `/var/tmp`.

As system `root`, perform the following steps to install `ndb_mgmd` and `ndb_mgm` on the management node host:

1. Change location to the `/var/tmp` directory, and extract the `ndb_mgm` and `ndb_mgmd` from the archive into a suitable directory such as `/usr/local/bin`:

   ```
   shell> cd /var/tmp
   shell> tar -zxvf mysql-5.1.77-ndb-7.1.37-linux-i686-glibc23.tar.gz
   shell> cd mysql-5.1.77-ndb-7.1.37-linux-i686-glibc23
   shell> cp bin/ndb_mgm* /usr/local/bin
   ```

   (You can safely delete the directory created by unpacking the downloaded archive, and the files it contains, from `/var/tmp` once `ndb_mgm` and `ndb_mgmd` have been copied to the executables directory.)

2. Change location to the directory into which you copied the files, and then make both of them executable:

   ```
   shell> cd /usr/local/bin
   shell> chmod +x ndb_mgm*
   ```

In Section 17.2.3, "Initial Configuration of MySQL Cluster", we create configuration files for all of the nodes in our example MySQL Cluster.

17.2.1.2 Installing MySQL Cluster from RPM

This section covers the steps necessary to install the correct executables for each type of MySQL Cluster node using RPM packages supplied by Oracle.

RPMs are available for both 32-bit and 64-bit Linux platforms. For a MySQL Cluster, three RPMs are required:

- The **Server** RPM (for example, `MySQL-Cluster-gpl-server-6.3.55-0.sles10.i586.rpm`, `MySQL-Cluster-gpl-server-7.0.42-0.sles10.i586.rpm`, or `MySQL-Cluster-gpl-server-7.1.37-0.sles10.i586.rpm`), which supplies the core files needed to run a MySQL Server with `NDBCLUSTER` storage engine support (that is, as a MySQL Cluster SQL node).

  If you do not have your own client application capable of administering a MySQL server, you should also obtain and install the **Client** RPM (for example, `MySQL-Cluster-gpl-client-6.3.55-0.sles10.i586.rpm`, `MySQL-Cluster-gpl-client-7.0.42-0.sles10.i586.rpm`, or `MySQL-Cluster-gpl-client-7.1.37-0.sles10.i586.rpm`).

- The **Cluster storage engine** RPM (for example, `MySQL-Cluster-gpl-storage-6.3.55-0.sles10.i586.rpm`, `MySQL-Cluster-gpl-storage-7.0.42-0.sles10.i586.rpm`, or `MySQL-Cluster-gpl-storage-7.1.37-0.sles10.i586.rpm`), which supplies the MySQL Cluster data node binary (`ndbd`).

- The **Cluster storage engine management RPM** (for example, `MySQL-Cluster-gpl-management-6.3.55-0.sles10.i586.rpm`, `MySQL-Cluster-gpl-management-7.0.42-0.sles10.i586.rpm`, or `MySQL-Cluster-gpl-management-7.1.37-0.sles10.i586.rpm`) which provides the MySQL Cluster management server binary (`ndb_mgmd`).

In addition, you should also obtain the **NDB Cluster - Storage engine basic tools** RPM (for example, `MySQL-Cluster-gpl-tools-6.3.55-0.sles10.i586.rpm`, `MySQL-Cluster-gpl-tools-7.0.42-0.sles10.i586.rpm`, or `MySQL-Cluster-gpl-tools-7.1.37-0.sles10.i586.rpm`), which supplies several useful applications for working with a MySQL Cluster. The most important of these is the MySQL Cluster management client (`ndb_mgm`). The **NDB Cluster - Storage engine extra tools** RPM (for example, `MySQL-Cluster-gpl-extra-6.3.55-0.sles10.i586.rpm`, `MySQL-Cluster-gpl-extra-7.0.42-0.sles10.i586.rpm`, or `MySQL-Cluster-gpl-extra-7.1.37-0.sles10.i586.rpm`) contains some additional testing and monitoring programs, but is not required to install a MySQL Cluster. (For more information about these additional programs, see Section 17.4, "MySQL Cluster Programs".)

The MySQL Cluster version number in the RPM file names (shown here as `6.3.55`, `7.0.42`, or `7.1.37`) can vary according to the version which you are actually using. *It is very important that all of the Cluster RPMs to be installed have the same version number.* The `glibc` version number (if present), and architecture designation (shown here as `i586`) should be appropriate to the machine on which the RPM is to be installed.

Data nodes.   On a computer that is to host a cluster data node it is necessary to install only the **NDB Cluster - Storage engine** RPM. To do so, copy this RPM to the data node host, and run the following command as the system root user, replacing the name shown for the RPM as necessary to match that of the RPM downloaded from the MySQL web site:

```
shell> rpm -Uhv MySQL-Cluster-gpl-storage-7.1.37-0.sles10.i586.rpm
```

The previous command installs the MySQL Cluster data node binary (`ndbd`) in the `/usr/sbin` directory.

SQL nodes.   On each machine to be used for hosting a cluster SQL node, install the **Server** RPM by executing the following command as the system root user, replacing the name shown for the RPM as necessary to match the name of the RPM downloaded from the MySQL web site:

```
shell> rpm -Uhv MySQL-Cluster-gpl-server-7.1.37-0.sles10.i586.rpm
```

This installs the MySQL server binary (`mysqld`) in the `/usr/sbin` directory, as well as all needed MySQL Server support files. It also installs the `mysql.server` and `mysqld_safe` startup scripts in `/usr/share/mysql` and `/usr/bin`, respectively. The RPM installer should take care of general configuration issues (such as creating the `mysql` user and group, if needed) automatically.

> **Note**
>
> To administer the SQL node (MySQL server), you should also install the **Client** RPM, as shown here:

```
shell> rpm -Uhv MySQL-Cluster-gpl-client-7.1.37-0.sles10.i586.rpm
```

This installs the `mysql` client program.

Management nodes.   To install the MySQL Cluster management server, it is necessary only to use the **NDB Cluster - Storage engine management** RPM. Copy this RPM to the computer intended to host the management node, and then install it by running the following command as the system root user (replace the name shown for the RPM as necessary to match that of the **Storage engine management** RPM downloaded from the MySQL web site):

```
shell> rpm -Uhv MySQL-Cluster-gpl-management-7.1.37-0.sles10.i586.rpm
```

This installs the management server binary (`ndb_mgmd`) to the `/usr/sbin` directory.

You should also install the `NDB` management client, which is supplied by the **Storage engine basic tools** RPM. Copy this RPM to the same computer as the management node, and then install it by running the following command as the system root user (again, replace the name shown for the RPM as necessary to match that of the **Storage engine basic tools** RPM downloaded from the MySQL web site):

```
shell> rpm -Uhv MySQL-Cluster-gpl-tools-7.1.37-0.sles10.i586.rpm
```

The **Storage engine basic tools** RPM installs the MySQL Cluster management client (`ndb_mgm`) to the `/usr/bin` directory.

> **Note**
>
> You can also install the **Cluster storage engine extra tools** RPM, if you wish, as shown here:
>
> ```
> shell> rpm -Uhv MySQL-Cluster-gpl-extra-7.1.37-0.sles10.i586.rpm
> ```
>
> You may find the extra tools useful; however the **Cluster storage engine extra tools** RPM is *not* required to install a working MySQL Cluster.

See Section 2.5.1, "Installing MySQL on Linux Using RPM Packages", for general information about installing MySQL using RPMs supplied by Oracle.

After installing from RPM, you still need to configure the cluster as discussed in Section 17.2.3, "Initial Configuration of MySQL Cluster".

17.2.1.3 Building MySQL Cluster from Source on Linux

This section provides information about compiling MySQL Cluster on Linux and other Unix-like platforms. Building MySQL Cluster from source is similar to building the standard MySQL Server, although it differs in a few key respects discussed here. For general information about building MySQL from source, see Section 2.11, "Installing MySQL from Source". Beginning with MySQL Cluster NDB 7.1.3, MySQL Cluster is also supported on Windows platforms, and can be built on Windows from source. For information about compiling MySQL Cluster on Windows platforms, see Section 17.2.2.2, "Compiling and Installing MySQL Cluster from Source on Windows".

Building MySQL Cluster requires using the MySQL Cluster sources. These are available from the MySQL Cluster downloads page at http://dev.mysql.com/downloads/cluster/. The archived source file should have a name similar to `mysql-cluster-gpl-6.3.55.tar.gz`, `mysql-cluster-gpl-7.0.42.tar.gz`,

or `mysql-cluster-gpl-7.1.37.tar.gz`. You can also obtain MySQL development sources from launchpad.net. Attempting to build MySQL Cluster from standard MySQL 5.1 sources is not supported.

In addition to any other `configure` options you wish to use, be sure to include `--with-plugins=ndbcluster`, `--with-plugins=max`, or , or `--with-plugins=max-no-innodb`. Either of these options causes the binaries for the management nodes, data nodes, and other MySQL Cluster programs to be built; it also causes `mysqld` to be compiled with `NDB` storage engine support.

After you have run `make && make install` (or your system's equivalent), the result is similar to what is obtained by unpacking a precompiled binary to the same location. However, the layout can differ. These differences are covered in the next few paragraphs.

Prior to MySQL Cluster NDB 7.1.9, MySQL Cluster was not compatible with the `InnoDB` Plugin; in earlier MySQL Cluster releases, only the version of `InnoDB` supplied with the MySQL Server could be used. Beginning with MySQL Cluster NDB 7.1.9, you can build MySQL Cluster with `InnoDB` storage engine or plugin support using the appropriate `--with-plugins` option for `configure`.

Management nodes.   When building from source and running the default `make install`, the management server binary (`ndb_mgmd`) is placed in `/usr/local/mysql/libexec`, while the management client binary (`ndb_mgm`) can be found in `/usr/local/mysql/bin`. Only `ndb_mgmd` is required to be present on a management node host; however, it is also a good idea to have `ndb_mgm` present on the same host machine. Neither of these executables requires a specific location on the host machine's file system.

Data nodes.   The only executable required on a data node host is `ndbd` (`mysqld`, for example, does not have to be present on the host machine). By default when doing a source build, this file is placed in the directory `/usr/local/mysql/libexec`. For installing on multiple data node hosts, only `ndbd` need be copied to the other host machine or machines. (This assumes that all data node hosts use the same architecture and operating system; otherwise you may need to compile separately for each different platform.) `ndbd` need not be in any particular location on the host's file system, as long as the location is known.

When compiling MySQL Cluster NDB 7.0 or later from source, no special options are required for building multi-threaded data node binaries. On Unix platforms, configuring the build with any of the options `--with-plugins=ndbcluster`, `--with-plugins=max`, or `--with-plugins=max-no-innodb` causes `ndbmtd` to be built automatically; `make install` places the `ndbmtd` binary in the `libexec` directory along with `mysqld`, `ndbd`, and `ndb_mgm`.

SQL nodes.   If you compile MySQL with clustering support, and perform the default installation (using `make install` as the system `root` user), `mysqld` is placed in `/usr/local/mysql/bin`. Follow the steps given in Section 2.11, "Installing MySQL from Source" to make `mysqld` ready for use. If you want to run multiple SQL nodes, you can use a copy of the same `mysqld` executable and its associated support files on several machines. The easiest way to do this is to copy the entire `/usr/local/mysql` directory and all directories and files contained within it to the other SQL node host or hosts, then repeat the steps from Section 2.11, "Installing MySQL from Source" on each machine. If you configure the build with a nondefault `--prefix`, you need to adjust the directory accordingly.

In Section 17.2.3, "Initial Configuration of MySQL Cluster", we create configuration files for all of the nodes in our example MySQL Cluster.

17.2.2 Installing MySQL Cluster on Windows

Experimental support for MySQL Cluster on Microsoft Windows operating systems was introduced in MySQL Cluster NDB 7.0. Beginning with MySQL Cluster NDB 7.1.3, production support is provided for MySQL Cluster on Windows, and MySQL Cluster binaries for Windows can be obtained from http://

dev.mysql.com/downloads/cluster/. For information about installing MySQL Cluster on Windows from a binary release provided by Oracle, see Section 17.2.2.1, "Installing MySQL Cluster on Windows from a Binary Release".

It is also possible to compile and install MySQL Cluster from source on Windows using Microsoft Visual Studio. For more information, see Section 17.2.2.2, "Compiling and Installing MySQL Cluster from Source on Windows".

17.2.2.1 Installing MySQL Cluster on Windows from a Binary Release

This section describes a basic installation of MySQL Cluster on Windows using a binary `no-install` MySQL Cluster release provided by Oracle, using the same 4-node setup outlined in the beginning of this section (see Section 17.2, "MySQL Cluster Installation and Upgrades"), as shown in the following table:

Node	IP Address
Management (MGMD) node	192.168.0.10
MySQL server (SQL) node	192.168.0.20
Data (NDBD) node "A"	192.168.0.30
Data (NDBD) node "B"	192.168.0.40

As on other platforms, the MySQL Cluster host computer running an SQL node must have installed on it a MySQL Server binary (`mysqld.exe`). You should also have the MySQL client (`mysql.exe`) on this host. For management nodes and data nodes, it is not necessary to install the MySQL Server binary; however, each management node requires the management server daemon (`ndb_mgmd.exe`); each data node requires the data node daemon (`ndbd.exe` or `ndbmtd.exe`). For this example, we refer to `ndbd.exe` as the data node executable, but you can install `ndbmtd.exe`, the multi-threaded version of this program, instead, in exactly the same way. You should also install the management client (`ndb_mgm.exe`) on the management server host. This section covers the steps necessary to install the correct Windows binaries for each type of MySQL Cluster node.

`ndbmtd.exe` was not included in MySQL Cluster NDB 7.1.3 binary releases for Windows, due to a problem with `make_win_bin_dist`. This issue was corrected in MySQL Cluster NDB 7.1.5.

> **Note**
>
> As with other Windows programs, MySQL Cluster executables are named with the `.exe` file extension. However, it is not necessary to include the `.exe` extension when invoking these programs from the command line. Therefore, we often simply refer to these programs in this documentation as `mysqld`, `mysql`, `ndb_mgmd`, and so on. You should understand that, whether we refer (for example) to `mysqld` or `mysqld.exe`, either name means the same thing (the MySQL Server program).

For setting up a MySQL Cluster using Oracles's `no-install` binaries, the first step in the installation process is to download the latest MySQL Cluster Windows binary archive from http://dev.mysql.com/downloads/cluster/. This archive has a filename of the form `mysql-cluster-gpl-noinstall-ver-winarch.zip`, where `ver` is the NDB storage engine version (such as `7.1.3`), and `arch` is the architecture (`32` for 32-bit binaries, and `64` for 64-bit binaries). For example, the MySQL Cluster NDB 7.1.3 `no-install` archive for 32-bit Windows systems is named `mysql-cluster-gpl-noinstall-7.1.3-win32.zip`.

You can run 32-bit MySQL Cluster binaries on both 32-bit and 64-bit versions of Windows; however, 64-bit MySQL Cluster binaries can be used only on 64-bit versions of Windows. If you are using a 32-bit version of Windows on a computer that has a 64-bit CPU, then you must use the 32-bit MySQL Cluster binaries.

To minimize the number of files that need to be downloaded from the Internet or copied between machines, we start with the computer where you intend to run the SQL node.

SQL node. We assume that you have placed a copy of the `no-install` archive in the directory `C:\Documents and Settings\`*`username`*`\My Documents\Downloads` on the computer having the IP address 192.168.0.20, where *`username`* is the name of the current user. (You can obtain this name using `ECHO %USERNAME%` on the command line.) To install and run MySQL Cluster executables as Windows services, this user should be a member of the `Administrators` group.

Extract all the files from the archive. The Extraction Wizard integrated with Windows Explorer is adequate for this task. (If you use a different archive program, be sure that it extracts all files and directories from the archive, and that it preserves the archive's directory structure.) When you are asked for a destination directory, enter `C:\`, which causes the Extraction Wizard to extract the archive to the directory `C:\mysql-cluster-gpl-noinstall-`*`ver`*`-`*`winarch`*. Rename this directory to `C:\mysql`.

It is possible to install the MySQL Cluster binaries to directories other than `C:\mysql\bin`; however, if you do so, you must modify the paths shown in this procedure accordingly. In particular, if the MySQL Server (SQL node) binary is installed to a location other than `C:\mysql` or `C:\Program Files\MySQL\MySQL Server 5.1`, or if the SQL node's data directory is in a location other than `C:\mysql\data` or `C:\Program Files\MySQL\MySQL Server 5.1\data`, extra configuration options must be used on the command line or added to the `my.ini` or `my.cnf` file when starting the SQL node. For more information about configuring a MySQL Server to run in a nonstandard location, see Section 2.3.6, "Installing MySQL on Microsoft Windows Using a noinstall Zip Archive".

For a MySQL Server with MySQL Cluster support to run as part of a MySQL Cluster, it must be started with the options `--ndbcluster` and `--ndb-connectstring`. While you can specify these options on the command line, it is usually more convenient to place them in an option file. To do this, create a new text file in Notepad or another text editor. Enter the following configuration information into this file:

```
[mysqld]
# Options for mysqld process:
ndbcluster                        # run NDB storage engine
ndb-connectstring=192.168.0.10  # location of management server
```

You can add other options used by this MySQL Server if desired (see Section 2.3.6.2, "Creating an Option File"), but the file must contain the options shown, at a minimum. Save this file as `C:\mysql\my.ini`. This completes the installation and setup for the SQL node.

Data nodes. A MySQL Cluster data node on a Windows host requires only a single executable, one of either `ndbd.exe` or `ndbmtd.exe`. For this example, we assume that you are using `ndbd.exe`, but the same instructions apply when using `ndbmtd.exe`. On each computer where you wish to run a data node (the computers having the IP addresses 192.168.0.30 and 192.168.0.40), create the directories `C:\mysql`, `C:\mysql\bin`, and `C:\mysql\cluster-data`; then, on the computer where you downloaded and extracted the `no-install` archive, locate `ndbd.exe` in the `C:\mysql\bin` directory. Copy this file to the `C:\mysql\bin` directory on each of the two data node hosts.

To function as part of a MySQL Cluster, each data node must be given the address or hostname of the management server. You can supply this information on the command line using the `--ndb-connectstring` or `-c` option when starting each data node process. However, it is usually preferable to put this information in an option file. To do this, create a new text file in Notepad or another text editor and enter the following text:

```
[mysql_cluster]
# Options for data node process:
```

```
ndb-connectstring=192.168.0.10   # location of management server
```

Save this file as `C:\mysql\my.ini` on the data node host. Create another text file containing the same information and save it on as `C:mysql\my.ini` on the other data node host, or copy the my.ini file from the first data node host to the second one, making sure to place the copy in the second data node's `C:\mysql` directory. Both data node hosts are now ready to be used in the MySQL Cluster, which leaves only the management node to be installed and configured.

Management node.   The only executable program required on a computer used for hosting a MySQL Cluster management node is the management server program `ndb_mgmd.exe`. However, in order to administer the MySQL Cluster once it has been started, you should also install the MySQL Cluster management client program `ndb_mgm.exe` on the same machine as the management server. Locate these two programs on the machine where you downloaded and extracted the `no-install` archive; this should be the directory `C:\mysql\bin` on the SQL node host. Create the directory `C:\mysql\bin` on the computer having the IP address 192.168.0.10, then copy both programs to this directory.

You should now create two configuration files for use by `ndb_mgmd.exe`:

1. A local configuration file to supply configuration data specific to the management node itself. Typically, this file needs only to supply the location of the MySQL Cluster global configuration file (see item 2).

    To create this file, start a new text file in Notepad or another text editor, and enter the following information:

    ```
    [mysql_cluster]
    # Options for management node process
    config-file=C:/mysql/bin/config.ini
    ```

    Save this file as the text file `C:\mysql\bin\my.ini`.

2. A global configuration file from which the management node can obtain configuration information governing the MySQL Cluster as a whole. At a minimum, this file must contain a section for each node in the MySQL Cluster, and the IP addresses or hostnames for the management node and all data nodes (`HostName` configuration parameter). It is also advisable to include the following additional information:

    *   The IP address or hostname of any SQL nodes

    *   The data memory and index memory allocated to each data node (`DataMemory` and `IndexMemory` configuration parameters)

    *   The number of replicas, using the `NoOfReplicas` configuration parameter (see Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions")

    *   The directory where each data node stores it data and log file, and the directory where the management node keeps its log files (in both cases, the `DataDir` configuration parameter)

    Create a new text file using a text editor such as Notepad, and input the following information:

    ```
    [ndbd default]
    # Options affecting ndbd processes on all data nodes:
    NoOfReplicas=2                       # Number of replicas
    DataDir=C:/mysql/cluster-data        # Directory for each data node's data files
                                         # Forward slashes used in directory path,
                                         # rather than backslashes. This is correct;
                                         # see Important note in text
    DataMemory=80M     # Memory allocated to data storage
    ```

```
IndexMemory=18M    # Memory allocated to index storage
                   # For DataMemory and IndexMemory, we have used the
                   # default values. Since the "world" database takes up
                   # only about 500KB, this should be more than enough for
                   # this example Cluster setup.

[ndb_mgmd]
# Management process options:
HostName=192.168.0.10              # Hostname or IP address of management node
DataDir=C:/mysql/bin/cluster-logs  # Directory for management node log files

[ndbd]
# Options for data node "A":
                                 # (one [ndbd] section per data node)
HostName=192.168.0.30            # Hostname or IP address

[ndbd]
# Options for data node "B":
HostName=192.168.0.40            # Hostname or IP address

[mysqld]
# SQL node options:
HostName=192.168.0.20            # Hostname or IP address
```

Save this file as the text file `C:\mysql\bin\config.ini`.

Important

A single backslash character (`\`) cannot be used when specifying directory paths in program options or configuration files used by MySQL Cluster on Windows. Instead, you must either escape each backslash character with a second backslash (`\\`), or replace the backslash with a forward slash character (`/`). For example, the following line from the `[ndb_mgmd]` section of a MySQL Cluster `config.ini` file does not work:

```
DataDir=C:\mysql\bin\cluster-logs
```

Instead, you may use either of the following:

```
DataDir=C:\\mysql\\bin\\cluster-logs  # Escaped backslashes
```

```
DataDir=C:/mysql/bin/cluster-logs     # Forward slashes
```

For reasons of brevity and legibility, we recommend that you use forward slashes in directory paths used in MySQL Cluster program options and configuration files on Windows.

17.2.2.2 Compiling and Installing MySQL Cluster from Source on Windows

Oracle provides precompiled MySQL Cluster binaries for Windows which should be adequate for most users. However, if you wish, it is also possible to compile MySQL Cluster for Windows from source code. The procedure for doing this is almost identical to the procedure used to compile the standard MySQL Server binaries for Windows, and uses the same tools. However, there are two major differences:

• To build MySQL Cluster, you must use the MySQL Cluster sources, which you can obtain from http://dev.mysql.com/downloads/cluster/.

Attempting to build MySQL Cluster from the source code for the standard MySQL Server is likely not to be successful, and is not supported by Oracle.

- You must configure the build using the `WITH_NDBCLUSTER_STORAGE_ENGINE` option in addition to any other build options you wish to use before creating the Visual Studio project files. Once you have run `configure.js` with the desired options, you can create the project files and build from them in the same manner as you do when compiling the standard MySQL Server. For more information, see Section 2.11.7, "Installing MySQL from Source on Windows".

Prior to MySQL Cluster NDB 7.1.9, MySQL Cluster was not compatible with the `InnoDB` Plugin; in earlier MySQL Cluster releases, only the version of `InnoDB` supplied with the MySQL Server could be used. Beginning with MySQL Cluster NDB 7.1.9, you can build MySQL Cluster with `InnoDB` storage engine or plugin support on Windows using `WITH_INNOBASE_STORAGE_ENGINE` with `configure.js`-

Once the build process is complete, you can create a Zip archive containing the compiled binaries by running `make_win_bin_dist`. The MySQL Cluster binaries can be found in the `bin` directory of the resulting archive, which is equivalent to the `no-install` archive, and which can be installed and configured in the same manner. For basic information about how to accomplish these tasks, see Section 17.2.2.1, "Installing MySQL Cluster on Windows from a Binary Release".

On Windows, beginning with MySQL Cluster NDB 7.0.11, using `WITH_NDBCLUSTER_STORAGE_ENGINE` with `configure.js` causes `ndbmtd.exe` to be built automatically, and to be found in the `bin` directory of the archive created by `make_win_bin_dist`. (It was not possible to build `ndbmtd.exe` on Windows prior to MySQL Cluster NDB 7.0.11.)

17.2.2.3 Initial Startup of MySQL Cluster on Windows

Once the MySQL Cluster executables and needed configuration files are in place, performing an initial start of the cluster is simply a matter of starting the MySQL Cluster executables for all nodes in the cluster. Each cluster node process must be started separately, and on the host computer where it resides. The management node should be started first, followed by the data nodes, and then finally by any SQL nodes.

1. On the management node host, issue the following command from the command line to start the management node process:

```
C:\mysql\bin> ndb_mgmd
2010-06-23 07:53:34 [MgmtSrvr] INFO -- NDB Cluster Management Server. mysql-5.1.77-ndb-7.1.37
2010-06-23 07:53:34 [MgmtSrvr] INFO -- Reading cluster configuration from 'config.ini'
```

The management node process continues to print logging output to the console. This is normal, because the management node is not running as a Windows service. (If you have used MySQL Cluster on a Unix-like platform such as Linux, you may notice that the management node's default behavior in this regard on Windows is effectively the opposite of its behavior on Unix systems, where it runs by default as a Unix daemon process. This behavior is also true of MySQL Cluster data node processes running on Windows.) For this reason, do not close the window in which `ndb_mgmd.exe` is running; doing so kills the management node process. (See Section 17.2.2.4, "Installing MySQL Cluster Processes as Windows Services", where we show how to install and run MySQL Cluster processes as Windows services.)

The required `-f` option tells the management node where to find the global configuration file (`config.ini`). The long form of this option is `--config-file`.

> **Important**
>
> A MySQL Cluster management node caches the configuration data that it reads from `config.ini`; once it has created a configuration cache, it ignores the `config.ini` file on subsequent starts unless forced to do otherwise. This means that, if the management node fails to start due to an error in this file, you must make the management node re-read `config.ini` after you have

corrected any errors in it. You can do this by starting `ndb_mgmd.exe` with the `--reload` or `--initial` option on the command line. Either of these options works to refresh the configuration cache.

It is not necessary or advisable to use either of these options in the management node's `my.ini` file.

For additional information about options which can be used with `ndb_mgmd`, see Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon", as well as Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

2. On each of the data node hosts, run the command shown here to start the data node processes:

```
C:\mysql\bin> ndbd
2010-06-23 07:53:46 [ndbd] INFO -- Configuration fetched from 'localhost:1186', generation: 1
```

In each case, the first line of output from the data node process should resemble what is shown in the preceding example, and is followed by additional lines of logging output. As with the management node process, this is normal, because the data node is not running as a Windows service. For this reason, do not close the console window in which the data node process is running; doing so kills `ndbd.exe`. (For more information, see Section 17.2.2.4, "Installing MySQL Cluster Processes as Windows Services".)

3. Do not start the SQL node yet; it cannot connect to the cluster until the data nodes have finished starting, which may take some time. Instead, in a new console window on the management node host, start the MySQL Cluster management client `ndb_mgm.exe`, which should be in `C:\mysql\bin` on the management node host. (Do not try to re-use the console window where `ndb_mgmd.exe` is running by typing **CTRL+C**, as this kills the management node.) The resulting output should look like this:

```
C:\mysql\bin> ndb_mgm
-- NDB Cluster -- Management Client --
ndb_mgm>
```

When the prompt `ndb_mgm>` appears, this indicates that the management client is ready to receive MySQL Cluster management commands. You can observe the status of the data nodes as they start by entering `ALL STATUS` at the management client prompt. This command causes a running report of the data nodes's startup sequence, which should look something like this:

```
ndb_mgm> ALL STATUS
Connected to Management Server at: localhost:1186
Node 2: starting (Last completed phase 3) (mysql-5.1.77-ndb-7.1.37)
Node 3: starting (Last completed phase 3) (mysql-5.1.77-ndb-7.1.37)

Node 2: starting (Last completed phase 4) (mysql-5.1.77-ndb-7.1.37)
Node 3: starting (Last completed phase 4) (mysql-5.1.77-ndb-7.1.37)

Node 2: Started (version 7.1.37)
Node 3: Started (version 7.1.37)

ndb_mgm>
```

Note

Commands issued in the management client are not case-sensitive; we use uppercase as the canonical form of these commands, but you are not required to observe this convention when inputting them into the `ndb_mgm` client. For more information, see Section 17.5.2, "Commands in the MySQL Cluster Management Client".

The output produced by `ALL STATUS` is likely to vary from what is shown here, according to the speed at which the data nodes are able to start, the release version number of the MySQL Cluster software you are using, and other factors. What is significant is that, when you see that both data nodes have started, you are ready to start the SQL node.

You can leave `ndb_mgm.exe` running; it has no negative impact on the performance of the MySQL Cluster, and we use it in the next step to verify that the SQL node is connected to the cluster after you have started it.

4. On the computer designated as the SQL node host, open a console window and navigate to the directory where you unpacked the MySQL Cluster binaries (if you are following our example, this is `C:\mysql\bin`).

   Start the SQL node by invoking `mysqld.exe` from the command line, as shown here:

   ```
   C:\mysql\bin> mysqld --console
   ```

   The `--console` option causes logging information to be written to the console, which can be helpful in the event of problems. (Once you are satisfied that the SQL node is running in a satisfactory manner, you can stop it and restart it out without the `--console` option, so that logging is performed normally.)

   In the console window where the management client (`ndb_mgm.exe`) is running on the management node host, enter the `SHOW` command, which should produce output similar to what is shown here:

   ```
   ndb_mgm> SHOW
   Connected to Management Server at: localhost:1186
   Cluster Configuration
   ---------------------
   [ndbd(NDB)]     2 node(s)
   id=2    @192.168.0.30  (Version: 5.1.77-ndb-7.1.37, Nodegroup: 0, *)
   id=3    @192.168.0.40  (Version: 5.1.77-ndb-7.1.37, Nodegroup: 0)

   [ndb_mgmd(MGM)] 1 node(s)
   id=1    @192.168.0.10  (Version: 5.1.77-ndb-7.1.37)

   [mysqld(API)]   1 node(s)
   id=4    @192.168.0.20  (Version: 5.1.77-ndb-7.1.37)
   ```

   You can also verify that the SQL node is connected to the MySQL Cluster in the `mysql` client (`mysql.exe`) using the `SHOW ENGINE NDB STATUS` statement.

You should now be ready to work with database objects and data using MySQL Cluster's `NDBCLUSTER` storage engine. See Section 17.2.5, "MySQL Cluster Example with Tables and Data", for more information and examples.

Beginning with MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5, you can install `ndb_mgmd.exe`, `ndbd.exe`, and `ndbmtd.exe` as Windows services. For information on how to do this, see Section 17.2.2.4, "Installing MySQL Cluster Processes as Windows Services").

17.2.2.4 Installing MySQL Cluster Processes as Windows Services

Once you are satisfied that MySQL Cluster is running as desired, you can—beginning with MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5—install the management nodes and data nodes as Windows services, so that these processes are started and stopped automatically whenever Windows is started or stopped. This also makes it possible to control these processes from the command line with the appropriate `NET START` or `NET STOP` command, or using the Windows graphical `Services` utility.

Installing programs as Windows services usually must be done using an account that has Administrator rights on the system.

To install the management node as a service on Windows, invoke `ndb_mgmd.exe` from the command line on the machine hosting the management node, using the `--install` option, as shown here:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --install
Installing service 'MySQL Cluster Management Server'
  as '"C:\mysql\bin\ndbd.exe" "--service=ndb_mgmd"'
Service successfully installed.
```

Important

When installing a MySQL Cluster program as a Windows service, you should always specify the complete path; otherwise the service installation may fail with the error `The system cannot find the file specified`.

The `--install` option must be used first, ahead of any other options that might be specified for `ndb_mgmd.exe`. However, it is preferable to specify such options in an options file instead. If your options file is not in one of the default locations as shown in the output of `ndb_mgmd.exe --help`, you can specify the location using the `--config-file` option.

Now you should be able to start and stop the management server like this:

```
C:\> NET START ndb_mgmd
The MySQL Cluster Management Server service is starting.
The MySQL Cluster Management Server service was started successfully.

C:\> NET STOP ndb_mgmd
The MySQL Cluster Management Server service is stopping..
The MySQL Cluster Management Server service was stopped successfully.
```

You can also start or stop the management server as a Windows service using the descriptive name, as shown here:

```
C:\> NET START 'MySQL Cluster Management Server'
The MySQL Cluster Management Server service is starting.
The MySQL Cluster Management Server service was started successfully.

C:\> NET STOP  'MySQL Cluster Management Server'
The MySQL Cluster Management Server service is stopping..
The MySQL Cluster Management Server service was stopped successfully.
```

However, it is usually simpler to specify a short service name or to permit the default service name to be used when installing the service, and then reference that name when starting or stopping the service. To specify a service name other than `ndb_mgmd`, append it to the `--install` option, as shown in this example:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --install=mgmd1
Installing service 'MySQL Cluster Management Server'
      as '"C:\mysql\bin\ndb_mgmd.exe" "--service=mgmd1"'
Service successfully installed.
```

Now you should be able to start or stop the service using the name you have specified, like this:

```
C:\> NET START mgmd1
```

```
The MySQL Cluster Management Server service is starting.
The MySQL Cluster Management Server service was started successfully.

C:\> NET STOP mgmd1
The MySQL Cluster Management Server service is stopping..
The MySQL Cluster Management Server service was stopped successfully.
```

To remove the management node service, invoke `ndb_mgmd.exe` with the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --remove
Removing service 'MySQL Cluster Management Server'
Service successfully removed.
```

If you installed the service using a service name other than the default, you can remove the service by passing this name as the value of the `--remove` option, like this:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --remove=mgmd1
Removing service 'mgmd1'
Service successfully removed.
```

Installation of a MySQL Cluster data node process as a Windows service can be done in a similar fashion, using the `--install` option for `ndbd.exe` (or `ndbmtd.exe`), as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --install
Installing service 'MySQL Cluster Data Node Daemon' as '"C:\mysql\bin\ndbd.exe" "--service=ndbd"'
Service successfully installed.
```

Now you can start or stop the data node using either the default service name or the descriptive name with `net start` or `net stop`, as shown in the following example:

```
C:\> NET START ndbd
The MySQL Cluster Data Node Daemon service is starting.
The MySQL Cluster Data Node Daemon service was started successfully.

C:\> NET STOP ndbd
The MySQL Cluster Data Node Daemon service is stopping..
The MySQL Cluster Data Node Daemon service was stopped successfully.

C:\> NET START 'MySQL Cluster Data Node Daemon'
The MySQL Cluster Data Node Daemon service is starting.
The MySQL Cluster Data Node Daemon service was started successfully.

C:\> NET STOP 'MySQL Cluster Data Node Daemon'
The MySQL Cluster Data Node Daemon service is stopping..
The MySQL Cluster Data Node Daemon service was stopped successfully.
```

To remove the data node service, invoke `ndbd.exe` with the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --remove
Removing service 'MySQL Cluster Data Node Daemon'
Service successfully removed.
```

As with `ndb_mgmd.exe` (and `mysqld.exe`), when installing `ndbd.exe` as a Windows service, you can also specify a name for the service as the value of `--install`, and then use it when starting or stopping the service, like this:

```
C:\> C:\mysql\bin\ndbd.exe --install=dnode1
Installing service 'dnode1' as '"C:\mysql\bin\ndbd.exe" "--service=dnode1"'
Service successfully installed.

C:\> NET START dnode1
The MySQL Cluster Data Node Daemon service is starting.
The MySQL Cluster Data Node Daemon service was started successfully.

C:\> NET STOP dnode1
The MySQL Cluster Data Node Daemon service is stopping..
The MySQL Cluster Data Node Daemon service was stopped successfully.
```

If you specified a service name when installing the data node service, you can use this name when removing it as well, by passing it as the value of the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --remove=dnode1
Removing service 'dnode1'
Service successfully removed.
```

Installation of the SQL node as a Windows service, starting the service, stopping the service, and removing the service are done in a similar fashion, using `mysqld --install`, `NET START`, `NET STOP`, and `mysqld --remove`. For additional information, see Section 2.3.6.7, "Starting MySQL Server as a Microsoft Windows Service".

17.2.3 Initial Configuration of MySQL Cluster

For our four-node, four-host MySQL Cluster, it is necessary to write four configuration files, one per node host.

- Each data node or SQL node requires a `my.cnf` file that provides two pieces of information: a *connection string* that tells the node where to find the management node, and a line telling the MySQL server on this host (the machine hosting the data node) to enable the `NDBCLUSTER` storage engine.

  For more information on connection strings, see Section 17.3.3.3, "MySQL Cluster Connection Strings".

- The management node needs a `config.ini` file telling it how many replicas to maintain, how much memory to allocate for data and indexes on each data node, where to find the data nodes, where to save data to disk on each data node, and where to find any SQL nodes.

Configuring the data nodes and SQL nodes.   The `my.cnf` file needed for the data nodes is fairly simple. The configuration file should be located in the `/etc` directory and can be edited using any text editor. (Create the file if it does not exist.) For example:

```
shell> vi /etc/my.cnf
```

Note

We show `vi` being used here to create the file, but any text editor should work just as well.

For each data node and SQL node in our example setup, `my.cnf` should look like this:

```
[mysqld]
# Options for mysqld process:
ndbcluster                      # run NDB storage engine

[mysql_cluster]
```

```
# Options for MySQL Cluster processes:
ndb-connectstring=192.168.0.10  # location of management server
```

After entering the preceding information, save this file and exit the text editor. Do this for the machines hosting data node "A", data node "B", and the SQL node.

> **Important**
>
> Once you have started a `mysqld` process with the `ndbcluster` and `ndb-connectstring` parameters in the `[mysqld]` and `[mysql_cluster]` sections of the `my.cnf` file as shown previously, you cannot execute any `CREATE TABLE` or `ALTER TABLE` statements without having actually started the cluster. Otherwise, these statements will fail with an error. This is by design.

Configuring the management node.   The first step in configuring the management node is to create the directory in which the configuration file can be found and then to create the file itself. For example (running as `root`):

```
shell> mkdir /var/lib/mysql-cluster
shell> cd /var/lib/mysql-cluster
shell> vi config.ini
```

For our representative setup, the `config.ini` file should read as follows:

```
[ndbd default]
# Options affecting ndbd processes on all data nodes:
NoOfReplicas=2     # Number of replicas
DataMemory=80M     # How much memory to allocate for data storage
IndexMemory=18M    # How much memory to allocate for index storage
                   # For DataMemory and IndexMemory, we have used the
                   # default values. Since the "world" database takes up
                   # only about 500KB, this should be more than enough for
                   # this example Cluster setup.

[tcp default]
# TCP/IP options:
portnumber=2202    # This the default; however, you can use any
                   # port that is free for all the hosts in the cluster
                   # Note: It is recommended that you do not specify the port
                   # number at all and simply allow the default value to be used
                   # instead

[ndb_mgmd]
# Management process options:
hostname=192.168.0.10           # Hostname or IP address of MGM node
datadir=/var/lib/mysql-cluster  # Directory for MGM node log files

[ndbd]
# Options for data node "A":
                                # (one [ndbd] section per data node)
hostname=192.168.0.30           # Hostname or IP address
datadir=/usr/local/mysql/data   # Directory for this data node's data files

[ndbd]
# Options for data node "B":
hostname=192.168.0.40           # Hostname or IP address
datadir=/usr/local/mysql/data   # Directory for this data node's data files

[mysqld]
# SQL node options:
hostname=192.168.0.20           # Hostname or IP address
                                # (additional mysqld connections can be
```

```
                              # specified for this node for various
                              # purposes such as running ndb_restore)
```

> **Note**
>
> The `world` database can be downloaded from http://dev.mysql.com/doc/index-other.html.

After all the configuration files have been created and these minimal options have been specified, you are ready to proceed with starting the cluster and verifying that all processes are running. We discuss how this is done in Section 17.2.4, "Initial Startup of MySQL Cluster".

For more detailed information about the available MySQL Cluster configuration parameters and their uses, see Section 17.3.3, "MySQL Cluster Configuration Files", and Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1". For configuration of MySQL Cluster as relates to making backups, see Section 17.5.3.3, "Configuration for MySQL Cluster Backups".

> **Note**
>
> The default port for Cluster management nodes is 1186; the default port for data nodes is 2202. However, the cluster can automatically allocate ports for data nodes from those that are already free.

17.2.4 Initial Startup of MySQL Cluster

Starting the cluster is not very difficult after it has been configured. Each cluster node process must be started separately, and on the host where it resides. The management node should be started first, followed by the data nodes, and then finally by any SQL nodes:

1. On the management host, issue the following command from the system shell to start the management node process:

   ```
   shell> ndb_mgmd -f /var/lib/mysql-cluster/config.ini
   ```

   ndb_mgmd must be told where to find its configuration file, using the `-f` or `--config-file` option. (See Section 17.4.4, "ndb_mgmd — The MySQL Cluster Management Server Daemon", for details.)

   For additional options which can be used with ndb_mgmd, see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

2. On each of the data node hosts, run this command to start the ndbd process:

   ```
   shell> ndbd
   ```

3. If you used RPM files to install MySQL on the cluster host where the SQL node is to reside, you can (and should) use the supplied startup script to start the MySQL server process on the SQL node.

If all has gone well, and the cluster has been set up correctly, the cluster should now be operational. You can test this by invoking the ndb_mgm management node client. The output should look like that shown here, although you might see some slight differences in the output depending upon the exact version of MySQL that you are using:

```
shell> ndb_mgm
-- NDB Cluster -- Management Client --
```

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=2    @192.168.0.30  (Version: 5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=3    @192.168.0.40  (Version: 5.1.77-ndb-7.1.37, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=1    @192.168.0.10  (Version: 5.1.77-ndb-7.1.37)

[mysqld(API)]   1 node(s)
id=4    @192.168.0.20  (Version: 5.1.77-ndb-7.1.37)
```

The SQL node is referenced here as `[mysqld(API)]`, which reflects the fact that the `mysqld` process is acting as a MySQL Cluster API node.

> **Note**
>
> The IP address shown for a given MySQL Cluster SQL or other API node in the output of `SHOW` is the address used by the SQL or API node to connect to the cluster data nodes, and not to any management node.

You should now be ready to work with databases, tables, and data in MySQL Cluster. See Section 17.2.5, "MySQL Cluster Example with Tables and Data", for a brief discussion.

17.2.5 MySQL Cluster Example with Tables and Data

> **Note**
>
> The information in this section applies to MySQL Cluster running on both Unix and Windows platforms.

Working with database tables and data in MySQL Cluster is not much different from doing so in standard MySQL. There are two key points to keep in mind:

- For a table to be replicated in the cluster, it must use the `NDBCLUSTER` storage engine. To specify this, use the `ENGINE=NDBCLUSTER` or `ENGINE=NDB` option when creating the table:

  ```
  CREATE TABLE tbl_name (col_name column_definitions) ENGINE=NDBCLUSTER;
  ```

  Alternatively, for an existing table that uses a different storage engine, use `ALTER TABLE` to change the table to use `NDBCLUSTER`:

  ```
  ALTER TABLE tbl_name ENGINE=NDBCLUSTER;
  ```

- Every `NDBCLUSTER` table has a primary key. If no primary key is defined by the user when a table is created, the `NDBCLUSTER` storage engine automatically generates a hidden one. Such a key takes up space just as does any other table index. (It is not uncommon to encounter problems due to insufficient memory for accommodating these automatically created indexes.)

If you are importing tables from an existing database using the output of `mysqldump`, you can open the SQL script in a text editor and add the `ENGINE` option to any table creation statements, or replace any existing `ENGINE` options. Suppose that you have the `world` sample database on another MySQL server that does not support MySQL Cluster, and you want to export the `City` table:

```
shell> mysqldump --add-drop-table world City > city_table.sql
```

The resulting `city_table.sql` file will contain this table creation statement (and the `INSERT` statements necessary to import the table data):

```
DROP TABLE IF EXISTS `City`;
CREATE TABLE `City` (
  `ID` int(11) NOT NULL auto_increment,
  `Name` char(35) NOT NULL default '',
  `CountryCode` char(3) NOT NULL default '',
  `District` char(20) NOT NULL default '',
  `Population` int(11) NOT NULL default '0',
  PRIMARY KEY  (`ID`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1;

INSERT INTO `City` VALUES (1,'Kabul','AFG','Kabol',1780000);
INSERT INTO `City` VALUES (2,'Qandahar','AFG','Qandahar',237500);
INSERT INTO `City` VALUES (3,'Herat','AFG','Herat',186800);
(remaining INSERT statements omitted)
```

You need to make sure that MySQL uses the `NDBCLUSTER` storage engine for this table. There are two ways that this can be accomplished. One of these is to modify the table definition *before* importing it into the Cluster database. Using the `City` table as an example, modify the `ENGINE` option of the definition as follows:

```
DROP TABLE IF EXISTS `City`;
CREATE TABLE `City` (
  `ID` int(11) NOT NULL auto_increment,
  `Name` char(35) NOT NULL default '',
  `CountryCode` char(3) NOT NULL default '',
  `District` char(20) NOT NULL default '',
  `Population` int(11) NOT NULL default '0',
  PRIMARY KEY  (`ID`)
) ENGINE=NDBCLUSTER DEFAULT CHARSET=latin1;

INSERT INTO `City` VALUES (1,'Kabul','AFG','Kabol',1780000);
INSERT INTO `City` VALUES (2,'Qandahar','AFG','Qandahar',237500);
INSERT INTO `City` VALUES (3,'Herat','AFG','Herat',186800);
(remaining INSERT statements omitted)
```

This must be done for the definition of each table that is to be part of the clustered database. The easiest way to accomplish this is to do a search-and-replace on the file that contains the definitions and replace all instances of `TYPE=`*engine_name* or `ENGINE=`*engine_name* with `ENGINE=NDBCLUSTER`. If you do not want to modify the file, you can use the unmodified file to create the tables, and then use `ALTER TABLE` to change their storage engine. The particulars are given later in this section.

Assuming that you have already created a database named `world` on the SQL node of the cluster, you can then use the `mysql` command-line client to read `city_table.sql`, and create and populate the corresponding table in the usual manner:

```
shell> mysql world < city_table.sql
```

It is very important to keep in mind that the preceding command must be executed on the host where the SQL node is running (in this case, on the machine with the IP address `192.168.0.20`).

To create a copy of the entire `world` database on the SQL node, use `mysqldump` on the noncluster server to export the database to a file named `world.sql`; for example, in the `/tmp` directory. Then modify the table definitions as just described and import the file into the SQL node of the cluster like this:

```
shell> mysql world < /tmp/world.sql
```

If you save the file to a different location, adjust the preceding instructions accordingly.

Running SELECT queries on the SQL node is no different from running them on any other instance of a MySQL server. To run queries from the command line, you first need to log in to the MySQL Monitor in the usual way (specify the root password at the Enter password: prompt):

```
shell> mysql -u root -p
Enter password:
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 1 to server version: 5.1.77-ndb-7.1.37

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql>
```

We simply use the MySQL server's root account and assume that you have followed the standard security precautions for installing a MySQL server, including setting a strong root password. For more information, see Section 2.12.4, "Securing the Initial MySQL Accounts".

It is worth taking into account that Cluster nodes do *not* make use of the MySQL privilege system when accessing one another. Setting or changing MySQL user accounts (including the root account) effects only applications that access the SQL node, not interaction between nodes. See Section 17.5.11.2, "MySQL Cluster and MySQL Privileges", for more information.

If you did not modify the ENGINE clauses in the table definitions prior to importing the SQL script, you should run the following statements at this point:

```
mysql> USE world;
mysql> ALTER TABLE city ENGINE=NDBCLUSTER;
mysql> ALTER TABLE country ENGINE=NDBCLUSTER;
mysql> ALTER TABLE countrylanguage ENGINE=NDBCLUSTER;
```

Selecting a database and running a SELECT query against a table in that database is also accomplished in the usual manner, as is exiting the MySQL Monitor:

```
mysql> USE world;
mysql> SELECT Name, Population FROM city ORDER BY Population DESC LIMIT 5;
+-----------+------------+
| Name      | Population |
+-----------+------------+
| Bombay    |   10500000 |
| Seoul     |    9981619 |
| São Paulo |    9968485 |
| Shanghai  |    9696300 |
| Jakarta   |    9604900 |
+-----------+------------+
5 rows in set (0.34 sec)

mysql> \q
Bye

shell>
```

Applications that use MySQL can employ standard APIs to access NDB tables. It is important to remember that your application must access the SQL node, and not the management or data nodes. This brief

example shows how we might execute the `SELECT` statement just shown by using the PHP 5.X `mysqli` extension running on a Web server elsewhere on the network:

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
  "http://www.w3.org/TR/html4/loose.dtd">
<html>
<head>
  <meta http-equiv="Content-Type"
          content="text/html; charset=iso-8859-1">
  <title>SIMPLE mysqli SELECT</title>
</head>
<body>
<?php
  # connect to SQL node:
  $link = new mysqli('192.168.0.20', 'root', 'root_password', 'world');
  # parameters for mysqli constructor are:
  #   host, user, password, database

  if( mysqli_connect_errno() )
    die("Connect failed: " . mysqli_connect_error());

  $query = "SELECT Name, Population
            FROM City
            ORDER BY Population DESC
            LIMIT 5";

  # if no errors...
  if( $result = $link->query($query) )
  {
?>
<table border="1" width="40%" cellpadding="4" cellspacing ="1">
  <tbody>
  <tr>
    <th width="10%">City</th>
    <th>Population</th>
  </tr>
<?
    # then display the results...
    while($row = $result->fetch_object())
      printf("<tr>\n  <td align=\"center\">%s</td><td>%d</td>\n</tr>\n",
              $row->Name, $row->Population);
?>
  </tbody
</table>
<?
  # ...and verify the number of rows that were retrieved
    printf("<p>Affected rows: %d</p>\n", $link->affected_rows);
  }
  else
    # otherwise, tell us what went wrong
    echo mysqli_error();

  # free the result set and the mysqli connection object
  $result->close();
  $link->close();
?>
</body>
</html>
```

We assume that the process running on the Web server can reach the IP address of the SQL node.

In a similar fashion, you can use the MySQL C API, Perl-DBI, Python-mysql, or MySQL Connectors to perform the tasks of data definition and manipulation just as you would normally with MySQL.

17.2.6 Safe Shutdown and Restart of MySQL Cluster

To shut down the cluster, enter the following command in a shell on the machine hosting the management node:

```
shell> ndb_mgm -e shutdown
```

The `-e` option here is used to pass a command to the `ndb_mgm` client from the shell. (See Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs", for more information about this option.) The command causes the `ndb_mgm`, `ndb_mgmd`, and any `ndbd` or `ndbmtd` processes to terminate gracefully. Any SQL nodes can be terminated using `mysqladmin shutdown` and other means. On Windows platforms, assuming that you have installed the SQL node as a Windows service, you can use `NET STOP MYSQL`.

To restart the cluster on Unix platforms, run these commands:

* On the management host (`192.168.0.10` in our example setup):

  ```
  shell> ndb_mgmd -f /var/lib/mysql-cluster/config.ini
  ```

* On each of the data node hosts (`192.168.0.30` and `192.168.0.40`):

  ```
  shell> ndbd
  ```

* Use the `ndb_mgm` client to verify that both data nodes have started successfully.

* On the SQL host (`192.168.0.20`):

  ```
  shell> mysqld_safe &
  ```

On Windows platforms, assuming that you have installed all MySQL Cluster processes as Windows services using the default service names (see Section 17.2.2.4, "Installing MySQL Cluster Processes as Windows Services"), you can restart the cluster as follows:

* On the management host (`192.168.0.10` in our example setup), execute the following command:

  ```
  C:\> NET START ndb_mgmd
  ```

* On each of the data node hosts (`192.168.0.30` and `192.168.0.40`), execute the following command:

  ```
  C:\> NET START ndbd
  ```

* On the management node host, use the `ndb_mgm` client to verify that the management node and both data nodes have started successfully (see Section 17.2.2.3, "Initial Startup of MySQL Cluster on Windows").

* On the SQL node host (`192.168.0.20`), execute the following command:

  ```
  C:\> NET START mysql
  ```

In a production setting, it is usually not desirable to shut down the cluster completely. In many cases, even when making configuration changes, or performing upgrades to the cluster hardware or software (or both), which require shutting down individual host machines, it is possible to do so without shutting down the cluster as a whole by performing a *rolling restart* of the cluster. For more information about doing this, see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster".

17.2.7 Upgrading and Downgrading MySQL Cluster

This section provides information about MySQL Cluster software and table file compatibility between MySQL 5.1.23 and earlier, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x releases with regard to performing upgrades and downgrades as well as compatibility matrices and notes. You are expected already to be familiar with installing and configuring a MySQL Cluster prior to attempting an upgrade or downgrade. See Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1".

For information regarding the rolling restart procedure used to perform an online upgrade, see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster".

> **Important**
>
> Only compatibility between MySQL versions with regard to `NDBCLUSTER` is taken into account in this section, and there are likely other issues to be considered. *As with any other MySQL software upgrade or downgrade, you are strongly encouraged to review the relevant portions of the MySQL Manual for the MySQL versions from which and to which you intend to migrate, before attempting an upgrade or downgrade of the MySQL Cluster software.* See Section 2.13.1, "Upgrading MySQL".

For information about upgrades and downgrades to, from, and between different releases of MySQL Cluster NDB 7.0 and MySQL Cluster NDB 7.1, see Section 17.2.7.1, "Upgrade and downgrade compatibility: MySQL Cluster NDB 7.x".

For information about upgrades and downgrades to, from, and between different releases of MySQL Cluster NDB 6.1, MySQL Cluster NDB 6.2, and MySQL Cluster NDB 6.3, see Section 17.2.7.2, "Upgrade and Downgrade Compatibility: MySQL Cluster NDB 6.x".

For information about upgrades and downgrades to, from, and between different releases of MySQL Cluster NDB 7.2, see Upgrading and Downgrading MySQL Cluster NDB 7.2.

For information about upgrades and downgrades to, from, and between different editions of MySQL Cluster as found in standard MySQL 5.1.23 and earlier releases, see Section 17.2.7.3, "Upgrade and downgrade compatibility: MySQL 5.1".

> **Important**
>
> Only compatibility between MySQL versions with regard to `NDBCLUSTER` is taken into account in this section, and there are likely other issues to be considered. *As with any other MySQL software upgrade or downgrade, you are strongly encouraged to review the relevant portions of the MySQL Manual for the MySQL versions from which and to which you intend to migrate, before attempting an upgrade or downgrade of the MySQL Cluster software.* See Section 2.13.1, "Upgrading MySQL".

17.2.7.1 Upgrade and downgrade compatibility: MySQL Cluster NDB 7.x

The table shown here provides information on MySQL Cluster upgrade and downgrade compatibility among different releases of MySQL Cluster NDB 7.0 and 7.1. Additional notes about upgrades and downgrades to, from, or within the MySQL Cluster NDB 7.x release series can be found immediately following the table.

Figure 17.5 MySQL Cluster Upgrade and Downgrade compatibility, MySQL Cluster NDB 7.x
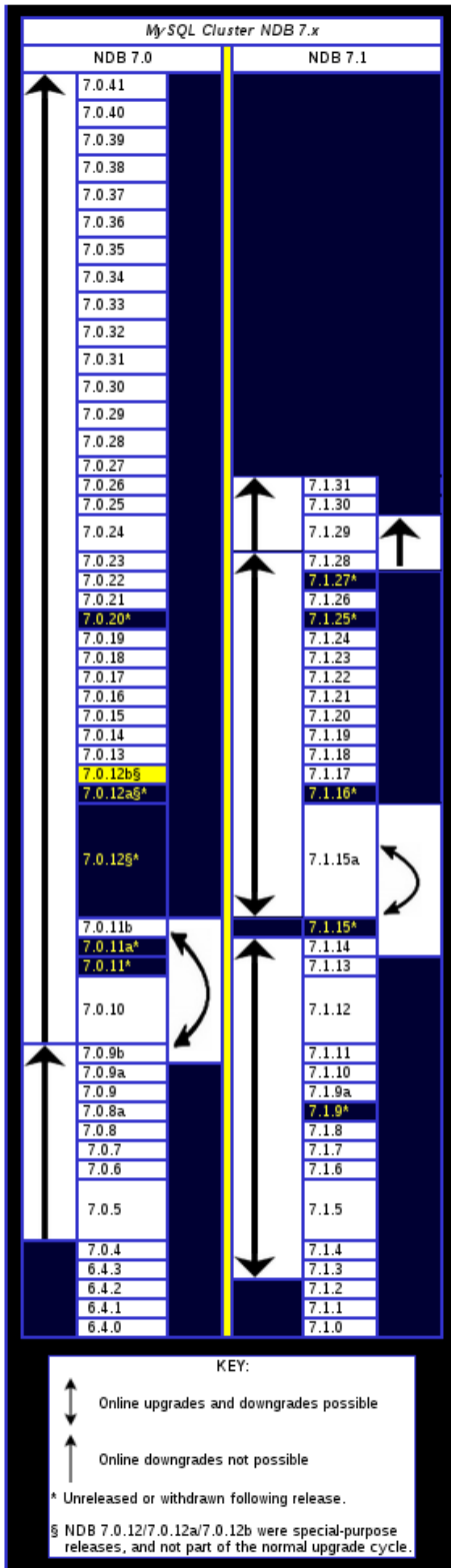
Notes: MySQL Cluster NDB 7.x

Versions supported.   Online upgrades from any MySQL Cluster NDB 7.0 release up to and including MySQL Cluster NDB 7.0.4 (as well as all early releases numbered NDB 6.4.x) to MySQL Cluster NDB 7.0.5 or later are not possible. Upgrades to MySQL Cluster NDB 7.0.6 or later from MySQL Cluster NDB 6.3.8 or a later MySQL Cluster NDB 6.3 release, or from MySQL Cluster NDB 7.0.5 or later, are supported. (Bug #44294)

Upgrading ndbd to ndbmtd.   When upgrading online from a MySQL Cluster NDB 6.3 release to a MySQL Cluster NDB 7.0 (or later) release, you should not try to upgrade the data nodes from `ndbd` to `ndbmtd` at the same time. Instead, perform the upgrade using the new `ndbd` executable (from the MySQL Cluster NDB 7.0 or later distribution to which you are upgrading) to replace the one in use on the data nodes. Once the version upgrade is complete, you can perform a second (online) upgrade to replace the data node executables with `ndbmtd` from the newer distribution. Changing the data node binary type should not be an issue when upgrading from MySQL Cluster NDB 7.0 or later version.

Changes in default values.   In MySQL Cluster NDB 7.0.4, the default values for a number of MySQL Cluster configuration parameters relating to memory usage and buffering changed (see http:// dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-5-1-32-ndb-7-0-4.html, for a list of the parameters whose defaults changed). For this reason, you may encounter issues if you try to use a configuration that does not explicitly define each of these buffers (because it was developed for a previous version of MySQL Cluster), `SendBufferMemory` and `ReceiveBufferMemory` in particular.

Other known issues include the following:

- Prior to MySQL Cluster NDB 7.0.7, DML statements failed if executed while performing an online upgrade from a MySQL Cluster NDB 6.3 release. (Bug #45917)

- Following an upgrade from any MySQL Cluster NDB 6.3.x release to MySQL Cluster NDB 7.0.6, DDL and backup operations failed. This issue was resolved in MySQL Cluster NDB 7.0.7. (Bug #46494, Bug #46563)

- In some cases, there could be problems with online upgrades from MySQL Cluster NDB 6.3 releases to MySQL Cluster NDB 7.0 releases due to a previous change in the signalling format used between nodes. This issue was corrected in MySQL Cluster NDB 7.0.9.

- Once an `NDB` table had an `ALTER ONLINE TABLE` operation performed on it using a MySQL Cluster NDB 6.3.x release, it could not be upgraded online to MySQL Cluster NDB 7.0. This issue was resolved in MySQL Cluster NDB 7.0.8. (See Bug #47542.)

- Following an upgrade from MySQL Cluster NDB 6.3 to MySQL Cluster NDB 7.0, if there were any tables having unique indexes prior to the upgrade, attempts to create unique indexes failed. This could also occur when performing offline `ALTER TABLE` operations on tables having indexes that were not dropped as a result of the `ALTER TABLE`. This issue was due to a change in the way that `NDB` tracked unique indexes internally, and was resolved in MySQL Cluster NDB 7.0.9. (Bug #48416)

  For upgrades to MySQL Cluster NDB 7.0 releases prior to version 7.0.9, a workaround is available: Following the upgrade, execute a *second* rolling restart of the cluster before performing any `ALTER TABLE` operations involving indexes.

- Due to an issue discovered after the release of MySQL Cluster NDB 7.0.10 (Bug #50433), it is not possible to perform an online upgrade from MySQL Cluster NDB 7.0.9b and earlier MySQL Cluster NDB 7.0 releases to MySQL Cluster NDB 7.0.10. Instead, you should upgrade your MySQL Cluster NDB 7.0 installation directly to MySQL Cluster NDB 7.0.11 or later.

This issue did not appear to affect MySQL Cluster NDB 6.3, and it should be possible to upgrade online from MySQL Cluster NDB 6.3 to MySQL Cluster NDB 7.0.10 without any problems other than those noted previously.

- It was not possible to perform an online upgrade from a MySQL Cluster NDB 6.3 or 7.0 release to MySQL Cluster NDB 7.1.0 or 7.1.1. This issue was fixed in MySQL Cluster NDB 7.1.2 (see Bug #51429).

- Following an upgrade to MySQL Cluster NDB 7.0.15 or later (MySQL Cluster NDB 7.0), or to MySQL Cluster NDB 7.1.4 or later (MySQL Cluster NDB 7.1), a table created in a previous version of MySQL Cluster does *not* automatically support `NDB`-native default values. Such a table continues to use default values supplied by the MySQL server until it is upgraded by performing an offline `ALTER TABLE` on it.

  When upgrading to a MySQL Cluster release that supports native default values from a MySQL Cluster release that does not, you should not attempt to create any new tables until all data nodes are using the new `ndbd` or `ndbmtd` binaries. This is because the older binaries do not provide support for native default values.

  > **Important**
  >
  > Tables created with native default value support cannot be used with versions of MySQL Cluster that do not support native default values.

- NDB API changes in MySQL Cluster NDB 7.1.16 and MySQL Cluster NDB 7.0.27 are not backward compatible. Due to these changes the version of the included NDB client library was increased from 4.0.0 to 5.0.0; NDB API applications must be recompiled as part of any upgrade to these or later MySQL Cluster releases.

  In addition, NDB API programs should be updated as part of such an upgrade, in order to take into account changes in the default behavior and values for the `Ndb_cluster_connection::connect()` method.

- Due to issues discovered shortly after release, MySQL Cluster NDB 7.0.20 was withdrawn and replaced with MySQL Cluster NDB 7.0.20a. Users of MySQL Cluster NDB 7.0.19 and previous MySQL Cluster NDB 7.0 releases should upgrade to MySQL Cluster NDB 7.0.20a, or to a later MySQL Cluster NDB 7.0 release. See http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-5-1-51-ndb-7-0-20a.html, for more information.

  Due to issues discovered following release, MySQL Cluster NDB 7.1.15 was withdrawn and replaced with MySQL Cluster NDB 7.1.15a. Users of MySQL Cluster NDB 7.1.14 and previous MySQL Cluster NDB 7.1 releases should upgrade to MySQL Cluster NDB 7.1.15a, or to a later MySQL Cluster NDB 7.1 release. See http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-5-1-56-ndb-7-1-15a.html, for more information.

  Due to issues discovered shortly after release, MySQL Cluster NDB 7.1.9 was withdrawn and replaced with MySQL Cluster NDB 7.1.9a. Users of MySQL Cluster NDB 7.1.8 and previous MySQL Cluster NDB 7.1 releases should upgrade to MySQL Cluster NDB 7.1.14 (the last release directly upgrade-compatible with MySQL Cluster 7.1.18 and earlier) before upgrading to MySQL Cluster 7.1.15a or later. See http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-5-1-51-ndb-7-1-9a.html, for more information.

- When performing an online upgrade or downgrade between MySQL Cluster NDB 7.1.8 or earlier and a later release up to and including MySQL Cluster NDB 7.1.14, you must upgrade or downgrade the data nodes before upgrading or downgrading any SQL nodes; otherwise `mysql_upgrade` fails on the SQL nodes due to differences between `ndbinfo` tables used in the "old" and "new" versions of the MySQL Cluster software. You should also upgrade or downgrade the data nodes prior to the SQL nodes when

performing an online upgrade or downgrade between MySQL Cluster NDB 7.1 releases where either of the versions involved is MySQL Cluster NDB 7.1.14 or earlier, and where one or more `ndbinfo` tables has more, fewer, or differing columns between the two versions.

This issue is resolved in MySQL Cluster NDB 7.1.15. (Bug #11885602)

- It was not possible to downgrade online to MySQL Cluster NDB 7.1 from some later versions of MySQL Cluster due to a change in the size used for table hash maps by `NDB`. (Bug #14645319) This issue was resolved in MySQL Cluster NDB 7.1.26, where the size is made configurable using the `DefaultHashMapSize` parameter. (Bug #14800539) See the description of this parameter for more information.

17.2.7.2 Upgrade and Downgrade Compatibility: MySQL Cluster NDB 6.x

The table shown here provides information on MySQL Cluster upgrade and downgrade compatibility among different releases of MySQL Cluster NDB 6.1, 6.2, and 6.3. Additional notes about upgrades and downgrades to, from, or within the MySQL Cluster NDB 6.x release series can be found immediately following the table.

Downgrade compatibility, MySQL Cluster NDB 6.x

MySQL Cluster NDB 6.x		
NDB 6.1†	NDB 6.2†	NDB 6.3
		6.3.54
		6.3.53
		6.3.52
		6.3.51
		6.3.50
		6.3.49
		6.3.48
		6.3.47
		6.3.46
		6.3.45
		6.3.44
		6.3.43
		6.3.42
		6.3.41
		6.3.40
		6.3.39
		6.3.38
		6.3.37
		6.3.36
		6.3.35
		6.3.34
		6.3.33
		6.3.32
		6.3.31b
		6.3.31a*
		6.3.31*
		6.3.30§
		6.3.29
		6.3.28b
		6.3.28a
		6.3.28
		6.3.27a
		6.3.27
		6.3.26
		6.3.25
		6.3.24
6.1.23		6.3.23
6.1.22		6.3.22
6.1.21		6.3.21
6.1.20		6.3.20
6.1.19	6.2.19	6.3.19
6.1.18*	6.2.18	6.3.18
6.1.17	6.2.17	6.3.17
6.1.16	6.2.16	6.3.16
6.1.15	6.2.15	6.3.15
6.1.14	6.2.14	6.3.14
6.1.13	6.2.13	6.3.13
6.1.12	6.2.12	6.3.12*
6.1.11	6.2.11	6.3.11*
6.1.10	6.2.10	6.3.10
6.1.9	6.2.9	6.3.9
6.1.8	6.2.8	6.3.8
6.1.7	6.2.7	6.3.7
6.1.6*	6.2.6	6.3.6
6.1.5	6.2.5	6.3.5
6.1.4	6.2.4	6.3.4
6.1.3	6.2.3	6.3.3
6.1.2	6.2.2	6.3.2
6.1.1	6.2.1	6.3.1
6.1.0	6.2.0	6.3.0

KEY:

↕ Online upgrades and downgrades possible

↑ Online downgrades not possible

* Unreleased or withdrawn following release.

† The NDB 6.1 and 6.2 series are no longer in production.

§ NDB 6.3.30 was a special-purpose release, and not part of the normal upgrade cycle.

Notes: MySQL Cluster NDB 6.1

Availability of older releases.   MySQL Cluster NDB 6.1 is no longer in production; information about this series of releases is of historical interest only. MySQL Cluster NDB 6.2 is still available, but is no longer supported in new deployments. If you are still using a MySQL Cluster NDB 6.1 or MySQL Cluster NDB 6.2 release, you should upgrade to the most recent MySQL Cluster NDB 7.0 or MySQL Cluster NDB 7.1 release as soon as possible.

- It is not possible to upgrade from MySQL Cluster NDB 6.1.2 (or an older 6.1 release) directly to 6.1.4 or a newer NDB 6.1 release, or to downgrade from 6.1.4 (or a newer 6.1 release) directly to 6.1.2 or an older NDB 6.1 release; in either case, you must upgrade or downgrade to MySQL Cluster NDB 6.1.3 first.

- It is not possible to perform an online downgrade from MySQL Cluster NDB 6.1.8 (or a newer 6.1 release) to MySQL Cluster NDB 6.1.7 (or an older 6.1 release).

- MySQL Cluster NDB 6.1.6 and 6.1.18 were not released.

- It is not possible to perform an online upgrade or downgrade between MySQL Cluster NDB 6.2 and any previous release series (including mainline MySQL 5.1 and MySQL Cluster NDB 6.1); it is necessary to perform a dump and reload. However, it should be possible to perform online upgrades or downgrades between any MySQL Cluster NDB 6.2 release and any MySQL Cluster NDB 6.3 release up to and including 6.3.7.

Notes: MySQL Cluster NDB 6.2 and MySQL Cluster NDB 6.3

Internal column specification changes.   The internal specifications for columns in `NDB` tables changed in MySQL Cluster NDB 6.1.17 and 6.2.1 to enable compatibility with later MySQL Cluster releases implementing online adding and dropping of columns (MySQL 5.1.17 through MySQL 5.1.23; MySQL Cluster NDB 6.2.3 and later; MySQL Cluster NDB 6.3.2 and later). This change is not backward-compatible with earlier MySQL Server or MySQL Cluster releases.

To make tables created in earlier versions compatible with online adding and dropping of columns in later versions, it is necessary to force MySQL Cluster to convert the tables to the new format by following this procedure following an upgrade:

1. Upgrade the MySQL Cluster software on all data, management, and SQL nodes

2. Back up all `NDB` tables

3. Shut down the cluster (all data, management, and SQL nodes)

4. Restart the cluster, starting all data nodes with the `--initial` option (to clear and rebuild the data node file systems)

5. Restore the tables from backup

To minimize possible later difficulties, it is strongly advised that the procedure outlined above be followed as soon as possible after to upgrading between the versions indicated. The procedure is *not* necessary for `NDBCLUSTER` tables created in any of the following versions:

- MySQL Cluster NDB 6.1.8 or a later MySQL Cluster NDB 6.1 release

- MySQL Cluster 6.2.1 or a later MySQL Cluster NDB 6.2 release

- Any MySQL Cluster NDB 6.3 release (or later MySQL Cluster release series)

Tables created in the versions listed previously (or later versions, as indicated) are already compatible with adding and dropping of columns online (as implemented beginning with MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2).

Additional issues encountered when upgrading or downgrading to or from MySQL Cluster NDB 6.2 and MySQL Cluster NDB 6.3 releases are listed here:

- It was not possible to perform an online upgrade between any MySQL Cluster NDB 6.2 release and MySQL Cluster NDB 6.3.8 and later MySQL Cluster 6.3 releases. This issue was fixed in MySQL Cluster NDB 6.3.21. (Bug #41435)

- Online downgrades between MySQL Cluster NDB 6.2.5 and earlier releases are not supported.

- Online downgrades between MySQL Cluster NDB 6.3.8 and earlier releases are not supported.

17.2.7.3 Upgrade and downgrade compatibility: MySQL 5.1

The table shown here provides information on MySQL Cluster upgrade and downgrade compatibility among different releases of MySQL 5.1 prior to MySQL 5.1.24. Additional notes about upgrades and downgrades to, from, or within the MySQL 5.1 release series can be found immediately following the table.

Figure 17.7 MySQL Cluster Upgrade and Downgrade compatibility, MySQL Cluster 5.1
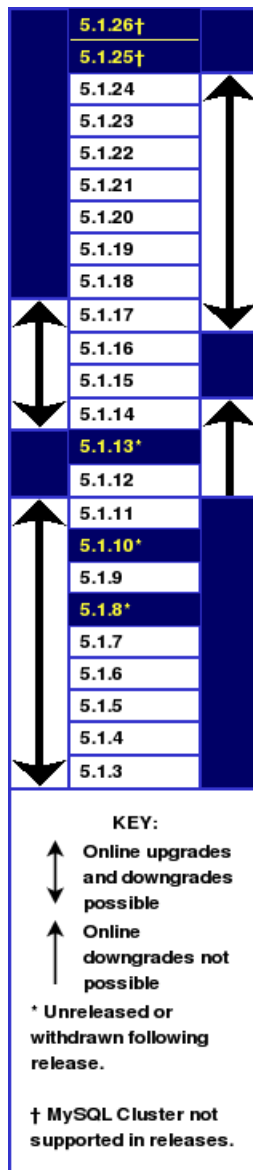
Notes: MySQL 5.1

- MySQL 5.1.3 was the first public release in this series.

- Direct upgrades or downgrades between MySQL Cluster 5.0 and 5.1 are not supported; you must dump all `NDBCLUSTER` tables using `mysqldump`, install the new version of the software, and then reload the tables from the dump.

- You cannot downgrade a MySQL Cluster based on MySQL 5.1.6 or later and using Disk Data tables to MySQL 5.1.5 or earlier unless you convert all such tables to in-memory `NDB` tables first.

- MySQL 5.1.8, MySQL 5.1.10, and MySQL 5.1.13 were not released.

- Online cluster upgrades and downgrades between MySQL 5.1.11 (or an earlier version) and 5.1.12 (or a later version) are not possible due to major changes in the cluster file system. In such cases, you must perform a backup or dump, upgrade (or downgrade) the software, start each data node with `--`

`initial`, and then restore from the backup or dump. You can use native `NDB` backup and restore, or `mysqldump` and `LOAD DATA INFILE` for this purpose.

- Online downgrades from MySQL 5.1.14 or later to versions previous to 5.1.14 are not supported due to incompatible changes in the cluster system tables.

MySQL Cluster Replication: changes in ndb_apply_status.   Online upgrades from MySQL 5.1.17 and earlier to 5.1.18 and later MySQL 5.1.x releases are not supported for clusters using replication due to incompatible changes in the `mysql.ndb_apply_status` table. (Online upgrades from MySQL 5.1 to MySQL Cluster NDB 6.2 and later are not supported, as discussed elsewhere in this section.) However, it should not be necessary to shut down the cluster entirely, if you follow this modified rolling restart procedure:

1. Stop the management server, update the management server software, then start the management server again. For multiple management servers, repeat this step for each management server in turn.

2. For each data node in turn: Stop the data node, update the data node daemon (in MySQL Cluster NDB 7.0 and later, this can be either `ndbd` or `ndbmtd`) with the new version, then restart the data node. It should not be necessary to use `--initial` when restarting any of the data nodes after updating the software.

3. Stop *all* SQL nodes. Upgrade the existing MySQL server installations to the new version on all SQL nodes, then restart them. It is not necessary to start them one at a time after upgrading the MySQL server software, but *there must be a time when none of them is running before starting any of them again using the 5.1.18 (or later)* `mysqld`. Otherwise—due to the fact that `mysql.ndb_apply_status` uses the `NDB` storage engine and is thus shared between all SQL nodes—there may be conflicts between the old and new versions of the table on different SQL nodes.

   You can find more information about the changes to `ndb_apply_status` in Section 17.6.4, "MySQL Cluster Replication Schema and Tables".

   > **Note**
   >
   > You should upgrade the MySQL Cluster software on each node using the same method by which it was originally installed. See Section 17.2, "MySQL Cluster Installation and Upgrades", for more information.

As with any other MySQL Cluster version upgrade, you should also update the MySQL Cluster management client (`ndb_mgm`) and other MySQL Cluster client programs such as `ndb_config` and `ndb_error_reporter`; however, this does not have to be done in any particular order.

Internal column specification changes.   The internal specifications for columns in `NDBCLUSTER` tables changed in MySQL 5.1.18 to enable compatibility with later MySQL Cluster releases that permit online adding and dropping of columns. *This change is not backward-compatible with earlier MySQL versions.*

To make tables created in MySQL 5.1.17 and earlier compatible with online adding and dropping of columns (available beginning with beginning with MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2—see Section 13.1.7, "ALTER TABLE Syntax", for more information), it is necessary to force MySQL 5.1.18 and later to convert the tables to the new format by following this procedure:

1. Back up all `NDBCLUSTER` tables.

2. Upgrade the MySQL Cluster software on all data, management, and SQL nodes.

3. Shut down the cluster completely (this includes all data, management, and API or SQL nodes).

4. Restart the cluster, starting all data nodes with the `--initial` option (to clear and rebuild the data node file systems).

5. Restore the `NDBCLUSTER` tables from backup.

It is not necessary to follow this procedure for `NDBCLUSTER` tables created in MySQL 5.1.18 and later; such tables are already compatible with online adding and dropping of columns (as implemented beginning with MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2).

To minimize possible later difficulties, it is strongly advised that the procedure outlined above be followed as soon as possible after to upgrading from MySQL 5.1.17 or earlier to MySQL 5.1.18 or later.

Information about how this change effects users of MySQL Cluster NDB 6.x and 7.x is provided later in this section.

MySQL Cluster not supported in MySQL Server 5.1.24 and later.   MySQL Cluster is not supported in standard MySQL 5.1 releases beginning with MySQL 5.1.24. If you are using MySQL Cluster in a standard MySQL 5.1 release, you should upgrade to the most recent MySQL Cluster NDB 7.0 or MySQL Cluster NDB 7.1 release.

17.3 Configuration of MySQL Cluster NDB 6.1-7.1

A MySQL server that is part of a MySQL Cluster differs in one chief respect from a normal (nonclustered) MySQL server, in that it employs the `NDB` storage engine. This engine is also referred to sometimes as `NDBCLUSTER`, although `NDB` is preferred.

To avoid unnecessary allocation of resources, the server is configured by default with the `NDB` storage engine disabled. To enable `NDB`, you must modify the server's `my.cnf` configuration file, or start the server with the `--ndbcluster` option.

This MySQL server is a part of the cluster, so it also must know how to access a management node to obtain the cluster configuration data. The default behavior is to look for the management node on `localhost`. However, should you need to specify that its location is elsewhere, this can be done in `my.cnf`, or with the `mysql` client. Before the `NDB` storage engine can be used, at least one management node must be operational, as well as any desired data nodes.

For more information about `--ndbcluster` and other `mysqld` options specific to MySQL Cluster, see MySQL Server Options for MySQL Cluster.

For information about installing MySQL Cluster, see Section 17.2, "MySQL Cluster Installation and Upgrades".

17.3.1 Quick Test Setup of MySQL Cluster

To familiarize you with the basics, we will describe the simplest possible configuration for a functional MySQL Cluster. After this, you should be able to design your desired setup from the information provided in the other relevant sections of this chapter.

First, you need to create a configuration directory such as `/var/lib/mysql-cluster`, by executing the following command as the system `root` user:

```
shell> mkdir /var/lib/mysql-cluster
```

In this directory, create a file named `config.ini` that contains the following information. Substitute appropriate values for `HostName` and `DataDir` as necessary for your system.

```
# file "config.ini" - showing minimal setup consisting of 1 data node,
# 1 management server, and 3 SQL nodes.
```

```
# The empty default sections are not required, and are shown only for
# the sake of completeness.
# Data nodes must provide a hostname but SQL nodes are not required
# to do so.
# If you do not know the hostname for your machine, use localhost.
# The DataDir parameter also has a default value, but it is recommended to
# set it explicitly.
# Note: [db], [api], and [mgm] are aliases for [ndbd], [mysqld], and [ndb_mgmd],
# respectively. [db] is deprecated and should not be used in new installations.

[ndbd default]
NoOfReplicas= 1

[mysqld  default]
[ndb_mgmd default]
[tcp default]

[ndb_mgmd]
HostName= myhost.example.com

[ndbd]
HostName= myhost.example.com
DataDir= /var/lib/mysql-cluster

[mysqld]
[mysqld]
[mysqld]
```

You can now start the `ndb_mgmd` management server. By default, it attempts to read the `config.ini` file in its current working directory, so change location into the directory where the file is located and then invoke `ndb_mgmd`:

```
shell> cd /var/lib/mysql-cluster
shell> ndb_mgmd
```

Then start a single data node by running `ndbd`:

```
shell> ndbd
```

For command-line options which can be used when starting `ndbd`, see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

By default, `ndbd` looks for the management server at `localhost` on port 1186.

> **Note**
>
> If you have installed MySQL from a binary tarball, you will need to specify the path of the `ndb_mgmd` and `ndbd` servers explicitly. (Normally, these will be found in `/usr/local/mysql/bin`.)

Finally, change location to the MySQL data directory (usually `/var/lib/mysql` or `/usr/local/mysql/data`), and make sure that the `my.cnf` file contains the option necessary to enable the NDB storage engine:

```
[mysqld]
ndbcluster
```

You can now start the MySQL server as usual:

```
shell> mysqld_safe --user=mysql &
```

Wait a moment to make sure the MySQL server is running properly. If you see the notice `mysql ended`, check the server's `.err` file to find out what went wrong.

If all has gone well so far, you now can start using the cluster. Connect to the server and verify that the NDB storage engine is enabled:

```
shell> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 1 to server version: 5.1.73

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SHOW ENGINES\G
...
*************************** 12. row ***************************
Engine: NDBCLUSTER
Support: YES
Comment: Clustered, fault-tolerant, memory-based tables
*************************** 13. row ***************************
Engine: NDB
Support: YES
Comment: Alias for NDBCLUSTER
...
```

The row numbers shown in the preceding example output may be different from those shown on your system, depending upon how your server is configured.

Try to create an NDB table:

```
shell> mysql
mysql> USE test;
Database changed

mysql> CREATE TABLE ctest (i INT) ENGINE=NDBCLUSTER;
Query OK, 0 rows affected (0.09 sec)

mysql> SHOW CREATE TABLE ctest \G
*************************** 1. row ***************************
       Table: ctest
Create Table: CREATE TABLE `ctest` (
  `i` int(11) default NULL
) ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

To check that your nodes were set up properly, start the management client:

```
shell> ndb_mgm
```

Use the SHOW command from within the management client to obtain a report on the cluster's status:

```
ndb_mgm> SHOW
Cluster Configuration
---------------------
[ndbd(NDB)]     1 node(s)
id=2    @127.0.0.1  (Version: 5.1.77-ndb-7.1.37, Nodegroup: 0, *)

[ndb_mgmd(MGM)] 1 node(s)
id=1    @127.0.0.1  (Version: 5.1.77-ndb-7.1.37)

[mysqld(API)]   3 node(s)
id=3    @127.0.0.1  (Version: 5.1.77-ndb-7.1.37)
```

```
id=4 (not connected, accepting connect from any host)
id=5 (not connected, accepting connect from any host)
```

At this point, you have successfully set up a working MySQL Cluster. You can now store data in the cluster by using any table created with `ENGINE=NDBCLUSTER` or its alias `ENGINE=NDB`.

17.3.2 Overview of MySQL Cluster Configuration Parameters, Options, and Variables

The next several sections provide summary tables of MySQL Cluster node configuration parameters used in the `config.ini` file to govern various aspects of node behavior, as well as of options and variables read by `mysqld` from a `my.cnf` file or from the command line when run as a MySQL Cluster process. Each of the node parameter tables lists the parameters for a given type (`ndbd`, `ndb_mgmd`, `mysqld`, `computer`, `tcp`, `shm`, or `sci`). All tables include the data type for the parameter, option, or variable, as well as its default, mimimum, and maximum values as applicable.

Considerations when restarting nodes.   For node parameters, these tables also indicate what type of restart is required (node restart or system restart)—and whether the restart must be done with `--initial`—to change the value of a given configuration parameter. When performing a node restart or an initial node restart, all of the cluster's data nodes must be restarted in turn (also referred to as a *rolling restart*). It is possible to update cluster configuration parameters marked as `node` online—that is, without shutting down the cluster—in this fashion. An initial node restart requires restarting each `ndbd` process with the `--initial` option.

A system restart requires a complete shutdown and restart of the entire cluster. An initial system restart requires taking a backup of the cluster, wiping the cluster file system after shutdown, and then restoring from the backup following the restart.

In any cluster restart, all of the cluster's management servers must be restarted for them to read the updated configuration parameter values.

> **Important**
>
> Values for numeric cluster parameters can generally be increased without any problems, although it is advisable to do so progressively, making such adjustments in relatively small increments. Many of these can be increased online, using a rolling restart.
>
> However, decreasing the values of such parameters—whether this is done using a node restart, node initial restart, or even a complete system restart of the cluster—is not to be undertaken lightly; it is recommended that you do so only after careful planning and testing. This is especially true with regard to those parameters that relate to memory usage and disk space, such as `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes`. In addition, it is the generally the case that configuration parameters relating to memory and disk usage can be raised using a simple node restart, but they require an initial node restart to be lowered.

Because some of these parameters can be used for configuring more than one type of cluster node, they may appear in more than one of the tables.

> **Note**
>
> `4294967039` often appears as a maximum value in these tables. This value is defined in the `NDBCLUSTER` sources as `MAX_INT_RNIL` and is equal to `0xFFFFFEFF`, or $2^{32} - 2^{8} - 1$.

17.3.2.1 MySQL Cluster Data Node Configuration Parameters

The summary table in this section provides information about parameters used in the `[ndbd]` or `[ndbd default]` sections of a `config.ini` file for configuring MySQL Cluster data nodes. For detailed descriptions and other additional information about each of these parameters, see Section 17.3.3.6, "Defining MySQL Cluster Data Nodes".

Beginning with MySQL Cluster NDB 6.4.0, these parameters also apply to `ndbmtd`, which is a multi-threaded version of `ndbd`. For more information, see Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)".

Restart types.   Changes in MySQL Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary table as follows:

- `N`—Node restart: The parameter can be updated using a rolling restart (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster").

- `S`—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.

- `I`—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 17.3.2, "Overview of MySQL Cluster Configuration Parameters, Options, and Variables".

Table 17.1 Data Node Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
Arbitration	enumeration	N	NDB 7.0.7
	Default		
	Default, Disabled, WaitExternal		
ArbitrationTimeout	milliseconds	N	NDB 7.2.0
	7500		
	10 / 4294967039 (0xFFFFFEFF)		
BackupDataBufferSize	bytes	N	NDB 7.0.4
	16M		
	0 / 4294967039 (0xFFFFFEFF)		
BackupDataDir	path	IN	all 5.1-based
	FileSystemPath		
	...		

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values		Restart Type	In Version ... (and later)
BackupLogBufferSize	bytes		N	NDB 7.0.4
	16M			
	0 / 4294967039 (0xFFFFFEFF)			
BackupMaxWriteSize	bytes		N	NDB 5.1.32
	1M			
	2K / 4294967039 (0xFFFFFEFF)			
BackupMemory	bytes		N	NDB 7.0.4
	32M			
	0 / 4294967039 (0xFFFFFEFF)			
BackupReportFrequency	seconds		N	NDB 6.2.3
	0			
	0 / 4294967039 (0xFFFFFEFF)			
BackupWriteSize	bytes		N	NDB 7.0.4
	256K			
	2K / 4294967039 (0xFFFFFEFF)			
BatchSizePerLocalScan	integer		N	NDB 7.2.1
	256			
	1 / 992			
BuildIndexThreads	numeric		S	NDB 7.0.11
	0			
	0 / 128			
CompressedBackup	boolean		N	NDB 6.3.7
	false			
	true, false			
CompressedLCP	boolean		N	NDB 6.3.7
	false			
	true, false			
ConnectCheckIntervalDelay	milliseconds		N	NDB 7.1.13
	1500			

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values		Restart Type	In Version ... (and later)
	0 / 4294967039 (0xFFFFFEFF)			
CrashOnCorruptedTuple	boolean		S	NDB 7.0.28, 5.1.56-ndb-7.1.17
	false			
	true, false			
DataDir	path		IN	all 5.1-based
	.			
	...			
DataMemory	bytes		N	all 5.1-based
	80M			
	1M / 1024G			
DefaultHashMapSize	LDM threads		N	NDB 7.1.27
	240			
	0 / 3840			
DictTrace	bytes		N	NDB 5.1.12
	undefined			
	0 / 100			
DiskCheckpointSpeed	bytes		N	NDB 5.1.12
	10M			
	1M / 4294967039 (0xFFFFFEFF)			
DiskCheckpointSpeedInRestart	bytes		N	NDB 5.1.12
	100M			
	1M / 4294967039 (0xFFFFFEFF)			
DiskIOThreadPool	threads		N	NDB 7.1.0
	2			
	0 / 4294967039 (0xFFFFFEFF)			
Diskless	true|false (1|0)		IS	all 5.1-based
	false			
	true, false			
DiskPageBufferMemory	bytes		N	NDB 5.1.6

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values		Restart Type	In Version ... (and later)
	64M			
	4M / 1T			
DiskSyncSize	bytes		N	NDB 5.1.12
	4M			
	32K / 4294967039 (0xFFFFFEFF)			
ExecuteOnComputer	name		S	all 5.1-based
	[none]			
	...			
ExtraSendBufferMemory	bytes		N	NDB 7.1.20
	0			
	0 / 32G			
FileSystemPath	path		IN	all 5.1-based
	DataDir			
	...			
FileSystemPathDataFiles	filename		IN	NDB 6.4.3
	[see text]			
	...			
FileSystemPathDD	filename		IN	NDB 6.4.3
	FileSystemPath			
	...			
FileSystemPathUndoFiles	filename		IN	NDB 6.4.3
	[see text]			
	...			
FragmentLogFileSize	bytes		IN	NDB 6.1.11
	16M			
	4M / 1G			
HeartbeatIntervalDbApi	milliseconds		N	all 5.1-based
	1500			
	100 / 4294967039 (0xFFFFFEFF)			
HeartbeatIntervalDbDb	milliseconds		N	NDB 7.2.0
	5000			

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values		Restart Type	In Version ... (and later)
	10 / 4294967039 (0xFFFFFEFF)			
HeartbeatOrder	numeric		S	NDB 7.1.5
	0			
	0 / 65535			
HostName	name or IP address		N	all 5.1- based
	localhost			
	...			
Id	unsigned		IS	all 5.1- based
	[none]			
	1 / 48			
IndexMemory	bytes		N	all 5.1- based
	18M			
	1M / 1T			
InitFragmentLogFiles	[see values]		IN	NDB 6.3.19
	SPARSE			
	SPARSE, FULL			
InitialLogFileGroup	string		S	NDB 6.4.3
	[see text]			
	...			
InitialNoOfOpenFiles	files		N	NDB 5.1.9
	27			
	20 / 4294967039 (0xFFFFFEFF)			
InitialTablespace	string		S	NDB 6.4.3
	[see text]			
	...			
IOThreadPool	threads		N	NDB 6.4.0
	8			
	0 / 4294967039 (0xFFFFFEFF)			
LateAlloc	numeric		N	NDB 6.4.0

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
	1		
	0 / 1		
LcpScanProgressTimeout	second	N	NDB 7.1.29
	60		
	0 / 4294967039 (0xFFFFFEFF)		
LockExecuteThreadToCPU	CPU ID	N	NDB 6.3.4
	64K		
	0 / 64K		
LockMaintThreadsToCPU	CPU ID	N	NDB 6.4.0
	[none]		
	0 / 64K		
LockPagesInMainMemory	numeric	N	NDB 5.1.15
	0		
	0 / 2		
LogLevelCheckpoint	log level	N	all 5.1-based
	0		
	0 / 15		
LogLevelCongestion	levelr	N	all 5.1-based
	0		
	0 / 15		
LogLevelConnection	integer	N	all 5.1-based
	0		
	0 / 15		
LogLevelError	integer	N	all 5.1-based
	0		
	0 / 15		
LogLevelInfo	integer	N	all 5.1-based
	0		
	0 / 15		
LogLevelNodeRestart	integer	N	all 5.1-based
	0		
	0 / 15		

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
LogLevelShutdown	integer	N	all 5.1-based
	0		
	0 / 15		
LogLevelStartup	integer	N	all 5.1-based
	1		
	0 / 15		
LogLevelStatistic	integer	N	all 5.1-based
	0		
	0 / 15		
LongMessageBuffer	bytes	N	NDB 7.1.31
	64M		
	512K / 4294967039 (0xFFFFFEFF)		
MaxAllocate	unsigned	N	NDB 5.1.20
	32M		
	1M / 1G		
MaxBufferedEpochs	epochs	N	NDB 6.2.14
	100		
	0 / 100000		
MaxBufferedEpochBytes	bytes	N	NDB 7.1.27
	26214400		
	26214400 (0x01900000) / 4294967039 (0xFFFFFEFF)		
MaxDMLOperationsPerTransaction	operations (DML)	N	NDB 7.1.15
	4294967295		
	32 / 4294967295		
MaxLCPStartDelay	seconds	N	NDB 6.4.3
	0		
	0 / 600		
MaxNoOfAttributes	integer	N	all 5.1-based
	1000		

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
	32 / 4294967039 (0xFFFFFEFF)		
MaxNoOfConcurrentIndexOperations	integer	N	all 5.1-based
	8K		
	0 / 4294967039 (0xFFFFFEFF)		
MaxNoOfConcurrentOperations	integer	N	all 5.1-based
	32K		
	32 / 4294967039 (0xFFFFFEFF)		
MaxNoOfConcurrentScans	integer	N	all 5.1-based
	256		
	2 / 500		
MaxNoOfConcurrentSubOperations	unsigned	N	NDB 6.3.7
	256		
	0 / 4294967039 (0xFFFFFEFF)		
MaxNoOfConcurrentTransactions	integer	N	all 5.1-based
	4096		
	32 / 4294967039 (0xFFFFFEFF)		
MaxNoOfFiredTriggers	integer	N	all 5.1-based
	4000		
	0 / 4294967039 (0xFFFFFEFF)		
MaxNoOfLocalOperations	integer	N	all 5.1-based
	UNDEFINED		
	32 / 4294967039 (0xFFFFFEFF)		
MaxNoOfLocalScans	integer	N	NDB 7.2.0
	[see text]		

Parameter Name	Type or Units		Restart Type	In Version ... (and later)
	Default Value			
	Minimum/ Maximum or Permitted Values			
	32 / 4294967039 (0xFFFFFEFF)			
MaxNoOfOpenFiles	unsigned		N	NDB 5.1.16
	0			
	20 / 4294967039 (0xFFFFFEFF)			
MaxNoOfOrderedIndexes	integer		N	all 5.1-based
	128			
	0 / 4294967039 (0xFFFFFEFF)			
MaxNoOfSavedMessages	integer		N	all 5.1-based
	25			
	0 / 4294967039 (0xFFFFFEFF)			
MaxNoOfSubscribers	unsigned		N	NDB 6.3.7
	0			
	0 / 4294967039 (0xFFFFFEFF)			
MaxNoOfSubscriptions	unsigned		N	NDB 6.3.7
	0			
	0 / 4294967039 (0xFFFFFEFF)			
MaxNoOfTables	integer		N	all 5.1-based
	128			
	8 / 20320			
MaxNoOfTriggers	integer		N	all 5.1-based
	768			
	0 / 4294967039 (0xFFFFFEFF)			
MaxNoOfUniqueHashIndexes	integer		N	all 5.1-based
	64			
	0 / 4294967039 (0xFFFFFEFF)			
MaxParallelScansPerFragment	bytes		N	NDB 7.2.0

Parameter Name	Type or Units		Restart Type	In Version ... (and later)
	Default Value			
	Minimum/ Maximum or Permitted Values			
	256			
	1 / 4294967039 (0xFFFFFEFF)			
MaxStartFailRetries	unsigned		N	NDB 6.2.19
	3			
	0 / 4294967039 (0xFFFFFEFF)			
MemReportFrequency	unsigned		N	NDB 5.1.16
	0			
	0 / 4294967039 (0xFFFFFEFF)			
MinFreePct	unsigned		N	NDB 7.1.18
	5			
	0 / 100			
NodeGroup			IS	NDB 6.4.0
	[none]			
	0 / 65536			
NodeId	unsigned		IS	all 5.1-based
	[none]			
	1 / 48			
NoOfDiskPagesToDiskAfterRestartACC	8K pages/100 milliseconds		N	all 5.1-based
	20			
	1 / 4294967039 (0xFFFFFEFF)			
NoOfDiskPagesToDiskAfterRestartTUP	8K pages/100 milliseconds		N	all 5.1-based
	40			
	1 / 4294967039 (0xFFFFFEFF)			
NoOfDiskPagesToDiskDuringRestartACC	8K pages/100 milliseconds		N	all 5.1-based
	20			
	1 / 4294967039 (0xFFFFFEFF)			

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values		Restart Type	In Version ... (and later)
NoOfDiskPagesToDiskDuringRestartTUP	8K pages/100 milliseconds		N	all 5.1-based
	40			
	1 / 4294967039 (0xFFFFFEFF)			
NoOfFragmentLogFiles	integer		IN	NDB 5.1.0
	16			
	3 / 4294967039 (0xFFFFFEFF)			
NoOfReplicas	integer		IS	NDB 7.0.6
	2			
	1 / 4			
Numa	boolean		N	NDB 7.1.9
	1			
	...			
ODirect	boolean		N	NDB 6.3.0
	false			
	true, false			
RealtimeScheduler	boolean		N	NDB 6.3.4
	false			
	true, false			
RedoBuffer	bytes		N	NDB 7.0.4
	32M			
	1M / 4294967039 (0xFFFFFEFF)			
RedoOverCommitCounter	numeric		N	NDB 7.1.10
	3			
	0 / 4294967039 (0xFFFFFEFF)			
RedoOverCommitLimit	seconds		N	NDB 7.1.10
	20			
	0 / 4294967039 (0xFFFFFEFF)			
ReservedSendBufferMemory	bytes		N	NDB 6.4.0
	256K			

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 / 4294967039 (0xFFFFFEFF)		
RestartOnErrorInsert	error code 2 0 / 4	N	all 5.1- based
SchedulerExecutionTimer	μs 50 0 / 11000	N	NDB 6.3.4
SchedulerSpinTimer	μs 0 0 / 500	N	NDB 6.3.4
ServerPort	unsigned [none] 1 / 64K	S	all 5.1- based
SharedGlobalMemory	bytes 20M 0 / 64T	N	NDB 5.1.6
StartFailRetryDelay	unsigned 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 6.2.19
StartFailureTimeout	milliseconds 0 0 / 4294967039 (0xFFFFFEFF)	N	all 5.1- based
StartNoNodeGroupTimeout	milliseconds 15000 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.0.24
StartPartialTimeout	milliseconds 30000 0 / 4294967039 (0xFFFFFEFF)	N	all 5.1- based
StartPartitionedTimeout	milliseconds 60000	N	all 5.1- based

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
	0 / 4294967039 (0xFFFFFEFF)		
StartupStatusReportFrequency	seconds	N	NDB 6.4.0
	0		
	0 / 4294967039 (0xFFFFFEFF)		
StopOnError	boolean	N	all 5.1-based
	1		
	0, 1		
StringMemory	% or bytes	S	NDB 5.1.6
	5		
	0 / 4294967039 (0xFFFFFEFF)		
TcpBind_INADDR_ANY	boolean	N	NDB 6.2.0
	false		
	true, false		
TimeBetweenEpochs	milliseconds	N	NDB 6.2.5
	100		
	0 / 32000		
TimeBetweenEpochsTimeout	milliseconds	N	NDB 5.1.51
	0		
	0 / 256000		
TimeBetweenGlobalCheckpoints	milliseconds	N	NDB 6.2.0
	2000		
	20 / 32000		
TimeBetweenInactiveTransactionAbortCheck	milliseconds	N	all 5.1-based
	1000		
	1000 / 4294967039 (0xFFFFFEFF)		
TimeBetweenLocalCheckpoints	number of 4-byte words, as a base-2 logarithm	N	all 5.1-based
	20		
	0 / 31		

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values		Restart Type	In Version ... (and later)
TimeBetweenWatchDogCheck	milliseconds		N	all 5.1-based
	6000			
	70 / 4294967039 (0xFFFFFEFF)			
TimeBetweenWatchDogCheckInitial	milliseconds		N	NDB 5.1.20
	6000			
	70 / 4294967039 (0xFFFFFEFF)			
TotalSendBufferMemory	bytes		N	NDB 6.4.0
	0			
	256K / 4294967039 (0xFFFFFEFF)			
TransactionBufferMemory	bytes		N	all 5.1-based
	1M			
	1K / 4294967039 (0xFFFFFEFF)			
TransactionDeadlockDetectionTimeout	milliseconds		N	all 5.1-based
	1200			
	50 / 4294967039 (0xFFFFFEFF)			
TransactionInactiveTimeout	milliseconds		N	all 5.1-based
	[see text]			
	0 / 4294967039 (0xFFFFFEFF)			
TwoPassInitialNodeRestartCopy	boolean		N	NDB 7.1.11
	false			
	true, false			
UndoDataBuffer	unsigned		N	all 5.1-based
	16M			
	1M / 4294967039 (0xFFFFFEFF)			

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
UndoIndexBuffer	unsigned	N	all 5.1-based
	2M		
	1M / 4294967039 (0xFFFFFEFF)		

Table 17.2 Multi-Threaded Data Node Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
MaxNoOfExecutionThreads	integer	IS	NDB 7.0.4
	2		
	2 / 8		
ThreadConfig	string	IS	NDB 7.1.17
	"		
	...		

> **Note**
>
> Prior to MySQL Cluster NDB 7.0, to add new data nodes to a MySQL Cluster, it is necessary to shut down the cluster completely, update the `config.ini` file, and then restart the cluster, starting all data node processes using the `--initial` option—that is, you must perform a system restart.
>
> Beginning in MySQL Cluster NDB 7.0, it is possible to add new data node groups to a running cluster online. For more information, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

17.3.2.2 MySQL Cluster Management Node Configuration Parameters

The summary table in this section provides information about parameters used in the `[ndb_mgmd]` or `[mgm]` sections of a `config.ini` file for configuring MySQL Cluster management nodes. For detailed descriptions and other additional information about each of these parameters, see Section 17.3.3.5, "Defining a MySQL Cluster Management Server".

Restart types.   Changes in MySQL Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary table as follows:

- N—Node restart: The parameter can be updated using a rolling restart (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster").

- `S`—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.

- `I`—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 17.3.2, "Overview of MySQL Cluster Configuration Parameters, Options, and Variables".

Table 17.3 Management Node Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
ArbitrationDelay	milliseconds	N	all 5.1-based
	0		
	0 / 4294967039 (0xFFFFFEFF)		
ArbitrationRank	0-2	N	all 5.1-based
	1		
	0 / 2		
DataDir	path	N	all 5.1-based
	.		
	...		
ExecuteOnComputer	name	S	all 5.1-based
	[none]		
	...		
ExtraSendBufferMemory	bytes	N	NDB 7.1.28
	0		
	0 / 32G		
HeartbeatIntervalMgmdMgmd	milliseconds	N	NDB 7.1.29
	1500		
	100 / 4294967039 (0xFFFFFEFF)		
HeartbeatThreadPriority	string	S	NDB 7.1.2
	[none]		
	...		
HostName	name or IP address	N	all 5.1-based
	[none]		
	...		

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
Id	unsigned	IS	NDB 6.1.1
	[none]		
	1 / 255		
LogDestination	{CONSOLE| SYSLOG|FILE}	N	all 5.1-based
	[see text]		
	...		
MaxNoOfSavedEvents	unsigned	N	all 5.1-based
	100		
	0 / 4294967039 (0xFFFFFEFF)		
NodeId	unsigned	IS	NDB 6.1.1
	[none]		
	1 / 255		
PortNumber	unsigned	S	all 5.1-based
	1186		
	0 / 64K		
PortNumberStats	unsigned	N	all 5.1-based
	[none]		
	0 / 64K		
TotalSendBufferMemory	bytes	N	NDB 6.4.0
	0		
	256K / 4294967039 (0xFFFFFEFF)		
wan	boolean	N	NDB 6.1.1
	false		
	true, false		

Note

After making changes in a management node's configuration, it is necessary to perform a rolling restart of the cluster for the new configuration to take effect. See Section 17.3.3.5, "Defining a MySQL Cluster Management Server", for more information.

To add new management servers to a running MySQL Cluster, it is also necessary perform a rolling restart of all cluster nodes after modifying any existing

`config.ini` files. For more information about issues arising when using multiple management nodes, see Section 17.1.6.10, "Limitations Relating to Multiple MySQL Cluster Nodes".

17.3.2.3 MySQL Cluster SQL Node and API Node Configuration Parameters

The summary table in this section provides information about parameters used in the `[mysqld]` and `[api]` sections of a `config.ini` file for configuring MySQL Cluster SQL nodes and API nodes. For detailed descriptions and other additional information about each of these parameters, see Section 17.3.3.7, "Defining SQL and Other API Nodes in a MySQL Cluster".

> **Note**
>
> For a discussion of MySQL server options for MySQL Cluster, see MySQL Server Options for MySQL Cluster; for information about MySQL server system variables relating to MySQL Cluster, see MySQL Cluster System Variables.

Restart types.　　Changes in MySQL Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary table as follows:

- `N`—Node restart: The parameter can be updated using a rolling restart (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster").

- `S`—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.

- `I`—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 17.3.2, "Overview of MySQL Cluster Configuration Parameters, Options, and Variables".

Table 17.4 SQL Node / API Node Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
`ArbitrationDelay`	milliseconds	N	all 5.1-based
	0		
	0 / 4294967039 (0xFFFFFEFF)		
`ArbitrationRank`	0-2	N	all 5.1-based
	0		
	0 / 2		
`AutoReconnect`	boolean	N	NDB 7.0.7
	false		
	true, false		
`BatchByteSize`	bytes	N	NDB 7.2.1
	16K		

Parameter Name	Type or Units / Default Value / Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	1024 / 1M		
`BatchSize`	records 256 1 / 992	N	NDB 7.2.1
`ConnectionMap`	string [none] ...	N	NDB 6.1.0
`DefaultHashMapSize`	buckets 240 0 / 3840	N	NDB 7.1.27
`DefaultOperationRedoProblemAction`	enumeration ABORT ABORT, QUEUE	S	NDB 7.1.10
`EventLogBufferSize`	bytes 8192 0 / 64K	S	NDB 7.0.4
`ExecuteOnComputer`	name [none] ...	S	all 5.1-based
`ExtraSendBufferMemory`	bytes 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.1.28
`HeartbeatThreadPriority`	string [none] ...	S	NDB 7.1.2
`HostName`	name or IP address [none] ...	N	all 5.1-based
`Id`	unsigned [none] 1 / 255	IS	NDB 6.1.1

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
`MaxScanBatchSize`	bytes	N	all 5.1-based
	256K		
	32K / 16M		
`NodeId`	unsigned	IS	NDB 6.1.1
	[none]		
	1 / 255		
`TotalSendBufferMemory`	bytes	N	NDB 6.4.0
	0		
	256K / 4294967039 (0xFFFFFEFF)		
`wan`	boolean	N	NDB 6.1.1
	false		
	true, false		

Note

To add new SQL or API nodes to the configuration of a running MySQL Cluster, it is necessary to perform a rolling restart of all cluster nodes after adding new `[mysqld]` or `[api]` sections to the `config.ini` file (or files, if you are using more than one management server). This must be done before the new SQL or API nodes can connect to the cluster.

It is *not* necessary to perform any restart of the cluster if new SQL or API nodes can employ previously unused API slots in the cluster configuration to connect to the cluster.

17.3.2.4 Other MySQL Cluster Configuration Parameters

The summary tables in this section provide information about parameters used in the `[computer]`, `[tcp]`, `[shm]`, and `[sci]` sections of a `config.ini` file for configuring MySQL Cluster management nodes. For detailed descriptions and other additional information about individual parameters, see Section 17.3.3.9, "MySQL Cluster TCP/IP Connections", Section 17.3.3.11, "MySQL Cluster Shared-Memory Connections", or Section 17.3.3.12, "SCI Transport Connections in MySQL Cluster", as appropriate.

Restart types.   Changes in MySQL Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary tables as follows:

- N—Node restart: The parameter can be updated using a rolling restart (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster").

- S—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.

- I—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 17.3.2, "Overview of MySQL Cluster Configuration Parameters, Options, and Variables".

Table 17.5 Computer Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
HostName	name or IP address	N	all 5.1-based
	[none]		
	...		
Id	string	IS	all 5.1-based
	[none]		
	...		

Table 17.6 TCP Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
Checksum	boolean	N	all 5.1-based
	false		
	true, false		
Group	unsigned	N	all 5.1-based
	55		
	0 / 200		
NodeId1	numeric	N	all 5.1-based
	[none]		
	...		
NodeId2	numeric	N	all 5.1-based
	[none]		
	...		
NodeIdServer	numeric	N	all 5.1-based
	[none]		
	...		

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Type or Units		
	Default Value		
	Minimum/ Maximum or Permitted Values		
OverloadLimit	bytes	N	NDB 6.4.0
	0		
	0 / 4294967039 (0xFFFFFEFF)		
PortNumber	unsigned	S	all 5.1-based
	[none]		
	0 / 64K		
Proxy	string	N	all 5.1-based
	[none]		
	...		
ReceiveBufferMemory	bytes	N	NDB 7.0.4
	2M		
	16K / 4294967039 (0xFFFFFEFF)		
SendBufferMemory	unsigned	N	NDB 7.0.4
	2M		
	256K / 4294967039 (0xFFFFFEFF)		
SendSignalId	boolean	N	all 5.1-based
	[see text]		
	true, false		
TCP_MAXSEG_SIZE	unsigned	N	NDB 6.1.1
	0		
	0 / 2G		
TCP_RCV_BUF_SIZE	unsigned	N	NDB 6.1.1
	70080		
	1 / 2G		
TCP_SND_BUF_SIZE	unsigned	N	NDB 6.1.1
	71540		
	1 / 2G		
TcpBind_INADDR_ANY	boolean	N	NDB 6.2.0
	false		
	true, false		

Table 17.7 Shared Memory Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
Checksum	boolean	N	all 5.1-based
	true		
	true, false		
Group	unsigned	N	all 5.1-based
	35		
	0 / 200		
NodeId1	numeric	N	all 5.1-based
	[none]		
	...		
NodeId2	numeric	N	all 5.1-based
	[none]		
	...		
NodeIdServer	numeric	N	all 5.1-based
	[none]		
	...		
OverloadLimit	bytes	N	NDB 6.4.0
	0		
	0 / 4294967039 (0xFFFFFEFF)		
PortNumber	unsigned	S	all 5.1-based
	[none]		
	0 / 64K		
SendSignalId	boolean	N	all 5.1-based
	false		
	true, false		
ShmKey	unsigned	N	all 5.1-based
	[none]		
	0 / 4294967039 (0xFFFFFEFF)		
ShmSize	bytes	N	all 5.1-based
	1M		
	64K / 4294967039 (0xFFFFFEFF)		

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
Signum	unsigned	N	all 5.1-based
	[none]		
	0 / 4294967039 (0xFFFFFEFF)		

Table 17.8 SCI Configuration Parameters

Parameter Name	Type or Units	Restart Type	In Version ... (and later)
	Default Value		
	Minimum/ Maximum or Permitted Values		
Checksum	boolean	N	all 5.1-based
	false		
	true, false		
Group	unsigned	N	all 5.1-based
	15		
	0 / 200		
Host1SciId0	unsigned	N	all 5.1-based
	[none]		
	0 / 4294967039 (0xFFFFFEFF)		
Host1SciId1	unsigned	N	all 5.1-based
	0		
	0 / 4294967039 (0xFFFFFEFF)		
Host2SciId0	unsigned	N	all 5.1-based
	[none]		
	0 / 4294967039 (0xFFFFFEFF)		
Host2SciId1	unsigned	N	all 5.1-based
	0		
	0 / 4294967039 (0xFFFFFEFF)		
NodeId1	numeric	N	all 5.1-based
	[none]		

Parameter Name	Type or Units		Restart Type	In Version ... (and later)
	Default Value			
	Minimum/ Maximum or Permitted Values			
	...			
`NodeId2`	numeric		N	all 5.1-based
	[none]			
	...			
`NodeIdServer`	numeric		N	all 5.1-based
	[none]			
	...			
`OverloadLimit`	bytes		N	NDB 6.4.0
	0			
	0 / 4294967039 (0xFFFFFEFF)			
`PortNumber`	unsigned		S	all 5.1-based
	[none]			
	0 / 64K			
`SendLimit`	unsigned		N	all 5.1-based
	8K			
	128 / 32K			
`SendSignalId`	boolean		N	all 5.1-based
	true			
	true, false			
`SharedBufferSize`	unsigned		N	all 5.1-based
	10M			
	64K / 4294967039 (0xFFFFFEFF)			

17.3.2.5 MySQL Cluster mysqld Option and Variable Reference

The following table provides a list of the command-line options, server and status variables applicable within `mysqld` when it is running as an SQL node in a MySQL Cluster. For a table showing *all* command-line options, server and status variables available for use with `mysqld`, see Section 5.1.1, "Server Option and Variable Reference".

Table 17.9 MySQL Server Options and Variables for MySQL Cluster: MySQL 5.1, MySQL Cluster NDB 6.3-7.1

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Com_show_ndb_status		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW NDB STATUS statements		
Handler_discover		
No	No	Yes
No	Both	No
DESCRIPTION: Number of times that tables have been discovered		
have_ndbcluster		
No	Yes	No
No	Global	No
DESCRIPTION: Whether mysqld supports NDB Cluster tables (set by --ndbcluster option)		
ndb-batch-size		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Size (in bytes) to use for NDB transaction batches		
ndb-blob-read-batch-bytes		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies size in bytes that large BLOB reads should be batched into. 0 = no limit.		
ndb-blob-write-batch-bytes		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies size in bytes that large BLOB writes should be batched into. 0 = no limit.		
ndb-cluster-connection-pool		
Yes	Yes	Yes
Yes	Global	No
DESCRIPTION: Number of connections to the cluster used by MySQL		
ndb-connectstring		
Yes	No	No
Yes		No
DESCRIPTION: Point to the management server that distributes the cluster configuration		
ndb-deferred-constraints		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies that constraint checks on unique indexes (where these are supported) should be deferred until commit time. Not normally needed or used; for testing purposes only.		
ndb-distribution		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH)		
ndb-log-apply-status		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Cause a MySQL server acting as a slave to log mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID. Effective only if the server is started with the --ndbcluster option.		
ndb-log-empty-epochs		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: When enabled, causes epochs in which there were no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled.		
ndb-log-orig		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Log originating server id and epoch in mysql.ndb_binlog_index table.		
ndb-log-transaction-id		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Write NDB transaction IDs in the binary log. Requires --log-bin-v1-events=OFF.		
ndb-log-update-as-write		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Toggles logging of updates on the master between updates (OFF) and writes (ON)		
ndb-mgmd-host		
Yes	No	No
Yes		No
DESCRIPTION: Set the host (and port, if desired) for connecting to management server		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
ndb-nodeid		
Yes	No	Yes
Yes	Global	No
DESCRIPTION: MySQL Cluster node ID for this MySQL server		
ndb-transid-mysql-connection-map		
Yes	No	No
No		No
DESCRIPTION: Enable or disable the ndb_transid_mysql_connection_map plugin; that is, enable or disable the INFORMATION_SCHEMA table having that name.		
ndb-wait-connected		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Time (in seconds) for the MySQL server to wait for connection to cluster management and data nodes before accepting MySQL client connections.		
ndb-wait-setup		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Time (in seconds) for the MySQL server to wait for NDB engine setup to complete.		
Ndb_api_bytes_received_count		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) received from the data nodes by this MySQL Server (SQL node).		
Ndb_api_bytes_received_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Amount of data (in bytes) received from the data nodes in this client session.		
Ndb_api_bytes_received_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) received from the data nodes by this slave.		
Ndb_api_bytes_sent_count		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) sent to the data nodes by this MySQL Server (SQL node).		
Ndb_api_bytes_sent_count_session		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Session	No
DESCRIPTION: Amount of data (in bytes) sent to the data nodes in this client session.		
Ndb_api_bytes_sent_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) sent to the data nodes by this slave.		
Ndb_api_event_bytes_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of bytes of events received by this MySQL Server (SQL node).		
Ndb_api_event_bytes_count_injector		
No	No	Yes
No	Global	No
DESCRIPTION: Number of bytes of events received by the NDB binary log injector thread.		
Ndb_api_event_data_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of row change events received by this MySQL Server (SQL node).		
Ndb_api_event_data_count_injector		
No	No	Yes
No	Global	No
DESCRIPTION: Number of row change events received by the NDB binary log injector thread.		
Ndb_api_event_nondata_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of events received, other than row change events, by this MySQL Server (SQL node).		
Ndb_api_event_nondata_count_injector		
No	No	Yes
No	Global	No
DESCRIPTION: Number of events received, other than row change events, by the NDB binary log injector thread.		
Ndb_api_pk_op_count		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of operations based on or using primary keys by this MySQL Server (SQL node).		
Ndb_api_pk_op_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of operations based on or using primary keys in this client session.		
Ndb_api_pk_op_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of operations based on or using primary keys by this slave.		
Ndb_api_pruned_scan_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of scans that have been pruned to a single partition by this MySQL Server (SQL node).		
Ndb_api_pruned_scan_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of scans that have been pruned to a single partition in this client session.		
Ndb_api_pruned_scan_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of scans that have been pruned to a single partition by this slave.		
Ndb_api_range_scan_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of range scans that have been started by this MySQL Server (SQL node).		
Ndb_api_range_scan_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of range scans that have been started in this client session.		
Ndb_api_range_scan_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of range scans that have been started by this slave.		
Ndb_api_read_row_count		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this MySQL Server (SQL node).		
	Ndb_api_read_row_count_session	
No	No	Yes
No	Session	No
DESCRIPTION: Total number of rows that have been read in this client session.		
	Ndb_api_read_row_count_slave	
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this slave.		
	Ndb_api_scan_batch_count	
No	No	Yes
No	Global	No
DESCRIPTION: Number of batches of rows received by this MySQL Server (SQL node).		
	Ndb_api_scan_batch_count_session	
No	No	Yes
No	Session	No
DESCRIPTION: Number of batches of rows received in this client session.		
	Ndb_api_scan_batch_count_slave	
No	No	Yes
No	Global	No
DESCRIPTION: Number of batches of rows received by this slave.		
	Ndb_api_table_scan_count	
No	No	Yes
No	Global	No
DESCRIPTION: Number of table scans that have been started, including scans of internal tables, by this MySQL Server (SQL node).		
	Ndb_api_table_scan_count_session	
No	No	Yes
No	Session	No
DESCRIPTION: Number of table scans that have been started, including scans of internal tables, in this client session.		
	Ndb_api_table_scan_count_slave	
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of table scans that have been started, including scans of internal tables, by this slave.		
Ndb_api_trans_abort_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted by this MySQL Server (SQL node).		
Ndb_api_trans_abort_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions aborted in this client session.		
Ndb_api_trans_abort_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted by this slave.		
Ndb_api_trans_close_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) by this MySQL Server (SQL node).		
Ndb_api_trans_close_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) in this client session.		
Ndb_api_trans_close_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) by this slave.		
Ndb_api_trans_commit_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions committed by this MySQL Server (SQL node).		
Ndb_api_trans_commit_count_session		
No	No	Yes
No	Session	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of transactions committed in this client session.		
Ndb_api_trans_commit_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions committed by this slave.		
Ndb_api_trans_local_read_row_count		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this MySQL Server (SQL node).		
Ndb_api_trans_local_read_row_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Total number of rows that have been read in this client session.		
Ndb_api_trans_local_read_row_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this slave.		
Ndb_api_trans_start_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions started by this MySQL Server (SQL node).		
Ndb_api_trans_start_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions started in this client session.		
Ndb_api_trans_start_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions started by this slave.		
Ndb_api_uk_op_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of operations based on or using unique keys by this MySQL Server (SQL node).		
Ndb_api_uk_op_count_session		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Session	No
DESCRIPTION: Number of operations based on or using unique keys in this client session.		
Ndb_api_uk_op_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of operations based on or using unique keys by this slave.		
Ndb_api_wait_exec_complete_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for execution of an operation to complete by this MySQL Server (SQL node).		
Ndb_api_wait_exec_complete_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of times thread has been blocked while waiting for execution of an operation to complete in this client session.		
Ndb_api_wait_exec_complete_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for execution of an operation to complete by this slave.		
Ndb_api_wait_meta_request_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked waiting for a metadata-based signal by this MySQL Server (SQL node).		
Ndb_api_wait_meta_request_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of times thread has been blocked waiting for a metadata-based signal in this client session.		
Ndb_api_wait_meta_request_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked waiting for a metadata-based signal by this slave.		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Ndb_api_wait_nanos_count		
No	No	Yes
No	Global	No
DESCRIPTION: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes by this MySQL Server (SQL node).		
Ndb_api_wait_nanos_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes in this client session.		
Ndb_api_wait_nanos_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes by this slave.		
Ndb_api_wait_scan_result_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for a scan-based signal by this MySQL Server (SQL node).		
Ndb_api_wait_scan_result_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of times thread has been blocked while waiting for a scan-based signal in this client session.		
Ndb_api_wait_scan_result_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for a scan-based signal by this slave.		
ndb_autoincrement_prefetch_sz		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: NDB auto-increment prefetch size		
ndb_cache_check_time		
Yes	Yes	No
Yes	Global	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of milliseconds between checks of cluster SQL nodes made by the MySQL query cache		
`Ndb_cluster_node_id`		
No	No	Yes
No	Both	No
DESCRIPTION: If the server is acting as a MySQL Cluster node, then the value of this variable its node ID in the cluster		
`Ndb_config_from_host`		
No	No	Yes
No	Both	No
DESCRIPTION: The host name or IP address of the Cluster management server. Formerly Ndb_connected_host		
`Ndb_config_from_port`		
No	No	Yes
No	Both	No
DESCRIPTION: The port for connecting to Cluster management server. Formerly Ndb_connected_port		
`Ndb_conflict_fn_epoch`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of rows that have been found in conflict by the NDB$EPOCH() conflict detection function		
`Ndb_conflict_fn_epoch_trans`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of rows that have been found in conflict by the NDB$EPOCH_TRANS() conflict detection function		
`Ndb_conflict_fn_max`		
No	No	Yes
No	Global	No
DESCRIPTION: If the server is part of a MySQL Cluster involved in cluster replication, the value of this variable indicates the number of times that conflict resolution based on "greater timestamp wins" has been applied		
`Ndb_conflict_fn_old`		
No	No	Yes
No	Global	No
DESCRIPTION: If the server is part of a MySQL Cluster involved in cluster replication, the value of this variable indicates the number of times that "same timestamp wins" conflict resolution has been applied		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Ndb_conflict_trans_conflict_commit_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of epoch transactions committed after requiring transactional conflict handling.		
Ndb_conflict_trans_detect_iter_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to Ndb_conflict_trans_conflict_commit_count.		
Ndb_conflict_trans_reject_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions rejected after being found in conflict by a transactional conflict function.		
Ndb_conflict_trans_row_reject_count		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows realigned after being found in conflict by a transactional conflict function. Includes Ndb_conflict_trans_row_conflict_count and any rows included in or dependent on conflicting transactions.		
ndb_deferred_constraints		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies that constraint checks should be deferred (where these are supported). Not normally needed or used; for testing purposes only.		
ndb_distribution		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH)		
ndb_eventbuffer_max_alloc		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Maximum memory that can be allocated for buffering events by the NDB API. Defaults to 0 (no limit).		
Ndb_execute_count		
No	No	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	No
DESCRIPTION: Provides the number of round trips to the NDB kernel made by operations		
ndb_extra_logging		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Controls logging of MySQL Cluster schema, connection, and data distribution events in the MySQL error log		
ndb_force_send		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Forces sending of buffers to NDB immediately, without waiting for other threads		
ndb_index_stat_cache_entries		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Sets the granularity of the statistics by determining the number of starting and ending keys		
ndb_index_stat_enable		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Use NDB index statistics in query optimization		
ndb_index_stat_option		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Comma-separated list of tunable options for NDB index statistics; the list should contain no spaces		
ndb_index_stat_update_freq		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: How often to query data nodes instead of the statistics cache		
ndb_join_pushdown		
No	Yes	No
No	Both	Yes
DESCRIPTION: Enables pushing down of joins to data nodes		
ndb_log_apply_status		
Yes	Yes	No
Yes	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Whether or not a MySQL server acting as a slave logs mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID.		
ndb_log_bin		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Write updates to NDB tables in the binary log. Effective only if binary logging is enabled with --log-bin.		
ndb_log_binlog_index		
Yes	Yes	No
No	Global	Yes
DESCRIPTION: Insert mapping between epochs and binary log positions into the ndb_binlog_index table. Defaults to ON. Effective only if binary logging is enabled on the server.		
ndb_log_empty_epochs		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: When enabled, epochs in which there were no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.		
ndb_log_orig		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Whether the id and epoch of the originating server are recorded in the mysql.ndb_binlog_index table. Set using the --ndb-log-orig option when starting mysqld.		
ndb_log_transaction_id		
No	Yes	No
No	Global	No
DESCRIPTION: Whether NDB transaction IDs are written into the binary log. (Read-only.)		
ndb_log_updated_only		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Log complete rows (ON) or updates only (OFF)		
Ndb_number_of_data_nodes		
No	No	Yes
No	Global	No
DESCRIPTION: If the server is part of a MySQL Cluster, the value of this variable is the number of data nodes in the cluster		
ndb_optimization_delay		
No	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	Yes
DESCRIPTION: Sets the number of milliseconds to wait between processing sets of rows by OPTIMIZE TABLE on NDB tables.		
	ndb_optimized_node_selection	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Determines how an SQL node chooses a cluster data node to use as transaction coordinator		
	Ndb_pruned_scan_count	
No	No	Yes
No	Global	No
DESCRIPTION: Number of scans executed by NDB since the cluster was last started where partition pruning could be used		
	Ndb_pushed_queries_defined	
No	No	Yes
No	Global	No
DESCRIPTION: Number of joins that API nodes have attempted to push down to the data nodes		
	Ndb_pushed_queries_dropped	
No	No	Yes
No	Global	No
DESCRIPTION: Number of joins that API nodes have tried to push down, but failed		
	Ndb_pushed_queries_executed	
No	No	Yes
No	Global	No
DESCRIPTION: Number of joins successfully pushed down and executed on the data nodes		
	Ndb_pushed_reads	
No	No	Yes
No	Global	No
DESCRIPTION: Number of reads executed on the data nodes by pushed-down joins		
	ndb_report_thresh_binlog_epoch_slip	
Yes	No	No
Yes		No
DESCRIPTION: This is a threshold on the number of epochs to be behind before reporting binary log status		
	ndb_report_thresh_binlog_mem_usage	
Yes	No	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes		No
DESCRIPTION: This is a threshold on the percentage of free memory remaining before reporting binary log status		
Ndb_scan_count		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of scans executed by NDB since the cluster was last started		
ndb_table_no_logging		
No	Yes	No
No	Session	Yes
DESCRIPTION: NDB tables created when this setting is enabled are not checkpointed to disk (although table schema files are created). The setting in effect when the table is created with or altered to use NDBCLUSTER persists for the lifetime of the table.		
ndb_table_temporary		
No	Yes	No
No	Session	Yes
DESCRIPTION: NDB tables are not persistent on disk: no schema files are created and the tables are not logged		
ndb_use_exact_count		
No	Yes	No
No	Both	Yes
DESCRIPTION: Use exact row count when planning queries		
ndb_use_transactions		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query		
ndb_version		
No	Yes	No
No	Global	No
DESCRIPTION: Shows build and NDB engine version as an integer.		
ndb_version_string		
No	Yes	No
No	Global	No
DESCRIPTION: Shows build information including NDB engine version in ndb-x.y.z format.		
ndbcluster		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	No	No
Yes		No
DESCRIPTION: Enable NDB Cluster (if this version of MySQL supports it)		
Disabled by `--skip-ndbcluster`		
ndbinfo_database		
No	Yes	No
No	Global	No
DESCRIPTION: The name used for the NDB information database; read only.		
ndbinfo_max_bytes		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Used for debugging only.		
ndbinfo_max_rows		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Used for debugging only.		
ndbinfo_offline		
No	Yes	No
No	Global	Yes
DESCRIPTION: Put the ndbinfo database into offline mode, in which no rows are returned from tables or views.		
ndbinfo_show_hidden		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Whether to show ndbinfo internal base tables in the mysql client. The default is OFF.		
ndbinfo_table_prefix		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: The prefix to use for naming ndbinfo internal base tables		
ndbinfo_version		
No	Yes	No
No	Global	No
DESCRIPTION: The version of the ndbinfo engine; read only.		
server-id-bits		
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	No
DESCRIPTION: Sets the number of least significant bits in the server_id actually used for identifying the server, permitting NDB API applications to store application data in the most significant bits. server_id must be less than 2 to the power of this value.		
	`server_id_bits`	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The effective value of server_id if the server was started with the --server-id-bits option set to a nondefault value.		
	`slave_allow_batching`	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Turns update batching on and off for a replication slave		
	`transaction_allow_batching`	
No	Yes	No
No	Session	Yes
DESCRIPTION: Allows batching of statements within a transaction. Disable AUTOCOMMIT to use.		

17.3.3 MySQL Cluster Configuration Files

Configuring MySQL Cluster requires working with two files:

- `my.cnf`: Specifies options for all MySQL Cluster executables. This file, with which you should be familiar with from previous work with MySQL, must be accessible by each executable running in the cluster.

- `config.ini`: This file, sometimes known as the *global configuration file*, is read only by the MySQL Cluster management server, which then distributes the information contained therein to all processes participating in the cluster. `config.ini` contains a description of each node involved in the cluster. This includes configuration parameters for data nodes and configuration parameters for connections between all nodes in the cluster. For a quick reference to the sections that can appear in this file, and what sorts of configuration parameters may be placed in each section, see Sections of the `config.ini` File.

Caching of configuration data. Beginning with MySQL Cluster NDB 6.4.0, MySQL Cluster uses *stateful configuration*. The global configuration file is no longer read every time the management server is restarted. Instead, the management server caches the configuration the first time it is started, and thereafter, the global configuration file is read only when one of the following items is true:

- **The management server is started using the --initial option.** When `--initial` is used, the global configuration file is re-read, any existing cache files are deleted, and the management server creates a new configuration cache.

- **The management server is started using the --reload option.** The `--reload` option causes the management server to compare its cache with the global configuration file. If they differ, the management server creates a new configuration cache; any existing configuration cache is preserved,

but not used. If the management server's cache and the global configuration file contain the same configuration data, then the existing cache is used, and no new cache is created.

- **The management server is started using --config-cache=FALSE.**   Beginning with MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, this disables `--config-cache` (enabled by default), and can be used to force the management server to bypass configuration caching altogether. In this case, the management server ignores any configuration files that may be present, always reading its configuration data from the `config.ini` file instead.

- **No configuration cache is found.**   In this case, the management server reads the global configuration file and creates a cache containing the same configuration data as found in the file.

Configuration cache files.   Beginning with MySQL Cluster 6.4.0, the management server by default creates configuration cache files in a directory named `mysql-cluster` in the MySQL installation directory. (If you build MySQL Cluster from source on a Unix system, the default location is `/usr/local/mysql-cluster`.) This can be overridden at runtime by starting the management server with the `--configdir` option. Configuration cache files are binary files named according to the pattern `ndb_node_id_config.bin.seq_id`, where `node_id` is the management server's node ID in the cluster, and `seq_id` is a cache idenitifer. Cache files are numbered sequentially using `seq_id`, in the order in which they are created. The management server uses the latest cache file as determined by the `seq_id`.

> **Note**
>
> It is possible to roll back to a previous configuration by deleting later configuration cache files, or by renaming an earlier cache file so that it has a higher `seq_id`. However, since configuration cache files are written in a binary format, you should not attempt to edit their contents by hand.

For more information about the `--configdir`, `--config-cache`, `--initial`, and `--reload` options for the MySQL Cluster management server, see Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon".

We are continuously making improvements in Cluster configuration and attempting to simplify this process. Although we strive to maintain backward compatibility, there may be times when introduce an incompatible change. In such cases we will try to let Cluster users know in advance if a change is not backward compatible. If you find such a change and we have not documented it, please report it in the MySQL bugs database using the instructions given in Section 1.7, "How to Report Bugs or Problems".

17.3.3.1 MySQL Cluster Configuration: Basic Example

To support MySQL Cluster, you will need to update `my.cnf` as shown in the following example. You may also specify these parameters on the command line when invoking the executables.

> **Note**
>
> The options shown here should not be confused with those that are used in `config.ini` global configuration files. Global configuration options are discussed later in this section.

```
# my.cnf
# example additions to my.cnf for MySQL Cluster
# (valid in MySQL 5.1)

# enable ndbcluster storage engine, and provide connection string for
```

```
# management server host (default port is 1186)
[mysqld]
ndbcluster
ndb-connectstring=ndb_mgmd.mysql.com


# provide connection string for management server host (default port: 1186)
[ndbd]
connect-string=ndb_mgmd.mysql.com

# provide connection string for management server host (default port: 1186)
[ndb_mgm]
connect-string=ndb_mgmd.mysql.com

# provide location of cluster configuration file
[ndb_mgmd]
config-file=/etc/config.ini
```

(For more information on connection strings, see Section 17.3.3.3, "MySQL Cluster Connection Strings".)

```
# my.cnf
# example additions to my.cnf for MySQL Cluster
# (will work on all versions)

# enable ndbcluster storage engine, and provide connection string for management
# server host to the default port 1186
[mysqld]
ndbcluster
ndb-connectstring=ndb_mgmd.mysql.com:1186
```

> **Important**
>
> Once you have started a `mysqld` process with the `NDBCLUSTER` and `ndb-connectstring` parameters in the `[mysqld]` in the `my.cnf` file as shown previously, you cannot execute any `CREATE TABLE` or `ALTER TABLE` statements without having actually started the cluster. Otherwise, these statements will fail with an error. *This is by design*.

You may also use a separate `[mysql_cluster]` section in the cluster `my.cnf` file for settings to be read and used by all executables:

```
# cluster-specific settings
[mysql_cluster]
ndb-connectstring=ndb_mgmd.mysql.com:1186
```

For additional `NDB` variables that can be set in the `my.cnf` file, see MySQL Cluster System Variables.

The MySQL Cluster global configuration file is by convention named `config.ini` (but this is not required). It is read by `ndb_mgmd` at startup and can be placed in any location that can be read by it. The location and name of the configuration are specified using `--config-file=path_name` with `ndb_mgmd` on the command line. Beginning with MySQL Cluster NDB 6.4.0, this option has no default value, and is ignored if `ndb_mgmd` uses the configuration cache.

The global configuration file for MySQL Cluster uses INI format, which consists of sections preceded by section headings (surrounded by square brackets), followed by the appropriate parameter names and values. One deviation from the standard INI format is that the parameter name and value can be separated by a colon ("`:`") as well as the equal sign ("`=`"); however, the equal sign is preferred. Another deviation is that sections are not uniquely identified by section name. Instead, unique sections (such as two different nodes of the same type) are identified by a unique ID specified as a parameter within the section.

Default values are defined for most parameters, and can also be specified in `config.ini`. (Prior to MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.6, there was no default value for `NoOfReplicas`, which always had to be specified explicitly in the `[ndbd default]` section. Beginning with versions just stated, the default value is 2, which is the recommended setting in most common usage scenarios.) To create a default value section, simply add the word `default` to the section name. For example, an `[ndbd]` section contains parameters that apply to a particular data node, whereas an `[ndbd default]` section contains parameters that apply to all data nodes. Suppose that all data nodes should use the same data memory size. To configure them all, create an `[ndbd default]` section that contains a `DataMemory` line to specify the data memory size.

The global configuration file must define the computers and nodes involved in the cluster and on which computers these nodes are located. An example of a simple configuration file for a cluster consisting of one management server, two data nodes and two SQL nodes is shown here:

```
# file "config.ini" - 2 data nodes and 2 SQL nodes
# This file is placed in the startup directory of ndb_mgmd (the
# management server)
# The first SQL node can be started from any host. The second
# can be started only on the host mysqld_5.mysql.com

[ndbd default]
NoOfReplicas= 2
DataDir= /var/lib/mysql-cluster

[ndb_mgmd]
Hostname= ndb_mgmd.mysql.com
DataDir= /var/lib/mysql-cluster

[ndbd]
HostName= ndbd_2.mysql.com

[ndbd]
HostName= ndbd_3.mysql.com

[mysqld]
[mysqld]
HostName= mysqld_5.mysql.com
```

> **Note**
>
> The preceding example is intended as a minimal starting configuration for purposes of familiarization with MySQL Cluster, and is almost certain not to be sufficient for production settings. See Section 17.3.3.2, "Recommended Starting Configurations for MySQL Cluster NDB 6.2 and Later", which provides more complete example starting configurations for use with MySQL Cluster NDB 6.2 and newer versions of MySQL Cluster.

Each node has its own section in the `config.ini` file. For example, this cluster has two data nodes, so the preceding configuration file contains two `[ndbd]` sections defining these nodes.

> **Note**
>
> Do not place comments on the same line as a section heading in the `config.ini` file; this causes the management server not to start because it cannot parse the configuration file in such cases.

Sections of the config.ini File

There are six different sections that you can use in the `config.ini` configuration file, as described in the following list:

- `[computer]`: Defines cluster hosts. This is not required to configure a viable MySQL Cluster, but be may used as a convenience when setting up a large cluster. See Section 17.3.3.4, "Defining Computers in a MySQL Cluster", for more information.

- `[ndbd]`: Defines a cluster data node (`ndbd` process). See Section 17.3.3.6, "Defining MySQL Cluster Data Nodes", for details.

- `[mysqld]`: Defines the cluster's MySQL server nodes (also called SQL or API nodes). For a discussion of SQL node configuration, see Section 17.3.3.7, "Defining SQL and Other API Nodes in a MySQL Cluster".

- `[mgm]` or `[ndb_mgmd]`: Defines a cluster management server (MGM) node. For information concerning the configuration of management nodes, see Section 17.3.3.5, "Defining a MySQL Cluster Management Server".

- `[tcp]`: Defines a TCP/IP connection between cluster nodes, with TCP/IP being the default connection protocol. Normally, `[tcp]` or `[tcp default]` sections are not required to set up a MySQL Cluster, as the cluster handles this automatically; however, it may be necessary in some situations to override the defaults provided by the cluster. See Section 17.3.3.9, "MySQL Cluster TCP/IP Connections", for information about available TCP/IP configuration parameters and how to use them. (You may also find Section 17.3.3.10, "MySQL Cluster TCP/IP Connections Using Direct Connections" to be of interest in some cases.)

- `[shm]`: Defines shared-memory connections between nodes. In MySQL 5.1, it is enabled by default, but should still be considered experimental. For a discussion of SHM interconnects, see Section 17.3.3.11, "MySQL Cluster Shared-Memory Connections".

- `[sci]`:Defines *Scalable Coherent Interface* connections between cluster data nodes. Such connections require software which, while freely available, is not part of the MySQL Cluster distribution, as well as specialized hardware. See Section 17.3.3.12, "SCI Transport Connections in MySQL Cluster" for detailed information about SCI interconnects.

You can define `default` values for each section. All Cluster parameter names are case-insensitive, which differs from parameters specified in `my.cnf` or `my.ini` files.

17.3.3.2 Recommended Starting Configurations for MySQL Cluster NDB 6.2 and Later

Achieving the best performance from a MySQL Cluster depends on a number of factors including the following:

- MySQL Cluster software version

- Numbers of data nodes and SQL nodes

- Hardware

- Operating system

- Amount of data to be stored

- Size and type of load under which the cluster is to operate

Therefore, obtaining an optimum configuration is likely to be an iterative process, the outcome of which can vary widely with the specifics of each MySQL Cluster deployment. Changes in configuration are also likely to be indicated when changes are made in the platform on which the cluster is run, or in applications that use the MySQL Cluster's data. For these reasons, it is not possible to offer a single configuration that is ideal for all usage scenarios. However, in this section, we provide recommended base configurations for MySQL Cluster NDB 6.2 and 6.3 that can serve as reasonable starting points.

Starting configuration for MySQL Cluster NDB 6.2.   The following is a recommended starting point for configuring a cluster running MySQL Cluster NDB 6.2.

```
# TCP PARAMETERS

[tcp default]
SendBufferMemory=2M
ReceiveBufferMemory=2M

# Increasing the sizes of these 2 buffers beyond the default values
# helps prevent bottlenecks due to slow disk I/O.

# MANAGEMENT NODE PARAMETERS

[ndb_mgmd default]
DataDir=path/to/management/server/data/directory

# It is possible to use a different data directory for each management
# server, but for ease of administration it is preferable to be
# consistent.

[ndb_mgmd]
HostName=management-server-1-hostname
# NodeId=management-server-1-nodeid

[ndb_mgmd]
HostName=management-server-2-hostname

# Using 2 management servers helps guarantee that there is always an
# arbitrator in the event of network partitioning, and so is
# recommended for high availability. Each management server must be
# identified by a HostName. You may for the sake of convenience specify
# a node ID for any management server, although one will be allocated
# for it automatically; if you do so, it must be in the range 1-255
# inclusive and must be unique among all IDs specified for cluster
# nodes.

# DATA NODE PARAMETERS

[ndbd default]
NoOfReplicas=2

# Using 2 replicas is recommended to guarantee availability of data;
# using only 1 replica does not provide any redundancy, which means
# that the failure of a single data node causes the entire cluster to
# shut down. We do not recommend using more than 2 replicas, since 2 is
# sufficient to provide high availability, and we do not currently test
# with greater values for this parameter.

LockPagesInMainMemory=1

# On Linux and Solaris systems, setting this parameter locks data node
# processes into memory. Doing so prevents them from swapping to disk,
# which can severely degrade cluster performance.

DataMemory=3072M
IndexMemory=384M

# The values provided for DataMemory and IndexMemory assume 4 GB RAM
# per data node. However, for best results, you should first calculate
# the memory that would be used based on the data you actually plan to
# store (you may find the ndb_size.pl utility helpful in estimating
# this), then allow an extra 20% over the calculated values. Naturally,
# you should ensure that each data node host has at least as much
# physical memory as the sum of these two values.
```

```
# ODirect=1

# Enabling this parameter causes NDBCLUSTER to try using O_DIRECT
# writes for local checkpoints and redo logs; this can reduce load on
# CPUs. We recommend doing so when using MySQL Cluster NDB 6.2.3 or
# newer on systems running Linux kernel 2.6 or later.

NoOfFragmentLogFiles=300
DataDir=path/to/data/node/data/directory
MaxNoOfConcurrentOperations=100000
TimeBetweenGlobalCheckpoints=1000
TimeBetweenEpochs=200
DiskCheckpointSpeed=10M
DiskCheckpointSpeedInRestart=100M
RedoBuffer=32M
# MaxNoOfLocalScans=64
MaxNoOfTables=1024
MaxNoOfOrderedIndexes=256

[ndbd]
HostName=data-node-A-hostname
# NodeId=data-node-A-nodeid

[ndbd]
HostName=data-node-B-hostname
# NodeId=data-node-B-nodeid

# You must have an [ndbd] section for every data node in the cluster;
# each of these sections must include a HostName. Each section may
# optionally include an Id for convenience, but in most cases, it is
# sufficient to allow the cluster to allocate node IDs dynamically. If
# you do specify the node ID for a data node, it must be in the range 1
# to 48 inclusive and must be unique among all IDs specified for
# cluster nodes.

# SQL NODE / API NODE PARAMETERS

[mysqld]
# HostName=SQL-node-1-hostname
# NodeId=sql-node-A-nodeid

[mysqld]

[mysqld]

# Each API or SQL node that connects to the cluster requires a [mysqld]
# or [api] section of its own. Each such section defines a connection
# "slot"; you should have at least as many of these sections in the
# config.ini file as the total number of API nodes and SQL nodes that
# you wish to have connected to the cluster at any given time. There is
# no performance or other penalty for having extra slots available in
# case you find later that you want or need more API or SQL nodes to
# connect to the cluster at the same time.
# If no HostName is specified for a given [mysqld] or [api] section,
# then any API or SQL node may use that slot to connect to the
# cluster. You may wish to use an explicit HostName for one connection slot
# to guarantee that an API or SQL node from that host can always
# connect to the cluster. If you wish to prevent API or SQL nodes from
# connecting from other than a desired host or hosts, then use a
# HostName for every [mysqld] or [api] section in the config.ini file.
# You can if you wish define a node ID (Id parameter) for any API or
# SQL node, but this is not necessary; if you do so, it must be in the
# range 1 to 255 inclusive and must be unique among all IDs specified
# for cluster nodes.
```

Starting configuration for MySQL Cluster NDB 6.3. The following is a recommended starting point for configuring a cluster running MySQL Cluster NDB 6.3. It is similar to the recommendation for MySQL Cluster NDB 6.2, with the addition of parameters for better control of NDBCLUSTER process threads.

```
# TCP PARAMETERS

[tcp default]
SendBufferMemory=2M
ReceiveBufferMemory=2M

# Increasing the sizes of these 2 buffers beyond the default values
# helps prevent bottlenecks due to slow disk I/O.

# MANAGEMENT NODE PARAMETERS

[ndb_mgmd default]
DataDir=path/to/management/server/data/directory

# It is possible to use a different data directory for each management
# server, but for ease of administration it is preferable to be
# consistent.

[ndb_mgmd]
HostName=management-server-A-hostname
# NodeId=management-server-A-nodeid

[ndb_mgmd]
HostName=management-server-B-hostname
# NodeId=management-server-B-nodeid

# Using 2 management servers helps guarantee that there is always an
# arbitrator in the event of network partitioning, and so is
# recommended for high availability. Each management server must be
# identified by a HostName. You may for the sake of convenience specify
# a NodeId for any management server, although one will be allocated
# for it automatically; if you do so, it must be in the range 1-255
# inclusive and must be unique among all IDs specified for cluster
# nodes.

# DATA NODE PARAMETERS

[ndbd default]
NoOfReplicas=2

# Using 2 replicas is recommended to guarantee availability of data;
# using only 1 replica does not provide any redundancy, which means
# that the failure of a single data node causes the entire cluster to
# shut down. We do not recommend using more than 2 replicas, since 2 is
# sufficient to provide high availability, and we do not currently test
# with greater values for this parameter.

LockPagesInMainMemory=1

# On Linux and Solaris systems, setting this parameter locks data node
# processes into memory. Doing so prevents them from swapping to disk,
# which can severely degrade cluster performance.

DataMemory=3072M
IndexMemory=384M

# The values provided for DataMemory and IndexMemory assume 4 GB RAM
# per data node. However, for best results, you should first calculate
# the memory that would be used based on the data you actually plan to
# store (you may find the ndb_size.pl utility helpful in estimating
# this), then allow an extra 20% over the calculated values. Naturally,
```

```
# you should ensure that each data node host has at least as much
# physical memory as the sum of these two values.

# ODirect=1

# Enabling this parameter causes NDBCLUSTER to try using O_DIRECT
# writes for local checkpoints and redo logs; this can reduce load on
# CPUs. We recommend doing so when using MySQL Cluster NDB 6.2.3 or
# newer on systems running Linux kernel 2.6 or later.

NoOfFragmentLogFiles=300
DataDir=path/to/data/node/data/directory
MaxNoOfConcurrentOperations=100000

SchedulerSpinTimer=400
SchedulerExecutionTimer=100
RealTimeScheduler=1
# Setting these parameters allows you to take advantage of real-time scheduling
# of NDB threads (introduced in MySQL Cluster NDB 6.3.4) to achieve increased
# throughput when using ndbd. They are not needed when using ndbmtd; in
# particular, you should not set RealTimeScheduler for ndbmtd data nodes.

TimeBetweenGlobalCheckpoints=1000
TimeBetweenEpochs=200
DiskCheckpointSpeed=10M
DiskCheckpointSpeedInRestart=100M
RedoBuffer=32M

# CompressedLCP=1
# CompressedBackup=1
# Enabling CompressedLCP and CompressedBackup causes, respectively, local
checkpoint files and backup files to be compressed, which can result in a space
savings of up to 50% over noncompressed LCPs and backups.

# MaxNoOfLocalScans=64
MaxNoOfTables=1024
MaxNoOfOrderedIndexes=256

[ndbd]
HostName=data-node-A-hostname
# NodeId=data-node-A-nodeid

LockExecuteThreadToCPU=1
LockMaintThreadsToCPU=0
# On systems with multiple CPUs, these parameters can be used to lock NDBCLUSTER
# threads to specific CPUs

[ndbd]
HostName=data-node-B-hostname
# NodeId=data-node-B-nodeid

LockExecuteThreadToCPU=1
LockMaintThreadsToCPU=0

# You must have an [ndbd] section for every data node in the cluster;
# each of these sections must include a HostName. Each section may
# optionally include a NodeId for convenience, but in most cases, it is
# sufficient to allow the cluster to allocate node IDs dynamically. If
# you do specify the node ID for a data node, it must be in the range 1
# to 48 inclusive and must be unique among all IDs specified for
# cluster nodes.

# SQL NODE / API NODE PARAMETERS

[mysqld]
# HostName=sql-node-A-hostname
# NodeId=sql-node-A-nodeid
```

```
[mysqld]

[mysqld]

# Each API or SQL node that connects to the cluster requires a [mysqld]
# or [api] section of its own. Each such section defines a connection
# "slot"; you should have at least as many of these sections in the
# config.ini file as the total number of API nodes and SQL nodes that
# you wish to have connected to the cluster at any given time. There is
# no performance or other penalty for having extra slots available in
# case you find later that you want or need more API or SQL nodes to
# connect to the cluster at the same time.
# If no HostName is specified for a given [mysqld] or [api] section,
# then any API or SQL node may use that slot to connect to the
# cluster. You may wish to use an explicit HostName for one connection slot
# to guarantee that an API or SQL node from that host can always
# connect to the cluster. If you wish to prevent API or SQL nodes from
# connecting from other than a desired host or hosts, then use a
# HostName for every [mysqld] or [api] section in the config.ini file.
# You can if you wish define a node ID (NodeId parameter) for any API or
# SQL node, but this is not necessary; if you do so, it must be in the
# range 1 to 255 inclusive and must be unique among all IDs specified
# for cluster nodes.
```

Recommended my.cnf options for SQL nodes. MySQL Servers acting as MySQL Cluster SQL nodes must always be started with the `--ndbcluster` and `--ndb-connectstring` options, either on the command line or in `my.cnf`. In addition, set the following options for all `mysqld` processes in the cluster, unless your setup requires otherwise:

- `--ndb-use-exact-count=0`

- `--ndb-index-stat-enable=0`

- `--ndb-force-send=1`

- `--engine-condition-pushdown=1`

17.3.3.3 MySQL Cluster Connection Strings

With the exception of the MySQL Cluster management server (`ndb_mgmd`), each node that is part of a MySQL Cluster requires a *connection string* that points to the management server's location. This connection string is used in establishing a connection to the management server as well as in performing other tasks depending on the node's role in the cluster. The syntax for a connection string is as follows:

```
[nodeid=node_id, ]host-definition[, host-definition[, ...]]

host-definition:
    host_name[:port_number]
```

`node_id` is an integer greater than or equal to 1 which identifies a node in `config.ini`. `host_name` is a string representing a valid Internet host name or IP address. `port_number` is an integer referring to a TCP/IP port number.

```
example 1 (long):    "nodeid=2,myhost1:1100,myhost2:1100,192.168.0.3:1200"
example 2 (short):   "myhost1"
```

`localhost:1186` is used as the default connection string value if none is provided. If `port_num` is omitted from the connection string, the default port is 1186. This port should always be available on the network because it has been assigned by IANA for this purpose (see http://www.iana.org/assignments/port-numbers for details).

By listing multiple host definitions, it is possible to designate several redundant management servers. A MySQL Cluster data or API node attempts to contact successive management servers on each host in the order specified, until a successful connection has been established.

Beginning with MySQL Cluster NDB 6.3.19, it is also possible in a connection string to specify one or more bind addresses to be used by nodes having multiple network interfaces for connecting to management servers. A bind address consists of a hostname or network address and an optional port number. This enhanced syntax for connection strings is shown here:

```
[nodeid=node_id, ]
    [bind-address=host-definition, ]
    host-definition[; bind-address=host-definition]
    host-definition[; bind-address=host-definition]
    [, ...]]

host-definition:
    host_name[:port_number]
```

If a single bind address is used in the connection string *prior* to specifying any management hosts, then this address is used as the default for connecting to any of them (unless overridden for a given management server; see later in this section for an example). For example, the following connection string causes the node to use 192.168.178.242 regardless of the management server to which it connects:

```
bind-address=192.168.178.242, poseidon:1186, perch:1186
```

If a bind address is specified *following* a management host definition, then it is used only for connecting to that management node. Consider the following connection string:

```
poseidon:1186;bind-address=localhost, perch:1186;bind-address=192.168.178.242
```

In this case, the node uses localhost to connect to the management server running on the host named poseidon and 192.168.178.242 to connect to the management server running on the host named perch.

You can specify a default bind address and then override this default for one or more specific management hosts. In the following example, localhost is used for connecting to the management server running on host poseidon; since 192.168.178.242 is specified first (before any management server definitions), it is the default bind address and so is used for connecting to the management servers on hosts perch and orca:

```
bind-address=192.168.178.242,poseidon:1186;bind-address=localhost,perch:1186,orca:2200
```

There are a number of different ways to specify the connection string:

- Each executable has its own command-line option which enables specifying the management server at startup. (See the documentation for the respective executable.)

- It is also possible to set the connection string for all nodes in the cluster at once by placing it in a [mysql_cluster] section in the management server's my.cnf file.

- For backward compatibility, two other options are available, using the same syntax:

  1. Set the NDB_CONNECTSTRING environment variable to contain the connection string.

  2. Write the connection string for each executable into a text file named Ndb.cfg and place this file in the executable's startup directory.

However, these are now deprecated and should not be used for new installations.

The recommended method for specifying the connection string is to set it on the command line or in the `my.cnf` file for each executable.

Previous to MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, the maximum length of a connection string was 1024 characters.

17.3.3.4 Defining Computers in a MySQL Cluster

The `[computer]` section has no real significance other than serving as a way to avoid the need of defining host names for each node in the system. All parameters mentioned here are required.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	string	[none]	...	IS

This is a unique identifier, used to refer to the host computer elsewhere in the configuration file.

> **Important**
>
> The computer ID is *not* the same as the node ID used for a management, API, or data node. Unlike the case with node IDs, you cannot use `NodeId` in place of `Id` in the `[computer]` section of the `config.ini` file.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

This is the computer's hostname or IP address.

17.3.3.5 Defining a MySQL Cluster Management Server

The `[ndb_mgmd]` section is used to configure the behavior of the management server. If multiple management servers are employed, you can specify parameters common to all of them in an `[ndb_mgmd default]` section. `[mgm]` and `[mgm default]` are older aliases for these, supported for backward compatibility.

All parameters in the following list are optional and assume their default values if omitted.

> **Note**
>
> If neither the `ExecuteOnComputer` nor the `HostName` parameter is present, the default value `localhost` will be assumed for both.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 63	IS
NDB 6.1.1	unsigned	[none]	1 - 255	IS

Each node in the cluster has a unique identity. For a management node, this is represented by an integer value in the range 1 to 63 inclusive (previous to MySQL Cluster NDB 6.1.1), or in the range 1 to

255 inclusive (MySQL Cluster NDB 6.1.1 and later). This ID is used by all internal cluster messages for addressing the node, and so must be unique for each MySQL Cluster node, regardless of the type of node.

Note

Data node IDs must be less than 49, regardless of the MySQL Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for management nodes (and API nodes) to values greater than 48.

The use of the `Id` parameter for identifying management nodes is deprecated in favor of `NodeId` beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.39, MySQL Cluster NDB 7.0.20, and MySQL Cluster NDB 7.1.9. Although `Id` continues to be supported for backward compatibility, it now generates a warning.

- `NodeId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 63	IS
NDB 6.1.1	unsigned	[none]	1 - 255	IS

Each node in the cluster has a unique identity. For a management node, this is represented by an integer value in the range 1 to 63 inclusive (previous to MySQL Cluster NDB 6.1.1), or in the range 1 to 255 inclusive (MySQL Cluster NDB 6.1.1 and later). This ID is used by all internal cluster messages for addressing the node, and so must be unique for each MySQL Cluster node, regardless of the type of node.

Note

Data node IDs must be less than 49, regardless of the MySQL Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for management nodes (and API nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying management nodes beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.39, MySQL Cluster NDB 7.0.20, and MySQL Cluster NDB 7.1.9. Although `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used.

- `ExecuteOnComputer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name	[none]	...	S

This refers to the `Id` set for one of the computers defined in a `[computer]` section of the `config.ini` file.

- `PortNumber`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	1186	0 - 64K	S

This is the port number on which the management server listens for configuration requests and management commands.

- HostName

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

Specifying this parameter defines the hostname of the computer on which the management node is to reside. To specify a hostname other than `localhost`, either this parameter or `ExecuteOnComputer` is required.

- LogDestination

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	{CONSOLE|SYSLOG|FILE}	[see text]	...	N

This parameter specifies where to send cluster logging information. There are three options in this regard—`CONSOLE`, `SYSLOG`, and `FILE`—with `FILE` being the default:

- `CONSOLE` outputs the log to `stdout`:

```
CONSOLE
```

- `SYSLOG` sends the log to a `syslog` facility, possible values being one of `auth`, `authpriv`, `cron`, `daemon`, `ftp`, `kern`, `lpr`, `mail`, `news`, `syslog`, `user`, `uucp`, `local0`, `local1`, `local2`, `local3`, `local4`, `local5`, `local6`, or `local7`.

> **Note**
>
> Not every facility is necessarily supported by every operating system.

```
SYSLOG:facility=syslog
```

- `FILE` pipes the cluster log output to a regular file on the same machine. The following values can be specified:

  - `filename`: The name of the log file.

    Prior to MySQL Cluster NDB 7.0.43 and MySQL Cluster NDB 7.1.23, the log file's default name, used if `FILE` was specified without also setting `filename`, was `logger.log`. Beginning with MySQL Cluster NDB 7.0.43 and MySQL Cluster NDB 7.1.23, the default log file name used in such cases is `ndb_nodeid_cluster.log`.

  - `maxsize`: The maximum size (in bytes) to which the file can grow before logging rolls over to a new file. When this occurs, the old log file is renamed by appending `.N` to the file name, where N is the next number not yet used with this name.

  - `maxfiles`: The maximum number of log files.

```
FILE:filename=cluster.log,maxsize=1000000,maxfiles=6
```

The default value for the `FILE` parameter is `FILE:filename=ndb_node_id_cluster.log,maxsize=1000000,maxfiles=6`, where `node_id` is the ID of the node.

It is possible to specify multiple log destinations separated by semicolons as shown here:

```
CONSOLE;SYSLOG:facility=local0;FILE:filename=/var/log/mgmd
```

- `ArbitrationRank`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	0-2	1	0 - 2	N

This parameter is used to define which nodes can act as arbitrators. Only management nodes and SQL nodes can be arbitrators. `ArbitrationRank` can take one of the following values:

- `0`: The node will never be used as an arbitrator.

- `1`: The node has high priority; that is, it will be preferred as an arbitrator over low-priority nodes.

- `2`: Indicates a low-priority node which be used as an arbitrator only if a node with a higher priority is not available for that purpose.

Normally, the management server should be configured as an arbitrator by setting its `ArbitrationRank` to 1 (the default for management nodes) and those for all SQL nodes to 0 (the default for SQL nodes).

Beginning with MySQL 5.1.16 and MySQL Cluster NDB 6.1.3, it is possible to disable arbitration completely by setting `ArbitrationRank` to 0 on all management and SQL nodes. In MySQL Cluster NDB 7.0.7 and later releases, you can also control arbitration by overriding this parameter; to do this, set the `Arbitration` parameter in the `[ndbd default]` section of the `config.ini` global configuration file.

- `ArbitrationDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

An integer value which causes the management server's responses to arbitration requests to be delayed by that number of milliseconds. By default, this value is 0; it is normally not necessary to change it.

- `DataDir`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	path	.	...	N

This specifies the directory where output files from the management server will be placed. These files include cluster log files, process output files, and the daemon's process ID (PID) file. (For log files, this location can be overridden by setting the `FILE` parameter for `LogDestination` as discussed previously in this section.)

The default value for this parameter is the directory in which `ndb_mgmd` is located.

- `PortNumberStats`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	0 - 64K	N

This parameter specifies the port number used to obtain statistical information from a MySQL Cluster management server. It has no default value.

- **Wan**

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.1	boolean	false	true, false	N

Use WAN TCP setting as default. Introduced in MySQL Cluster NDB 6.1.1.

- **HeartbeatThreadPriority**

Beginning with MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2, it is possible to use this parameter to set the scheduling policy and priority of heartbeat threads for management and API nodes.

The syntax for setting this parameter is shown here:

```
HeartbeatThreadPriority = policy[, priority]

policy:
  {FIFO | RR}
```

When setting this parameter, you must specify a policy. This is one of `FIFO` (first in, first out) or `RR` (round robin). The policy value is followed optionally by the priority (an integer).

- **ExtraSendBufferMemory**

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.39	bytes	0	0 - 32G	N
NDB 7.1.28	bytes	0	0 - 32G	N

This parameter specifies the amount of transporter send buffer memory to allocate in addition to any that has been set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

This parameter was added in MySQL Cluster NDB 7.0.39 and MySQL Cluster NDB 7.1.28. (Bug #14555359)

- **TotalSendBufferMemory**

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	bytes	0	256K - 4294967039 (0xFFFFFEFF)	N

This parameter is available beginning with MySQL Cluster NDB 6.4.0. It is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

- `HeartbeatIntervalMgmdMgmd`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.40	milliseconds	1500	100 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.29	milliseconds	1500	100 - 4294967039 (0xFFFFFEFF)	N

Specify the interval between heartbeat messages used to determine whether another management node is on contact with this one. The management node waits after 3 of these intervals to declare the connection dead; thus, the default setting of 1500 milliseconds causes the management node to wait for approximately 1600 ms before timing out.

This parameter was added in MySQL Cluster NDB 7.0.40 and MySQL Cluster NDB 7.1.29. (Bug #16426805)

> **Note**
>
> After making changes in a management node's configuration, it is necessary to perform a rolling restart of the cluster for the new configuration to take effect.
>
> To add new management servers to a running MySQL Cluster, it is also necessary to perform a rolling restart of all cluster nodes after modifying any existing `config.ini` files. For more information about issues arising when using multiple management nodes, see Section 17.1.6.10, "Limitations Relating to Multiple MySQL Cluster Nodes".

17.3.3.6 Defining MySQL Cluster Data Nodes

The `[ndbd]` and `[ndbd default]` sections are used to configure the behavior of the cluster's data nodes.

`[ndbd]` and `[ndbd default]` are always used as the section names whether you are using `ndbd` or (in MySQL Cluster NDB 6.4.0 and later) `ndbmtd` binaries for the data node processes.

There are many parameters which control buffer sizes, pool sizes, timeouts, and so forth. The only mandatory parameters are:

- Either `ExecuteOnComputer` or `HostName`, which must be defined in the local `[ndbd]` section.

- The parameter `NoOfReplicas`, which must be defined in the `[ndbd default]` section, as it is common to all Cluster data nodes.

> **Note**
>
> It is no longer strictly necessary to set `NoOfReplicas` starting with MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.6, where it acquires a default value (2). However, it remains good practice to set it explicitly.

Most data node parameters are set in the `[ndbd default]` section. Only those parameters explicitly stated as being able to set local values are permitted to be changed in the `[ndbd]` section. Where

present, `HostName`, `NodeId` and `ExecuteOnComputer` *must* be defined in the local `[ndbd]` section, and not in any other section of `config.ini`. In other words, settings for these parameters are specific to one data node.

For those parameters affecting memory usage or buffer sizes, it is possible to use `K`, `M`, or `G` as a suffix to indicate units of 1024, 1024×1024, or 1024×1024×1024. (For example, `100K` means 100 × 1024 = 102400.) Parameter names and values are currently case-sensitive.

Information about configuration parameters specific to MySQL Cluster Disk Data tables can be found later in this section (see Disk Data Configuration Parameters).

Beginning with MySQL Cluster NDB 6.4.0, all of these parameters also apply to `ndbmtd` (the multi-threaded version of `ndbd`). Two additional data node configuration parameters —`MaxNoOfExecutionThreads` and `ThreadConfig`—apply to `ndbmtd` only; these have no effect when used with `ndbd`. For more information, see Multi-Threading Configuration Parameters (ndbmtd). See also Section 17.4.3, "ndbmtd — The MySQL Cluster Data Node Daemon (Multi-Threaded)".

Identifying data nodes.   The `NodeId` or `Id` value (that is, the data node identifier) can be allocated on the command line when the node is started or in the configuration file.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 48	IS

A unique node ID is used as the node's address for all cluster internal messages. For data nodes, this is an integer in the range 1 to 48 inclusive. Each node in the cluster must have a unique identifier.

`NodeId` is the preferred parameter name to use when identifying data nodes beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.39, MySQL Cluster NDB 7.0.20, and MySQL Cluster NDB 7.1.9. Although `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used.

- `NodeId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 48	IS

A unique node ID is used as the node's address for all cluster internal messages. For data nodes, this is an integer in the range 1 to 48 inclusive. Each node in the cluster must have a unique identifier.

`NodeId` is the preferred parameter name to use when identifying data nodes beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.39, MySQL Cluster NDB 7.0.20, and MySQL Cluster NDB 7.1.9. Although `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used.

- `ExecuteOnComputer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name	[none]	...	S

This refers to the `Id` set for one of the computers defined in a `[computer]` section.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	localhost	...	N

Specifying this parameter defines the hostname of the computer on which the data node is to reside. To specify a hostname other than `localhost`, either this parameter or `ExecuteOnComputer` is required.

- `ServerPort`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 64K	S

Each node in the cluster uses a port to connect to other nodes. By default, this port is allocated dynamically in such a way as to ensure that no two nodes on the same host computer receive the same port number, so it should normally not be necessary to specify a value for this parameter.

However, if you need to be able to open specific ports in a firewall to permit communication between data nodes and API nodes (including SQL nodes), you can set this parameter to the number of the desired port in an `[ndbd]` section or (if you need to do this for multiple data nodes) the `[ndbd default]` section of the `config.ini` file, and then open the port having that number for incoming connections from SQL nodes, API nodes, or both.

> **Note**
>
> Connections from data nodes to management nodes is done using the `ndb_mgmd` management port (the management server's `PortNumber`; see Section 17.3.3.5, "Defining a MySQL Cluster Management Server") so outgoing connections to that port from any data nodes should always be permitted.

- `TcpBind_INADDR_ANY`

Setting this parameter to `TRUE` or `1` binds `IP_ADDR_ANY` so that connections can be made from anywhere (for autogenerated connections). The default is `FALSE` (`0`).

This parameter was added in MySQL Cluster NDB 6.2.0.

- `NodeGroup`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0		[none]	0 - 65536	IS

This parameter can be used to assign a data node to a specific node group. It is read only when the cluster is started for the first time, and cannot be used to reassign a data node to a different node group online. It is generally not desirable to use this parameter in the `[ndbd default]` section of the `config.ini` file, and care must be taken not to assign nodes to node groups in such a way that an invalid numbers of nodes are assigned to any node groups.

The `NodeGroup` parameter is chiefly intended for use in adding a new node group to a running MySQL Cluster without having to perform a rolling restart. For this purpose, you should set it to 65536 (the maximum value). You are not required to set a `NodeGroup` value for all cluster data nodes, only for those nodes which are to be started and added to the cluster as a new node group at a later time. For more information, see Section 17.5.13.3, "Adding MySQL Cluster Data Nodes Online: Detailed Example".

This parameter was added in MySQL Cluster NDB 6.4.0.

- `NoOfReplicas`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	[none]	1 - 4	IS
NDB 6.3.25	integer	2	1 - 4	IS
NDB 7.0.6	integer	2	1 - 4	IS

This global parameter can be set only in the `[ndbd default]` section, and defines the number of replicas for each table stored in the cluster. This parameter also specifies the size of node groups. A node group is a set of nodes all storing the same information.

Node groups are formed implicitly. The first node group is formed by the set of data nodes with the lowest node IDs, the next node group by the set of the next lowest node identities, and so on. By way of example, assume that we have 4 data nodes and that `NoOfReplicas` is set to 2. The four data nodes have node IDs 2, 3, 4 and 5. Then the first node group is formed from nodes 2 and 3, and the second node group by nodes 4 and 5. It is important to configure the cluster in such a manner that nodes in the same node groups are not placed on the same computer because a single hardware failure would cause the entire cluster to fail.

If no node IDs are provided, the order of the data nodes will be the determining factor for the node group. Whether or not explicit assignments are made, they can be viewed in the output of the management client's `SHOW` command.

Prior to MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.6, there was no default value for `NoOfReplicas`; beginning with these versions, the default value is 2, which is the recommended setting in most common usage scenarios. (Bug #44746)

The maximum possible value is 4; *currently, only the values 1 and 2 are actually supported*.

> **Important**
>
> Setting `NoOfReplicas` to 1 means that there is only a single copy of all Cluster data; in this case, the loss of a single data node causes the cluster to fail because there are no additional copies of the data stored by that node.

The value for this parameter must divide evenly into the number of data nodes in the cluster. For example, if there are two data nodes, then `NoOfReplicas` must be equal to either 1 or 2, since 2/3 and 2/4 both yield fractional values; if there are four data nodes, then `NoOfReplicas` must be equal to 1, 2, or 4.

- `DataDir`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	path	.	...	IN

This parameter specifies the directory where trace files, log files, pid files and error logs are placed.

The default is the data node process working directory.

- `FileSystemPath`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	path	DataDir	...	IN

This parameter specifies the directory where all files created for metadata, REDO logs, UNDO logs (for Disk Data tables), and data files are placed. The default is the directory specified by `DataDir`.

> **Note**
>
> This directory must exist before the `ndbd` process is initiated.

The recommended directory hierarchy for MySQL Cluster includes `/var/lib/mysql-cluster`, under which a directory for the node's file system is created. The name of this subdirectory contains the node ID. For example, if the node ID is 2, this subdirectory is named `ndb_2_fs`.

- `BackupDataDir`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	path	[see text]	...	IN

This parameter specifies the directory in which backups are placed.

> **Important**
>
> The string '`/BACKUP`' is always appended to this value. For example, if you set the value of `BackupDataDir` to `/var/lib/cluster-data`, then all backups are stored under `/var/lib/cluster-data/BACKUP`. This also means that the *effective* default backup location is the directory named `BACKUP` under the location specified by the `FileSystemPath` parameter.

Data Memory, Index Memory, and String Memory

`DataMemory` and `IndexMemory` are `[ndbd]` parameters specifying the size of memory segments used to store the actual records and their indexes. In setting values for these, it is important to understand how `DataMemory` and `IndexMemory` are used, as they usually need to be updated to reflect actual usage by the cluster:

- `DataMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	80M	1M - 1024G	N

This parameter defines the amount of space (in bytes) available for storing database records. The entire amount specified by this value is allocated in memory, so it is extremely important that the machine has sufficient physical memory to accommodate it.

The memory allocated by `DataMemory` is used to store both the actual records and indexes. There is a 16-byte overhead on each record; an additional amount for each record is incurred because it is stored in a 32KB page with 128 byte page overhead (see below). There is also a small amount wasted per page due to the fact that each record is stored in only one page.

For variable-size table attributes in MySQL 5.1, the data is stored on separate data pages, allocated from `DataMemory`. Variable-length records use a fixed-size part with an extra overhead of 4 bytes to reference the variable-size part. The variable-size part has 2 bytes overhead plus 2 bytes per attribute.

Prior to MySQL Cluster NDB 7.0, the maximum record size was 8052 bytes; in MySQL Cluster NDB 7.0 and later, it is 14000 bytes.

The memory space defined by `DataMemory` is also used to store ordered indexes, which use about 10 bytes per record. Each table row is represented in the ordered index. A common error among users is to assume that all indexes are stored in the memory allocated by `IndexMemory`, but this is not the case: Only primary key and unique hash indexes use this memory; ordered indexes use the memory allocated by `DataMemory`. However, creating a primary key or unique hash index also creates an ordered index on the same keys, unless you specify `USING HASH` in the index creation statement. This can be verified by running `ndb_desc -d db_name table_name` in the management client.

MySQL Cluster can use a maximum of 512 MB for hash indexes per partition, which means in some cases it is possible to get `Table is full` errors in MySQL client applications even when `ndb_mgm -e "ALL REPORT MEMORYUSAGE"` shows significant free `DataMemory`. This can also pose a problem with data node restarts on nodes that are heavily loaded with data. You can force `NDB` to create extra partitions for MySQL Cluster tables and thus have more memory available for hash indexes by using the `MAX_ROWS` option for `CREATE TABLE`. In general, setting `MAX_ROWS` to twice the number of rows that you expect to store in the table should be sufficient. In MySQL Cluster 7.1.18 and later, you can also use the `MinFreePct` configuration parameter to help avoid problems with node restarts. (Bug #13436216)

The memory space allocated by `DataMemory` consists of 32KB pages, which are allocated to table fragments. Each table is normally partitioned into the same number of fragments as there are data nodes in the cluster. Thus, for each node, there are the same number of fragments as are set in `NoOfReplicas`.

In addition, due to the way in which new pages are allocated when the capacity of the current page is exhausted, there is an additional overhead of approximately 18.75%. When more `DataMemory` is required, more than one new page is allocated, according to the following formula:

```
number of new pages = FLOOR(number of current pages × 0.1875) + 1
```

For example, if 15 pages are currently allocated to a given table and an insert to this table requires additional storage space, the number of new pages allocated to the table is `FLOOR(15 × 0.1875) + 1 = FLOOR(2.8125) + 1 = 2 + 1 = 3`. Now 15 + 3 = 18 memory pages are allocated to the table. When the last of these 18 pages becomes full, `FLOOR(18 × 0.1875) + 1 = FLOOR(3.3750) + 1 = 3 + 1 = 4` new pages are allocated, so the total number of pages allocated to the table is now 22.

> **Note**
>
> The "18.75% + 1" overhead is no longer required beginning with MySQL Cluster NDB 6.2.3 and MySQL Cluster NDB 6.3.0.

Once a page has been allocated, it is currently not possible to return it to the pool of free pages, except by deleting the table. (This also means that `DataMemory` pages, once allocated to a given table, cannot be used by other tables.) Performing a node recovery also compresses the partition because all records are inserted into empty partitions from other live nodes.

The `DataMemory` memory space also contains UNDO information: For each update, a copy of the unaltered record is allocated in the `DataMemory`. There is also a reference to each copy in the ordered table indexes. Unique hash indexes are updated only when the unique index columns are updated, in which case a new entry in the index table is inserted and the old entry is deleted upon commit. For this reason, it is also necessary to allocate enough memory to handle the largest transactions performed by applications using the cluster. In any case, performing a few large transactions holds no advantage over using many smaller ones, for the following reasons:

- Large transactions are not any faster than smaller ones

- Large transactions increase the number of operations that are lost and must be repeated in event of transaction failure

- Large transactions use more memory

The default value for `DataMemory` is 80MB; the minimum is 1MB. There is no maximum size, but in reality the maximum size has to be adapted so that the process does not start swapping when the limit is reached. This limit is determined by the amount of physical RAM available on the machine and by the amount of memory that the operating system may commit to any one process. 32-bit operating systems are generally limited to 2−4GB per process; 64-bit operating systems can use more. For large databases, it may be preferable to use a 64-bit operating system for this reason.

- `IndexMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	18M	1M - 1T	N

This parameter controls the amount of storage used for hash indexes in MySQL Cluster. Hash indexes are always used for primary key indexes, unique indexes, and unique constraints. When defining a primary key or a unique index, two indexes are created, one of which is a hash index used for all tuple accesses as well as lock handling. This index is also used to enforce unique constraints.

You can estimate the size of a hash index using this formula:

```
size  = ( (fragments * 32K) + (rows * 18) )
          * replicas
```

fragments is the number of fragments, *replicas* is the number of replicas (normally 2), and *rows* is the number of rows. If a table has one million rows, 8 fragments, and 2 replicas, the expected index memory usage is calculated as shown here:

```
((8 * 32K) + (1000000 * 18)) * 2 = ((8 * 32768) + (1000000 * 18)) * 2
= (262144 + 18000000) * 2
= 18262144 * 2 = 36524288 bytes = ~35MB
```

The default value for `IndexMemory` is 18MB. The minimum is 1MB.

- `StringMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	% or bytes	0	0 - 4294967039 (0xFFFFFEFF)	S
MySQL 5.1.32	% or bytes	25	0 - 4294967039 (0xFFFFFEFF)	S
MySQL 5.1.6	% or bytes	5	0 - 4294967039 (0xFFFFFEFF)	S
NDB 7.2.1	% or bytes	25	0 - 4294967039 (0xFFFFFEFF)	S

This parameter determines how much memory is allocated for strings such as table names, and is specified in an `[ndbd]` or `[ndbd default]` section of the `config.ini` file. A value between `0` and `100` inclusive is interpreted as a percent of the maximum default value, which is calculated based on a number of factors including the number of tables, maximum table name size, maximum size of `.FRM` files, `MaxNoOfTriggers`, maximum column name size, and maximum default column value.

A value greater than `100` is interpreted as a number of bytes.

The default value is 25—that is, 25 percent of the default maximum. (Previously, prior to MySQL Cluster NDB 6.2.18, MySQL Cluster NDB 6.3.24, and MySQL Cluster NDB 7.0.5, the default value was 5; prior to MySQL 5.1.6, the default was 0.)

Under most circumstances, the default value should be sufficient, but when you have a great many Cluster tables (1000 or more), it is possible to get Error 773 `Out of string memory, please modify StringMemory config parameter: Permanent error: Schema error`, in which case you should increase this value. `25` (25 percent) is not excessive, and should prevent this error from recurring in all but the most extreme conditions.

The following example illustrates how memory is used for a table. Consider this table definition:

```
CREATE TABLE example (
  a INT NOT NULL,
  b INT NOT NULL,
  c INT NOT NULL,
  PRIMARY KEY(a),
  UNIQUE(b)
) ENGINE=NDBCLUSTER;
```

For each record, there are 12 bytes of data plus 12 bytes overhead. Having no nullable columns saves 4 bytes of overhead. In addition, we have two ordered indexes on columns `a` and `b` consuming roughly 10 bytes each per record. There is a primary key hash index on the base table using roughly 29 bytes per record. The unique constraint is implemented by a separate table with `b` as primary key and `a` as a column. This other table consumes an additional 29 bytes of index memory per record in the `example` table as well 8 bytes of record data plus 12 bytes of overhead.

Thus, for one million records, we need 58MB for index memory to handle the hash indexes for the primary key and the unique constraint. We also need 64MB for the records of the base table and the unique index table, plus the two ordered index tables.

You can see that hash indexes takes up a fair amount of memory space; however, they provide very fast access to the data in return. They are also used in MySQL Cluster to handle uniqueness constraints.

The only partitioning algorithm is hashing and ordered indexes are local to each node. Thus, ordered indexes cannot be used to handle uniqueness constraints in the general case.

An important point for both `IndexMemory` and `DataMemory` is that the total database size is the sum of all data memory and all index memory for each node group. Each node group is used to store replicated information, so if there are four nodes with two replicas, there will be two node groups. Thus, the total data memory available is 2 × `DataMemory` for each data node.

It is highly recommended that `DataMemory` and `IndexMemory` be set to the same values for all nodes. Data distribution is even over all nodes in the cluster, so the maximum amount of space available for any node can be no greater than that of the smallest node in the cluster.

`DataMemory` and `IndexMemory` can be changed, but decreasing either of these can be risky; doing so can easily lead to a node or even an entire MySQL Cluster that is unable to restart due to there being insufficient memory space. Increasing these values should be acceptable, but it is recommended that

such upgrades are performed in the same manner as a software upgrade, beginning with an update of the configuration file, and then restarting the management server followed by restarting each data node in turn.

MinFreePct.   Beginning with MySQL Cluster NDB 7.0.29 and MySQL Cluster NDB 7.1.18, a proportion (5% by default) of data node resources including `DataMemory` and `IndexMemory` is kept in reserve to insure that the data node does not exhaust its memory when performing a restart. This can be adjusted using the `MinFreePct` data node configuration parameter (default 5) introduced in the same versions of MySQL Cluster.

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.29	unsigned	5	0 - 100	N
NDB 7.1.18	unsigned	5	0 - 100	N
NDB 7.2.3	unsigned	5	0 - 100	N

Updates do not increase the amount of index memory used. Inserts take effect immediately; however, rows are not actually deleted until the transaction is committed.

Transaction parameters.   The next few `[ndbd]` parameters that we discuss are important because they affect the number of parallel transactions and the sizes of transactions that can be handled by the system. `MaxNoOfConcurrentTransactions` sets the number of parallel transactions possible in a node. `MaxNoOfConcurrentOperations` sets the number of records that can be in update phase or locked simultaneously.

Both of these parameters (especially `MaxNoOfConcurrentOperations`) are likely targets for users setting specific values and not using the default value. The default value is set for systems using small transactions, to ensure that these do not use excessive memory.

`MaxDMLOperationsPerTransaction`, added in MySQL Cluster NDB 7.0.26 and MySQL Cluster NDB 7.1.15, sets the maximum number of DML operations that can be performed in a given transaction.

- `MaxNoOfConcurrentTransactions`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	4096	32 - 4294967039 (0xFFFFFEFF)	N

Each cluster data node requires a transaction record for each active transaction in the cluster. The task of coordinating transactions is distributed among all of the data nodes. The total number of transaction records in the cluster is the number of transactions in any given node times the number of nodes in the cluster.

Transaction records are allocated to individual MySQL servers. Each connection to an SQL node requires at least one transaction record, plus an additional transaction object per table accessed by that connection. This means that a reasonable minimum for this parameter is

```
MaxNoOfConcurrentTransactions =
    (maximum number of tables accessed in any single transaction + 1)
    * number of cluster SQL nodes
```

Suppose that there are 10 SQL nodes using the cluster. A single join involving 10 tables requires 11 transaction records; if there are 10 such joins in a transaction, then 10 * 11 = 110 transaction records are required for this transaction, per SQL node, or 110 * 10 = 1100 transaction records total. Each data node can be expected to handle TotalNoOfConcurrentTransactions / number of data nodes. For a MySQL Cluster having 4 data nodes, this would mean setting `MaxNoOfConcurrentTransactions`

on each data node to 1100 / 4 = 275. In addition, you should provide for failure recovery by ensuring that a single node group can accommodate all concurrent transactions; in other words, that each data node's MaxNoOfConcurrentTransactions is sufficient to cover a number of transaction equal to TotalNoOfConcurrentTransactions / number of node groups. If this cluster has a single node group, then `MaxNoOfConcurrentTransactions` should be set to 1100 (the same as the total number of concurrent transactions for the entire cluster).

In addition, each transaction involves at least one operation; for this reason, the value set for `MaxNoOfConcurrentTransactions` should always be no more than the value of `MaxNoOfConcurrentOperations`.

This parameter must be set to the same value for all cluster data nodes. This is due to the fact that, when a data node fails, the oldest surviving node re-creates the transaction state of all transactions that were ongoing in the failed node.

It is possible to change this value using a rolling restart, but the amount of traffic on the cluster must be such that no more transactions occur than the lower of the old and new levels while this is taking place.

The default value is 4096.

- `MaxNoOfConcurrentOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	32K	32 - 4294967039 (0xFFFFFEFF)	N

It is a good idea to adjust the value of this parameter according to the size and number of transactions. When performing transactions which involve only a few operations and records, the default value for this parameter is usually sufficient. Performing large transactions involving many records usually requires that you increase its value.

Records are kept for each transaction updating cluster data, both in the transaction coordinator and in the nodes where the actual updates are performed. These records contain state information needed to find UNDO records for rollback, lock queues, and other purposes.

This parameter should be set to the number of records to be updated simultaneously in transactions, divided by the number of cluster data nodes. For example, in a cluster which has four data nodes and which is expected to handle one million concurrent updates using transactions, you should set this value to 1000000 / 4 = 250000. To help provide resiliency against failures, it is suggested that you set this parameter to a value that is high enough to permit an individual data node to handle the load for its node group. In other words, you should set the value equal to `total number of concurrent operations / number of node groups`. (In the case where there is a single node group, this is the same as the total number of concurrent operations for the entire cluster.)

Because each transaction always involves at least one operation, the value of `MaxNoOfConcurrentOperations` should always be greater than or equal to the value of `MaxNoOfConcurrentTransactions`.

Read queries which set locks also cause operation records to be created. Some extra space is allocated within individual nodes to accommodate cases where the distribution is not perfect over the nodes.

When queries make use of the unique hash index, there are actually two operation records used per record in the transaction. The first record represents the read in the index table and the second handles the operation on the base table.

The default value is 32768.

This parameter actually handles two values that can be configured separately. The first of these specifies how many operation records are to be placed with the transaction coordinator. The second part specifies how many operation records are to be local to the database.

A very large transaction performed on an eight-node cluster requires as many operation records in the transaction coordinator as there are reads, updates, and deletes involved in the transaction. However, the operation records of the are spread over all eight nodes. Thus, if it is necessary to configure the system for one very large transaction, it is a good idea to configure the two parts separately. `MaxNoOfConcurrentOperations` will always be used to calculate the number of operation records in the transaction coordinator portion of the node.

It is also important to have an idea of the memory requirements for operation records. These consume about 1KB per record.

- `MaxNoOfLocalOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	UNDEFINED	32 - 4294967039 (0xFFFFFEFF)	N

By default, this parameter is calculated as 1.1 × `MaxNoOfConcurrentOperations`. This fits systems with many simultaneous transactions, none of them being very large. If there is a need to handle one very large transaction at a time and there are many nodes, it is a good idea to override the default value by explicitly specifying this parameter.

- `MaxDMLOperationsPerTransaction`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.26	operations (DML)	4294967295	32 - 4294967295	N
NDB 7.1.15	operations (DML)	4294967295	32 - 4294967295	N

Added in MySQL Cluster NDB 7.0.26 and MySQL Cluster NDB 7.1.15, this parameter limits the size of a transaction. The transaction is aborted if it requires more than this many DML operations. The minimum number of operations per transaction is 32; however, you can set `MaxDMLOperationsPerTransaction` to 0 to disable any limitation on the number of DML operations per transaction. The maximum (and default) is 4294967295.

Transaction temporary storage. The next set of `[ndbd]` parameters is used to determine temporary storage when executing a statement that is part of a Cluster transaction. All records are released when the statement is completed and the cluster is waiting for the commit or rollback.

The default values for these parameters are adequate for most situations. However, users with a need to support transactions involving large numbers of rows or operations may need to increase these values to enable better parallelism in the system, whereas users whose applications require relatively small transactions can decrease the values to save memory.

- `MaxNoOfConcurrentIndexOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	8K	0 - 4294967039 (0xFFFFFEFF)	N

For queries using a unique hash index, another temporary set of operation records is used during a query's execution phase. This parameter sets the size of that pool of records. Thus, this record is allocated only while executing a part of a query. As soon as this part has been executed, the record is released. The state needed to handle aborts and commits is handled by the normal operation records, where the pool size is set by the parameter `MaxNoOfConcurrentOperations`.

The default value of this parameter is 8192. Only in rare cases of extremely high parallelism using unique hash indexes should it be necessary to increase this value. Using a smaller value is possible and can save memory if the DBA is certain that a high degree of parallelism is not required for the cluster.

- `MaxNoOfFiredTriggers`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	4000	0 - 4294967039 (0xFFFFFEFF)	N

The default value of `MaxNoOfFiredTriggers` is 4000, which is sufficient for most situations. In some cases it can even be decreased if the DBA feels certain the need for parallelism in the cluster is not high.

A record is created when an operation is performed that affects a unique hash index. Inserting or deleting a record in a table with unique hash indexes or updating a column that is part of a unique hash index fires an insert or a delete in the index table. The resulting record is used to represent this index table operation while waiting for the original operation that fired it to complete. This operation is short-lived but can still require a large number of records in its pool for situations with many parallel write operations on a base table containing a set of unique hash indexes.

- `TransactionBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	1M	1K - 4294967039 (0xFFFFFEFF)	N

The memory affected by this parameter is used for tracking operations fired when updating index tables and reading unique indexes. This memory is used to store the key and column information for these operations. It is only very rarely that the value for this parameter needs to be altered from the default.

The default value for `TransactionBufferMemory` is 1MB.

Normal read and write operations use a similar buffer, whose usage is even more short-lived. The compile-time parameter `ZATTRBUF_FILESIZE` (found in `ndb/src/kernel/blocks/Dbtc/Dbtc.hpp`) set to 4000 × 128 bytes (500KB). A similar buffer for key information, `ZDATABUF_FILESIZE` (also in `Dbtc.hpp`) contains 4000 × 16 = 62.5KB of buffer space. `Dbtc` is the module that handles transaction coordination.

Scans and buffering. There are additional `[ndbd]` parameters in the `Dblqh` module (in `ndb/src/kernel/blocks/Dblqh/Dblqh.hpp`) that affect reads and updates. These include `ZATTRINBUF_FILESIZE`, set by default to 10000 × 128 bytes (1250KB) and `ZDATABUF_FILE_SIZE`, set by default to 10000*16 bytes (roughly 156KB) of buffer space. To date, there have been neither any reports from users nor any results from our own extensive tests suggesting that either of these compile-time limits should be increased.

- `MaxNoOfConcurrentScans`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	256	2 - 500	N

This parameter is used to control the number of parallel scans that can be performed in the cluster. Each transaction coordinator can handle the number of parallel scans defined for this parameter. Each scan query is performed by scanning all partitions in parallel. Each partition scan uses a scan record in the node where the partition is located, the number of records being the value of this parameter times the number of nodes. The cluster should be able to sustain MaxNoOfConcurrentScans scans concurrently from all nodes in the cluster.

Scans are actually performed in two cases. The first of these cases occurs when no hash or ordered indexes exists to handle the query, in which case the query is executed by performing a full table scan. The second case is encountered when there is no hash index to support the query but there is an ordered index. Using the ordered index means executing a parallel range scan. The order is kept on the local partitions only, so it is necessary to perform the index scan on all partitions.

The default value of MaxNoOfConcurrentScans is 256. The maximum value is 500.

- MaxNoOfLocalScans

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	[see text]	32 - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.0	integer	[see text]	32 - 4294967039 (0xFFFFFEFF)	N

Specifies the number of local scan records if many scans are not fully parallelized. In MySQL Cluster NDB 7.2.0 and later, when the number of local scan records is not provided, it is calculated as shown here:

```
4 * MaxNoOfConcurrentScans * [# data nodes] + 2
```

In MySQL Cluster NDB 7.1 and earlier, the default is calculated as the product of MaxNoOfConcurrentScans and the number of data nodes, plus 2. The minimum value is 32.

- BatchSizePerLocalScan

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	64	1 - 992	N
NDB 7.2.1	integer	256	1 - 992	N

This parameter is used to calculate the number of lock records used to handle concurrent scan operations.

BatchSizePerLocalScan has a strong connection to the BatchSize defined in the SQL nodes.

- LongMessageBuffer

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	1M	512K - 4294967039 (0xFFFFFEFF)	N
		2057		

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.4	bytes	4M	512K - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.0	bytes	4M	512K - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.31	bytes	64M	512K - 4294967039 (0xFFFFFEFF)	N

This is an internal buffer used for passing messages within individual nodes and between nodes. In MySQL Cluster NDB 6.4.3 and earlier, the default is 1MB; beginning with MySQL Cluster NDB 7.0.4, this increased to 4MB; the default increased to 64MB in MySQL Cluster NDB 7.1.31.

This parameter seldom needs to be changed from the default. However, when replicating a MySQL Cluster using `ndbmtd` for the data nodes, you may need to increase this value to 8MB (or possibly more) to prevent data node instability, because `ndbmtd` uses much more of this resource than `ndbd` does. Beginning with MySQL Cluster NDB 7.0.13 and MySQL Cluster NDB 7.1.2, this should no longer be necessary when using `ndbmtd` with MySQL Cluster Replication (Bug #46914).

- `MaxParallelScansPerFragment`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.23	bytes	32	1 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.12	bytes	32	1 - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.0	bytes	256	1 - 4294967039 (0xFFFFFEFF)	N

Beginning with MySQL Cluster NDB 7.0.23 and MySQL Cluster NDB 7.1.12, it is possible to configure the maximum number of parallel scans (`TUP` scans and `TUX` scans) allowed before they begin queuing for serial handling. (Previously, the maximum number of parallel scans per fragment was fixed at 32.) You can increase this to take advantage of any unused CPU when performing large number of scans in parallel and improve their performance.

Beginning with MySQL Cluster NDB 7.2.0, the default value for this parameter is increased from 32 to 256.

Memory Allocation

`MaxAllocate`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.19	unsigned	32M	1M - 1G	N
NDB 6.2.3	unsigned	32M	1M - 1G	N
MySQL 5.1.20	unsigned	32M	1M - 1G	N

This is the maximum size of the memory unit to use when allocating memory for tables. In cases where `NDB` gives `Out of memory` errors, but it is evident by examining the cluster logs or the output of `DUMP 1000` that all available memory has not yet been used, you can increase the value of this parameter (or `MaxNoOfTables`, or both) to cause `NDB` to make sufficient memory available.

This parameter was introduced in MySQL 5.1.20, MySQL Cluster NDB 6.1.12 and MySQL Cluster NDB 6.2.3.

Hash Map Size

`DefaultHashMapSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.38	LDM threads	240	0 - 3840	N
NDB 7.1.27	LDM threads	240	0 - 3840	N

Beginning with MySQL Cluster NDB 7.0.38 and MySQL Cluster NDB 7.1.26, the size of the table hash maps used by `NDB` is configurable using this parameter; previously this value was hard-coded. `DefaultHashMapSize` can take any of three possible values (0, 240, 3840). These values and their effects are described in the following table:

Value	Description / Effect
0	Use the lowest value set, if any, for this parameter among all data nodes and API nodes in the cluster; if it is not set on any data or API node, use the default value.
240	Original hash map size used by default in all MySQL Cluster NDB 7.1 and MySQL Cluster NDB 7.0 (and earlier) releases; effectively the only value prior to versions 7.0.38 and 7.1.26 (when this parameter was introduced).
3840	Larger hash map size available beginning with MySQL Cluster NDB 7.0.38 and MySQL Cluster NDB 7.1.26

The primary intended use for this parameter is to facilitate upgrades and esecially downgrades between MySQL Cluster NDB 7.1 and later MySQL Cluster versions in which the larger hash map size (3840) is the default; by setting this parameter to 240 prior to performing an upgrade, you can cause the cluster to continue using the smaller size for table hash maps, in which case the tables remain compatible with earlier versions. `DefaultHashMapSize` can be set for individual data nodes, API nodes, or both, but setting it once only, in the `[ndbd default]` section of the `config.ini` file, is the recommended practice. You can also set this parameter to 0, in which case the default value is used.

After increasing this parameter, to have existing tables to take advantage of the new size, you can run `ALTER TABLE ... REORGANIZE PARTITION` on them, after which they can use the larger hash map size. This is in addition to performing a rolling restart, which makes the larger hash maps available to new tables, but does not enable existing tables to use them.

Decreasing this parameter online after any tables have been created or modified with `DefaultHashMapSize` equal to 3840 is not currently supported.

Logging and checkpointing.   The following `[ndbd]` parameters control log and checkpoint behavior.

- `NoOfFragmentLogFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	8	3 - 4294967039 (0xFFFFFEFF)	IN
MySQL 5.1.0	integer	16	3 - 4294967039 (0xFFFFFEFF)	IN

This parameter sets the number of REDO log files for the node, and thus the amount of space allocated to REDO logging. Because the REDO log files are organized in a ring, it is extremely important that the

first and last log files in the set (sometimes referred to as the "head" and "tail" log files, respectively) do not meet. When these approach one another too closely, the node begins aborting all transactions encompassing updates due to a lack of room for new log records.

A `REDO` log record is not removed until the required number of local checkpoints has been completed since that log record was inserted (prior to MySQL Cluster NDB 6.3.8, this was 3 local checkpoints; in later versions of MySQL Cluster, only 2 local checkpoints are necessary). Checkpointing frequency is determined by its own set of configuration parameters discussed elsewhere in this chapter.

How these parameters interact and proposals for how to configure them are discussed in Section 17.3.3.13, "Configuring MySQL Cluster Parameters for Local Checkpoints".

The default parameter value is 16, which by default means 16 sets of 4 16MB files for a total of 1024MB. Beginning with MySQL Cluster NDB 6.1.1, the size of the individual log files is configurable using the `FragmentLogFileSize` parameter. In scenarios requiring a great many updates, the value for `NoOfFragmentLogFiles` may need to be set as high as 300 or even higher to provide sufficient space for REDO logs.

If the checkpointing is slow and there are so many writes to the database that the log files are full and the log tail cannot be cut without jeopardizing recovery, all updating transactions are aborted with internal error code 410 (`Out of log file space temporarily`). This condition prevails until a checkpoint has completed and the log tail can be moved forward.

> **Important**
>
> This parameter cannot be changed "on the fly"; you must restart the node using `--initial`. If you wish to change this value for all data nodes in a running cluster, you can do so using a rolling node restart (using `--initial` when starting each data node).

- `FragmentLogFileSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.11	bytes	16M	4M - 1G	IN

Setting this parameter enables you to control directly the size of redo log files. This can be useful in situations when MySQL Cluster is operating under a high load and it is unable to close fragment log files quickly enough before attempting to open new ones (only 2 fragment log files can be open at one time); increasing the size of the fragment log files gives the cluster more time before having to open each new fragment log file. The default value for this parameter is 16M. `FragmentLogFileSize` was added in MySQL Cluster NDB 6.1.11.

For more information about fragment log files, see the description for `NoOfFragmentLogFiles`.

- `InitFragmentLogFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.19	[see values]	SPARSE	SPARSE, FULL	IN

By default, fragment log files are created sparsely when performing an initial start of a data node—that is, depending on the operating system and file system in use, not all bytes are necessarily written to disk. Beginning with MySQL Cluster NDB 6.3.19, it is possible to override this behavior and force all bytes to be written regardless of the platform and file system type being used by mean of this parameter.

`InitFragmentLogFiles` takes one of two values:

- **SPARSE**. Fragment log files are created sparsely. This is the default value.

- **FULL**. Force all bytes of the fragment log file to be written to disk.

Depending on your operating system and file system, setting `InitFragmentLogFiles=FULL` may help eliminate I/O errors on writes to the REDO log.

- MaxNoOfOpenFiles

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	40	20 - 4294967039 (0xFFFFFEFF)	N
MySQL 5.1.16	unsigned	0	20 - 4294967039 (0xFFFFFEFF)	N

This parameter sets a ceiling on how many internal threads to allocate for open files. *Any situation requiring a change in this parameter should be reported as a bug.*

The default value is 0. (Prior to MySQL 5.1.16, the default was 40.) However, the minimum value to which this parameter can be set is 20.

- InitialNoOfOpenFiles

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.9	files	27	20 - 4294967039 (0xFFFFFEFF)	N

This parameter sets the initial number of internal threads to allocate for open files.

The default value is 27.

- MaxNoOfSavedMessages

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	25	0 - 4294967039 (0xFFFFFEFF)	N

This parameter sets the maximum number of errors written in the error log as well as the maximum number of trace files that are kept before overwriting the existing ones. Trace files are generated when, for whatever reason, the node crashes.

The default is 25, which sets these maximums to 25 error messages and 25 trace files.

- MaxLCPStartDelay

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.23	seconds	0	0 - 600	N
NDB 6.4.3	seconds	0	0 - 600	N

In parallel data node recovery (supported in MySQL Cluster NDB 6.3.8 and later), only table data is actually copied and synchronized in parallel; synchronization of metadata such as dictionary and checkpoint information is done in a serial fashion. In addition, recovery of dictionary and checkpoint

information cannot be executed in parallel with performing of local checkpoints. This means that, when starting or restarting many data nodes concurrently, data nodes may be forced to wait while a local checkpoint is performed, which can result in longer node recovery times.

Beginning with MySQL Cluster NDB 6.3.23 and MySQL Cluster NDB 6.4.3, it is possible to force a delay in the local checkpoint to permit more (and possibly all) data nodes to complete metadata synchronization; once each data node's metadata synchronization is complete, all of the data nodes can recover table data in parallel, even while the local checkpoint is being executed.

To force such a delay, you can set `MaxLCPStartDelay`, which determines the number of seconds the cluster can wait to begin a local checkpoint while data nodes continue to synchronize metadata. This parameter should be set in the `[ndbd default]` section of the `config.ini` file, so that it is the same for all data nodes. The maximum value is 600; the default is 0.

- `LcpScanProgressTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.40	second	60	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.29	second	60	0 - 4294967039 (0xFFFFFEFF)	N

A local checkpoint fragment scan watchdog checks periodically for no progress in each fragment scan performed as part of a local checkpoint, and shuts down the node if there is no progress after a given amount of time has elapsed. Prior to MySQL Cluster NDB 7.0.39 and MySQL Cluster NDB 7.1.29, this interval is always 60 seconds (Bug #16630410). In MySQL Cluster NDB 7.0.39, MySQL Cluster NDB 7.1.29, and later this interval can be set using the `LcpScanProgressTimeout` data node configuration parameter, which sets the maximum time for which the local checkpoint can be stalled before the LCP fragment scan watchdog shuts down the node.

The default value is 60 seconds (providing compatibility with previous releases). Setting this parameter to 0 disables the LCP fragment scan watchdog altogether.

Metadata objects.   The next set of `[ndbd]` parameters defines pool sizes for metadata objects, used to define the maximum number of attributes, tables, indexes, and trigger objects used by indexes, events, and replication between clusters. Note that these act merely as "suggestions" to the cluster, and any that are not specified revert to the default values shown.

- `MaxNoOfAttributes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	1000	32 - 4294967039 (0xFFFFFEFF)	N

This parameter sets a suggested maximum number of attributes that can be defined in the cluster; like `MaxNoOfTables`, it is not intended to function as a hard upper limit.

Prior to MySQL Cluster NDB 6.3.45, MySQL Cluster NDB 7.0.26, and MySQL Cluster NDB 7.1.15, this parameter was sometimes treated as a hard limit for certain operations. This caused problems with MySQL Cluster Replication, when it was possible to create more tables than could be replicated, and sometimes led to confusion when it was possible (or not possible, depending on the circumstances) to create more than `MaxNoOfAttributes` attributes. (Bug #61684)

The default value is 1000, with the minimum possible value being 32. The maximum is 4294967039. Each attribute consumes around 200 bytes of storage per node due to the fact that all metadata is fully replicated on the servers.

When setting `MaxNoOfAttributes`, it is important to prepare in advance for any `ALTER TABLE` statements that you might want to perform in the future. This is due to the fact, during the execution of `ALTER TABLE` on a Cluster table, 3 times the number of attributes as in the original table are used, and a good practice is to permit double this amount. For example, if the MySQL Cluster table having the greatest number of attributes (`greatest_number_of_attributes`) has 100 attributes, a good starting point for the value of `MaxNoOfAttributes` would be `6 * greatest_number_of_attributes = 600`.

You should also estimate the average number of attributes per table and multiply this by `MaxNoOfTables`. If this value is larger than the value obtained in the previous paragraph, you should use the larger value instead.

Assuming that you can create all desired tables without any problems, you should also verify that this number is sufficient by trying an actual `ALTER TABLE` after configuring the parameter. If this is not successful, increase `MaxNoOfAttributes` by another multiple of `MaxNoOfTables` and test it again.

- `MaxNoOfTables`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	128	8 - 20320	N

A table object is allocated for each table and for each unique hash index in the cluster. This parameter sets a suggested maximum number of table objects for the cluster as a whole; like `MaxNoOfAttributes`, it is not intended to function as a hard upper limit.

Prior to MySQL Cluster NDB 6.3.45, MySQL Cluster NDB 7.0.26, and MySQL Cluster NDB 7.1.15, this parameter was sometimes treated as a hard limit for certain operations. This caused problems with MySQL Cluster Replication, when it was possible to create more tables than could be replicated, and sometimes led to confusion when it was possible (or not possible, depending on the circumstances) to create more than `MaxNoOfTables` tables.

For each attribute that has a `BLOB` data type an extra table is used to store most of the `BLOB` data. These tables also must be taken into account when defining the total number of tables.

The default value of this parameter is 128. The minimum is 8 and the maximum is 20320. Each table object consumes approximately 20KB per node.

> **Note**
>
> The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfOrderedIndexes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	128	0 - 4294967039 (0xFFFFFEFF)	N

For each ordered index in the cluster, an object is allocated describing what is being indexed and its storage segments. By default, each index so defined also defines an ordered index. Each unique index

and primary key has both an ordered index and a hash index. `MaxNoOfOrderedIndexes` sets the total number of ordered indexes that can be in use in the system at any one time.

The default value of this parameter is 128. Each index object consumes approximately 10KB of data per node.

> **Note**
>
> The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfUniqueHashIndexes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	64	0 - 4294967039 (0xFFFFFEFF)	N

For each unique index that is not a primary key, a special table is allocated that maps the unique key to the primary key of the indexed table. By default, an ordered index is also defined for each unique index. To prevent this, you must specify the `USING HASH` option when defining the unique index.

The default value is 64. Each index consumes approximately 15KB per node.

> **Note**
>
> The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfTriggers`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	768	0 - 4294967039 (0xFFFFFEFF)	N

Internal update, insert, and delete triggers are allocated for each unique hash index. (This means that three triggers are created for each unique hash index.) However, an *ordered* index requires only a single trigger object. Backups also use three trigger objects for each normal table in the cluster.

Replication between clusters also makes use of internal triggers.

This parameter sets the maximum number of trigger objects in the cluster.

The default value is 768.

- `MaxNoOfIndexes`

This parameter is deprecated. You should use `MaxNoOfOrderedIndexes` and `MaxNoOfUniqueHashIndexes` instead.

This parameter is used only by unique hash indexes. There needs to be one record in this pool for each unique hash index defined in the cluster.

The default value of this parameter is 128.

- `MaxNoOfSubscriptions`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.10	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N
NDB 6.3.7	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

Each `NDB` table in a MySQL Cluster requires a subscription in the NDB kernel. For some NDB API applications, it may be necessary or desirable to change this parameter, which became available in MySQL Cluster NDB 6.2.10 and MySQL Cluster NDB 6.3.7. However, for normal usage with MySQL servers acting as SQL nodes, there is not any need to do so.

The default value for `MaxNoOfSubscriptions` is 0, which is treated as equal to `MaxNoOfTables`. Each subscription consumes 108 bytes.

- `MaxNoOfSubscribers`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.10	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N
NDB 6.3.7	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter, added in MySQL Cluster NDB 6.2.10 and MySQL Cluster NDB 6.3.7, is of interest only when using MySQL Cluster Replication. The default value is 0, which is treated as `2 * MaxNoOfTables`; that is, there is one subscription per `NDB` table for each of two MySQL servers (one acting as the replication master and the other as the slave). Each subscriber uses 16 bytes of memory.

When using circular replication, multi-master replication, and other replication setups involving more than 2 MySQL servers, you should increase this parameter to the number of `mysqld` processes included in replication (this is often, but not always, the same as the number of clusters). For example, if you have a circular replication setup using three MySQL Clusters, with one `mysqld` attached to each cluster, and each of these `mysqld` processes acts as a master and as a slave, you should set `MaxNoOfSubscribers` equal to `3 * MaxNoOfTables`.

For more information, see Section 17.6, "MySQL Cluster Replication".

- `MaxNoOfConcurrentSubOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.10	unsigned	256	0 - 4294967039 (0xFFFFFEFF)	N
NDB 6.3.7	unsigned	256	0 - 4294967039 (0xFFFFFEFF)	N

This parameter sets a ceiling on the number of operations that can be performed by all API nodes in the cluster at one time. The default value (256) is sufficient for normal operations, and might need to be adjusted only in scenarios where there are a great many API nodes each performing a high volume of operations concurrently.

This parameter was added in MySQL Cluster NDB 6.2.10 and MySQL Cluster NDB 6.3.7.

Boolean parameters. The behavior of data nodes is also affected by a set of `[ndbd]` parameters taking on boolean values. These parameters can each be specified as `TRUE` by setting them equal to `1` or `Y`, and as `FALSE` by setting them equal to `0` or `N`.

- `LateAlloc`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	numeric	1	0 - 1	N

Allocate memory for this data node after a connection to the management server has been established. Enabled by default.

Added in MySQL Cluster NDB 6.4.0.

- `LockPagesInMainMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	0	0 - 2	N
MySQL 5.1.0	true|false (1|0)	0	0 - 1	N
MySQL 5.1.15	numeric	0	0 - 2	N

For a number of operating systems, including Solaris and Linux, it is possible to lock a process into memory and so avoid any swapping to disk. This can be used to help guarantee the cluster's real-time characteristics.

Beginning with MySQL 5.1.15 and MySQL Cluster NDB 6.1.1, this parameter takes one of the integer values `0`, `1`, or `2`, which act as follows:

- `0`: Disables locking. This is the default value.

- `1`: Performs the lock after allocating memory for the process.

- `2`: Performs the lock before memory for the process is allocated.

Previously, this parameter was a Boolean. `0` or `false` was the default setting, and disabled locking. `1` or `true` enabled locking of the process after its memory was allocated.

> **Important**
>
> Beginning with MySQL 5.1.15 and MySQL Cluster NDB 6.1.1, it is no longer possible to use `true` or `false` for the value of this parameter; when upgrading from a previous version, you must change the value to `0`, `1`, or `2`.

Prior to MySQL Cluster NDB 6.3.31 and MySQL Cluster NDB 7.0.11, setting this parameter did not cause the stated memory to be allocated when the node was started, but rather only when the memory was used by the data node process for other reasons. (Bug #37430)

> **Note**
>
> If the operating system is not configured to permit unprivileged users to lock pages, then the data node process making use of this parameter may have to be run as system root. (`LockPagesInMainMemory` uses the `mlockall` function. From Linux kernel 2.6.9, unprivileged users can lock memory as limited by `max`

> `locked memory`. For more information, see `ulimit -l` and http://linux.die.net/man/2/mlock).

> **Important**
>
> Beginning with `glibc` 2.10, `glibc` uses per-thread arenas to reduce lock contention on a shared pool, which consumes real memory. In general, a data node process does not need per-thread arenas, since it does not perform any memory allocation after startup. (This difference in allocators does not appear to affect performance significantly.)
>
> The `glibc` behavior is intended to be configurable via the `MALLOC_ARENA_MAX` environment variable, but a bug in this mechanism prior to `glibc` 2.16 meant that this variable could not be set to less than 8, so that the wasted memory could not be reclaimed. (Bug #15907219; see also http://sourceware.org/bugzilla/show_bug.cgi?id=13137 for more information concerning this issue.)
>
> One possible workaround for this problem is to use the `LD_PRELOAD` environment variable to preload a `jemalloc` memory allocation library to take the place of that supplied with `glibc`.

- `StopOnError`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	1	0, 1	N

This parameter specifies whether a data node process should exit or perform an automatic restart when an error condition is encountered.

This parameter's default value is `1`; this means that, by default, an error causes the data node process to halt.

Users of MySQL Cluster Manager should note that, when `StopOnError` equals 1, this prevents the MySQL Cluster Manager agent from restarting any data nodes after it has performed its own restart and recovery. See Starting and Stopping the Agent on Linux, for more information.

- `CrashOnCorruptedTuple`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.28, 5.1.56-ndb-7.1.17	boolean	false	true, false	S
NDB 7.2.1	boolean	true	true, false	S

This parameter was introduced in MySQL Cluster NDB 7.0.28 and MySQL Cluster NDB 7.1.17. When enabled, it forces a data node to shut down whenever it encounters a corrupted tuple. By default, it is disabled.

- `Diskless`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	true|false (1|0)	false	true, false	IS

It is possible to specify MySQL Cluster tables as *diskless*, meaning that tables are not checkpointed to disk and that no logging occurs. Such tables exist only in main memory. A consequence of using

diskless tables is that neither the tables nor the records in those tables survive a crash. However, when operating in diskless mode, it is possible to run `ndbd` on a diskless computer.

Important

This feature causes the *entire* cluster to operate in diskless mode.

When this feature is enabled, Cluster online backup is disabled. In addition, a partial start of the cluster is not possible.

`Diskless` is disabled by default.

- `ODirect`

Effective Version	Type/Units	Default	Range/Values	**Restart Type**
NDB 6.1.11	boolean	false	true, false	N
NDB 6.2.3	boolean	false	true, false	N
NDB 6.3.0	boolean	false	true, false	N

Enabling this parameter causes `NDB` to attempt using `O_DIRECT` writes for LCP, backups, and redo logs, often lowering `kswapd` and CPU usage. When using MySQL Cluster on Linux, enable `ODirect` if you are using a 2.6 or later kernel.

This parameter was added in MySQL 5.1.20, MySQL Cluster NDB 6.1.11, MySQL Cluster NDB 6.2.3, and MySQL Cluster NDB 6.3.0.

`ODirect` is disabled by default.

- `RestartOnErrorInsert`

Effective Version	Type/Units	Default	Range/Values	**Restart Type**
MySQL 5.1.0	error code	2	0 - 4	N

This feature is accessible only when building the debug version where it is possible to insert errors in the execution of individual blocks of code as part of testing.

This feature is disabled by default.

- `CompressedBackup`

Effective Version	Type/Units	Default	Range/Values	**Restart Type**
NDB 6.3.7	boolean	false	true, false	N

Setting this parameter to `1` causes backup files to be compressed. The compression used is equivalent to `gzip --fast`, and can save 50% or more of the space required on the data node to store uncompressed backup files. Compressed backups can be enabled for individual data nodes, or for all data nodes (by setting this parameter in the `[ndbd default]` section of the `config.ini` file).

Important

You cannot restore a compressed backup to a cluster running a MySQL version that does not support this feature.

The default value is `0` (disabled).

This parameter was introduced in MySQL Cluster NDB 6.3.7.

- `CompressedLCP`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.7	boolean	false	true, false	N

Setting this parameter to `1` causes local checkpoint files to be compressed. The compression used is equivalent to `gzip --fast`, and can save 50% or more of the space required on the data node to store uncompressed checkpoint files. Compressed LCPs can be enabled for individual data nodes, or for all data nodes (by setting this parameter in the `[ndbd default]` section of the `config.ini` file).

> ⚠️ **Important**
>
> You cannot restore a compressed local checkpoint to a cluster running a MySQL version that does not support this feature.

The default value is `0` (disabled).

This parameter was introduced in MySQL Cluster NDB 6.3.7.

Controlling Timeouts, Intervals, and Disk Paging

There are a number of `[ndbd]` parameters specifying timeouts and intervals between various actions in Cluster data nodes. Most of the timeout values are specified in milliseconds. Any exceptions to this are mentioned where applicable.

- `TimeBetweenWatchDogCheck`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	6000	70 - 4294967039 (0xFFFFFEFF)	N

To prevent the main thread from getting stuck in an endless loop at some point, a "watchdog" thread checks the main thread. This parameter specifies the number of milliseconds between checks. If the process remains in the same state after three checks, the watchdog thread terminates it.

This parameter can easily be changed for purposes of experimentation or to adapt to local conditions. It can be specified on a per-node basis although there seems to be little reason for doing so.

The default timeout is 6000 milliseconds (6 seconds).

- `TimeBetweenWatchDogCheckInitial`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.20	milliseconds	6000	70 - 4294967039 (0xFFFFFEFF)	N

This is similar to the `TimeBetweenWatchDogCheck` parameter, except that `TimeBetweenWatchDogCheckInitial` controls the amount of time that passes between execution checks inside a database node in the early start phases during which memory is allocated.

The default timeout is 6000 milliseconds (6 seconds).

This parameter was added in MySQL 5.1.20.

- `StartPartialTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	30000	0 - 4294967039 (0xFFFFFEFF)	N

This parameter specifies how long the Cluster waits for all data nodes to come up before the cluster initialization routine is invoked. This timeout is used to avoid a partial Cluster startup whenever possible.

This parameter is overridden when performing an initial start or initial restart of the cluster.

The default value is 30000 milliseconds (30 seconds). 0 disables the timeout, in which case the cluster may start only if all nodes are available.

- `StartPartitionedTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	60000	0 - 4294967039 (0xFFFFFEFF)	N

If the cluster is ready to start after waiting for `StartPartialTimeout` milliseconds but is still possibly in a partitioned state, the cluster waits until this timeout has also passed. If `StartPartitionedTimeout` is set to 0, the cluster waits indefinitely.

This parameter is overridden when performing an initial start or initial restart of the cluster.

The default timeout is 60000 milliseconds (60 seconds).

- `StartFailureTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

If a data node has not completed its startup sequence within the time specified by this parameter, the node startup fails. Setting this parameter to 0 (the default value) means that no data node timeout is applied.

For nonzero values, this parameter is measured in milliseconds. For data nodes containing extremely large amounts of data, this parameter should be increased. For example, in the case of a data node containing several gigabytes of data, a period as long as 10−15 minutes (that is, 600000 to 1000000 milliseconds) might be required to perform a node restart.

- `StartNoNodeGroupTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.24	milliseconds	15000	0 - 4294967039 (0xFFFFFEFF)	N

When a data node is configured with `Nodegroup = 65536`, is regarded as not being assigned to any node group. When that is done, the cluster waits `StartNoNodegroupTimeout` milliseconds, then

treats such nodes as though they had been added to the list passed to the `--nowait-nodes` option, and starts. The default value is `15000` (that is, the management server waits 15 seconds). Setting this parameter equal to `0` means that the cluster waits indefinitely.

`StartNoNodegroupTimeout` must be the same for all data nodes in the cluster; for this reason, you should always set it in the `[ndbd default]` section of the `config.ini` file, rather than for individual data nodes.

This parameter was added in MySQL Cluster NDB 7.0.24 and MySQL Cluster NDB 7.1.13. See Section 17.5.13, "Adding MySQL Cluster Data Nodes Online", for more information.

- `HeartbeatIntervalDbDb`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	1500	10 - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.0	milliseconds	5000	10 - 4294967039 (0xFFFFFEFF)	N

One of the primary methods of discovering failed nodes is by the use of heartbeats. This parameter states how often heartbeat signals are sent and how often to expect to receive them. After missing three heartbeat intervals in a row, the node is declared dead. Thus, the maximum time for discovering a failure through the heartbeat mechanism is four times the heartbeat interval.

In MySQL Cluster NDB 7.2.0 and later, the default heartbeat interval is 5000 milliseconds (5 seconds). Previously, the default was 1500 milliseconds (1.5 seconds). This parameter must not be changed drastically and should not vary widely between nodes. If one node uses 5000 milliseconds and the node watching it uses 1000 milliseconds, obviously the node will be declared dead very quickly. This parameter can be changed during an online software upgrade, but only in small increments.

See also Network communication and latency.

- `HeartbeatIntervalDbApi`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	1500	100 - 4294967039 (0xFFFFFEFF)	N

Each data node sends heartbeat signals to each MySQL server (SQL node) to ensure that it remains in contact. If a MySQL server fails to send a heartbeat in time it is declared "dead," in which case all ongoing transactions are completed and all resources released. The SQL node cannot reconnect until all activities initiated by the previous MySQL instance have been completed. The three-heartbeat criteria for this determination are the same as described for `HeartbeatIntervalDbDb`.

The default interval is 1500 milliseconds (1.5 seconds). This interval can vary between individual data nodes because each data node watches the MySQL servers connected to it, independently of all other data nodes.

For more information, see Network communication and latency.

- `HeartbeatOrder`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.35	numeric	0	0 - 65535	S

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.16	numeric	0	0 - 65535	S
NDB 7.1.5	numeric	0	0 - 65535	S

Data nodes send heartbeats to one another in a circular fashion whereby each data node monitors the previous one. If a heartbeat is not detected by a given data node, this node declares the previous data node in the circle "dead" (that is, no longer accessible by the cluster). The determination that a data node is dead is done globally; in other words; once a data node is declared dead, it is regarded as such by all nodes in the cluster.

It is possible for heartbeats between data nodes residing on different hosts to be too slow compared to heartbeats between other pairs of nodes (for example, due to a very low heartbeat interval or temporary connection problem), such that a data node is declared dead, even though the node can still function as part of the cluster.

In this type of situation, it may be that the order in which heartbeats are transmitted between data nodes makes a difference as to whether or not a particular data node is declared dead. If this declaration occurs unnecessarily, this can in turn lead to the unnecessary loss of a node group and as thus to a failure of the cluster.

Consider a setup where there are 4 data nodes A, B, C, and D running on 2 host computers `host1` and `host2`, and that these data nodes make up 2 node groups, as shown in the following table:

Node Group	Nodes Running on `host1`	Nodes Running on `host2`
Node Group 0:	Node A	Node B
Node Group 1:	Node C	Node D

Suppose the heartbeats are transmitted in the order A->B->C->D->A. In this case, the loss of the heartbeat between the hosts causes node B to declare node A dead and node C to declare node B dead. This results in loss of Node Group 0, and so the cluster fails. On the other hand, if the order of transmission is A->B->D->C->A (and all other conditions remain as previously stated), the loss of the heartbeat causes nodes A and D to be declared dead; in this case, each node group has one surviving node, and the cluster survives.

Priot to MySQL Cluster NDB 6.3.35, MySQL Cluster NDB 7.0.16, and MySQL Cluster NDB 7.1.5, the order of heartbeat transmission between data nodes was always automatically determined by NDB. However, beginning with these versions, the `HeartbeatOrder` configuration parameter makes the order of heartbeat transmission user-configurable.

The default value for `HeartbeatOrder` is zero; allowing the default value to be used on all data nodes causes the order of heartbeat transmission to be determined by NDB. If this parameter is used, it must be set to a nonzero value (maximum 65535) for every data node in the cluster, and this value must be unique for each data node; this causes the heartbeat transmission to proceed from data node to data node in the order of their `HeartbeatOrder` values from lowest to highest (and then directly from the data node having the highest `HeartbeatOrder` to the data node having the lowest value, to complete the circle). The values need not be consecutive; for example, to force the heartbeat transmission order A->B->D->C->A in the scenario outlined previously, you could set the `HeartbeatOrder` values as shown here:

Node	`HeartbeatOrder`
A	10
B	20

Node	**HeartbeatOrder**
C	30
D	25

To use this parameter to change the heartbeat transmission order in a running MySQL Cluster, you must first set `HeartbeatOrder` for each data node in the cluster in the global configuration (`config.ini`) file (or files). To cause the change to take effect, you must perform either of the following:

- A complete shutdown and restart of the entire cluster.

- 2 rolling restarts of the cluster in succession. *All nodes must be restarted in the same order in both rolling restarts.*

You can use `DUMP 908` to observe the effect of this parameter in the data node logs.

- `ConnectCheckIntervalDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.1.13	milliseconds	1500	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.1	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter enables connection checking between data nodes. A data node that fails to respond within an interval of `ConnectCheckIntervalDelay` milliseconds is considered suspect, and is considered dead after two such intervals.

- `TimeBetweenLocalCheckpoints`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	number of 4-byte words, as a base-2 logarithm	20	0 - 31	N

This parameter is an exception in that it does not specify a time to wait before starting a new local checkpoint; rather, it is used to ensure that local checkpoints are not performed in a cluster where relatively few updates are taking place. In most clusters with high update rates, it is likely that a new local checkpoint is started immediately after the previous one has been completed.

The size of all write operations executed since the start of the previous local checkpoints is added. This parameter is also exceptional in that it is specified as the base-2 logarithm of the number of 4-byte words, so that the default value 20 means 4MB (4×2^{20}) of write operations, 21 would mean 8MB, and so on up to a maximum value of 31, which equates to 8GB of write operations.

All the write operations in the cluster are added together. Setting `TimeBetweenLocalCheckpoints` to 6 or less means that local checkpoints will be executed continuously without pause, independent of the cluster's workload.

- `TimeBetweenGlobalCheckpoints`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	2000	10 - 32000	N

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.0	milliseconds	2000	20 - 32000	N

When a transaction is committed, it is committed in main memory in all nodes on which the data is mirrored. However, transaction log records are not flushed to disk as part of the commit. The reasoning behind this behavior is that having the transaction safely committed on at least two autonomous host machines should meet reasonable standards for durability.

It is also important to ensure that even the worst of cases—a complete crash of the cluster—is handled properly. To guarantee that this happens, all transactions taking place within a given interval are put into a global checkpoint, which can be thought of as a set of committed transactions that has been flushed to disk. In other words, as part of the commit process, a transaction is placed in a global checkpoint group. Later, this group's log records are flushed to disk, and then the entire group of transactions is safely committed to disk on all computers in the cluster.

This parameter defines the interval between global checkpoints. The default is 2000 milliseconds.

- `TimeBetweenEpochs`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.5	milliseconds	100	0 - 32000	N

This parameter defines the interval between synchronization epochs for MySQL Cluster Replication. The default value is 100 milliseconds.

`TimeBetweenEpochs` is part of the implementation of "micro-GCPs", which can be used to improve the performance of MySQL Cluster Replication. This parameter was introduced in MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2.

- `TimeBetweenEpochsTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.22	milliseconds	4000	0 - 32000	N
MySQL 5.1.51	milliseconds	0	0 - 256000	N

This parameter defines a timeout for synchronization epochs for MySQL Cluster Replication. If a node fails to participate in a global checkpoint within the time determined by this parameter, the node is shut down. In MySQL Cluster NDB 7.2.0 and later, the default value is 0; in other words, the timeout is disabled. This represents a change from previous versions of MySQL Cluster, in which the default value was 4000 milliseconds (4 seconds).

`TimeBetweenEpochsTimeout` is part of the implementation of "micro-GCPs", which can be used to improve the performance of MySQL Cluster Replication. This parameter was introduced in MySQL Cluster NDB 6.2.7 and MySQL Cluster NDB 6.3.4.

The following changes regarding this parameter were made in MySQL Cluster NDB 7.0.21 and MySQL Cluster NDB 7.1.10:

- The maximum possible value for this parameter was increased from 32000 milliseconds to 256000 milliseconds.

- Setting this parameter to zero now has the effect of disabling GCP stops caused by save timeouts, commit timeouts, or both.

- The current value of this parameter and a warning are now written to the cluster log whenever a GCP save takes longer than 1 minute or a GCP save takes longer than 10 seconds.

- `MaxBufferedEpochs`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.14	epochs	100	0 - 100000	N

The number of unprocessed epochs by which a subscribing node can lag behind. Exceeding this number causes a lagging subscriber to be disconnected.

The default value of 100 is sufficient for most normal operations. If a subscribing node does lag enough to cause disconnections, it is usually due to network or scheduling issues with regard to processes or threads. (In rare circumstances, the problem may be due to a bug in the NDB client.) It may be desirable to set the value lower than the default when epochs are longer.

Disconnection prevents client issues from affecting the data node service, running out of memory to buffer data, and eventually shutting down. Instead, only the client is affected as a result of the disconnect (by, for example gap events in the binary log), forcing the client to reconnect or restart the process.

- `MaxBufferedEpochBytes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.52	bytes	26214400	26214400 (0x01900000) - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.38	bytes	26214400	26214400 (0x01900000) - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.27	bytes	26214400	26214400 (0x01900000) - 4294967039 (0xFFFFFEFF)	N

The total number of bytes allocated for buffering epochs by this node.

This parameter was introduced in MySQL Cluster NDB 6.3.52, MySQL Cluster NDB 7.0.38, and MySQL Cluster NDB 7.1.27. (Bug #16203623)

- `TimeBetweenInactiveTransactionAbortCheck`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	1000	1000 - 4294967039 (0xFFFFFEFF)	N

Timeout handling is performed by checking a timer on each transaction once for every interval specified by this parameter. Thus, if this parameter is set to 1000 milliseconds, every transaction will be checked for timing out once per second.

The default value is 1000 milliseconds (1 second).

- `TransactionInactiveTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	[see text]	0 - 4294967039 (0xFFFFFEFF)	N

This parameter states the maximum time that is permitted to lapse between operations in the same transaction before the transaction is aborted.

The default for this parameter is `4G` (also the maximum). For a real-time database that needs to ensure that no transaction keeps locks for too long, this parameter should be set to a relatively small value. The unit is milliseconds.

- `TransactionDeadlockDetectionTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	1200	50 - 4294967039 (0xFFFFFEFF)	N

When a node executes a query involving a transaction, the node waits for the other nodes in the cluster to respond before continuing. A failure to respond can occur for any of the following reasons:

- The node is "dead"

- The operation has entered a lock queue

- The node requested to perform the action could be heavily overloaded.

This timeout parameter states how long the transaction coordinator waits for query execution by another node before aborting the transaction, and is important for both node failure handling and deadlock detection. In MySQL 5.1.10 and earlier versions, setting it too high could cause undesirable behavior in situations involving deadlocks and node failure. Beginning with MySQL 5.1.11, active transactions occurring during node failures are actively aborted by the MySQL Cluster Transaction Coordinator, and so high settings are no longer an issue with this parameter.

The default timeout value is 1200 milliseconds (1.2 seconds).

Prior to MySQL Cluster NDB versions 6.2.18, 6.3.24, and 7.0.5, the effective minimum for this parameter was 100 milliseconds. (Bug #44099) Beginning with these versions, the actual minimum is 50 milliseconds.

- `DiskSyncSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.12	bytes	4M	32K - 4294967039 (0xFFFFFEFF)	N

This is the maximum number of bytes to store before flushing data to a local checkpoint file. This is done to prevent write buffering, which can impede performance significantly. This parameter is *not* intended to take the place of `TimeBetweenLocalCheckpoints`.

> **Note**
>
> When `ODirect` is enabled, it is not necessary to set `DiskSyncSize`; in fact, in such cases its value is simply ignored.

The default value is 4M (4 megabytes).

This parameter was added in MySQL 5.1.12.

- `DiskCheckpointSpeed`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.12	bytes	10M	1M - 4294967039 (0xFFFFFEFF)	N

The amount of data,in bytes per second, that is sent to disk during a local checkpoint. This allocation is shared by DML operations and backups (but not backup logging), which means that backups started during times of intensive DML may be impaired by flooding of the redo log buffer and may fail altogether if the contention is sufficiently severe.

The default value is 10M (10 megabytes per second).

This parameter was added in MySQL 5.1.12.

- `DiskCheckpointSpeedInRestart`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.12	bytes	100M	1M - 4294967039 (0xFFFFFEFF)	N

The amount of data,in bytes per second, that is sent to disk during a local checkpoint as part of a restart operation.

The default value is 100M (100 megabytes per second).

This parameter was added in MySQL 5.1.12.

- `NoOfDiskPagesToDiskAfterRestartTUP`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	8K pages/100 milliseconds	40	1 - 4294967039 (0xFFFFFEFF)	N

When executing a local checkpoint, the algorithm flushes all data pages to disk. Merely doing so as quickly as possible without any moderation is likely to impose excessive loads on processors, networks, and disks. To control the write speed, this parameter specifies how many pages per 100 milliseconds are to be written. In this context, a "page" is defined as 8KB. This parameter is specified in units of 80KB per second, so setting `NoOfDiskPagesToDiskAfterRestartTUP` to a value of `20` entails writing 1.6MB in data pages to disk each second during a local checkpoint. This value includes the writing of UNDO log records for data pages. That is, this parameter handles the limitation of writes from data memory. (See the entry for `IndexMemory` for information about index pages.)

In short, this parameter specifies how quickly to execute local checkpoints. It operates in conjunction with `NoOfFragmentLogFiles`, `DataMemory`, and `IndexMemory`.

For more information about the interaction between these parameters and possible strategies for choosing appropriate values for them, see Section 17.3.3.13, "Configuring MySQL Cluster Parameters for Local Checkpoints".

The default value is 40 (3.2MB of data pages per second).

> **Note**
>
> This parameter is deprecated as of MySQL 5.1.6. For MySQL 5.1.12 and later versions, use `DiskCheckpointSpeed` and `DiskSyncSize` instead.

- `NoOfDiskPagesToDiskAfterRestartACC`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	8K pages/100 milliseconds	20	1 - 4294967039 (0xFFFFFEFF)	N

This parameter uses the same units as `NoOfDiskPagesToDiskAfterRestartTUP` and acts in a similar fashion, but limits the speed of writing index pages from index memory.

The default value of this parameter is 20 (1.6MB of index memory pages per second).

> **Note**
>
> This parameter is deprecated as of MySQL 5.1.6. For MySQL 5.1.12 and later versions, use `DiskCheckpointSpeed` and `DiskSyncSize`.

- `NoOfDiskPagesToDiskDuringRestartTUP` (DEPRECATED)

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	8K pages/100 milliseconds	40	1 - 4294967039 (0xFFFFFEFF)	N

This parameter is used in a fashion similar to `NoOfDiskPagesToDiskAfterRestartTUP` and `NoOfDiskPagesToDiskAfterRestartACC`, only it does so with regard to local checkpoints executed in the node when a node is restarting. A local checkpoint is always performed as part of all node restarts. During a node restart it is possible to write to disk at a higher speed than at other times, because fewer activities are being performed in the node.

This parameter covers pages written from data memory.

The default value is 40 (3.2MB per second).

> **Note**
>
> This parameter is deprecated as of MySQL 5.1.6. For MySQL 5.1.12 and later versions, use `DiskCheckpointSpeedInRestart` and `DiskSyncSize`.

- `NoOfDiskPagesToDiskDuringRestartACC` (DEPRECATED)

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	8K pages/100 milliseconds	20	1 - 4294967039 (0xFFFFFEFF)	N

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Controls the number of index memory pages that can be written to disk during the local checkpoint phase of a node restart.

As with `NoOfDiskPagesToDiskAfterRestartTUP` and `NoOfDiskPagesToDiskAfterRestartACC`, values for this parameter are expressed in terms of 8KB pages written per 100 milliseconds (80KB/second).

The default value is 20 (1.6MB per second).

> **Note**
>
> This parameter is deprecated as of MySQL 5.1.6. For MySQL 5.1.12 and later versions, use `DiskCheckpointSpeedInRestart` and `DiskSyncSize`.

- `ArbitrationTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	3000	10 - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.0	milliseconds	7500	10 - 4294967039 (0xFFFFFEFF)	N

This parameter specifies how long data nodes wait for a response from the arbitrator to an arbitration message. If this is exceeded, the network is assumed to have split.

In MySQL Cluster NDB 7.2.0 and later, the default value is 7500 milliseconds (7.5 seconds). Previously, this was 3000 milliseconds (3 seconds).

- `Arbitration`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.7	enumeration	Default	Default, Disabled, WaitExternal	N

The `Arbitration` parameter, added in MySQL Cluster NDB 7.0.7, enables a choice of arbitration schemes, corresponding to one of 3 possible values for this parameter:

- **Default.** This enables arbitration to proceed normally, as determined by the `ArbitrationRank` settings for the management and API nodes. This is the default value.

- **Disabled.** Previously, it was possible to disable arbitration only by setting `ArbitrationRank` to 0 on all management and API nodes. Now, you can now use `Arbitration = Disabled` in the `[ndbd default]` section of the `config.ini` file to accomplish this task. In this case, any `ArbitrationRank` settings are ignored.

- **WaitExternal.** The `Arbitration` parameter also makes it possible to configure arbitration in such a way that the cluster waits until after the time determined by `ArbitrationTimeout` has passed for an external cluster manager application to perform arbitration instead of handling arbitration internally. This can be done by setting `Arbitration = WaitExternal` in the `[ndbd default]` section of the `config.ini` file. For best results with the `WaitExternal` setting, it is recommended that `ArbitrationTimeout` be 2 times as long as the interval required by the external cluster manager to perform arbitration.

> ⚠️ **Important**
>
> This parameter should be used only in the `[ndbd default]` section of the cluster configuration file. The behavior of the cluster is unspecified when `Arbitration` is set to different values for individual data nodes.

Buffering and logging.   Several `[ndbd]` configuration parameters enable the advanced user to have more control over the resources used by node processes and to adjust various buffer sizes at need.

These buffers are used as front ends to the file system when writing log records to disk. If the node is running in diskless mode, these parameters can be set to their minimum values without penalty due to the fact that disk writes are "faked" by the `NDB` storage engine's file system abstraction layer.

- `UndoIndexBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	2M	1M - 4294967039 (0xFFFFFEFF)	N

The UNDO index buffer, whose size is set by this parameter, is used during local checkpoints. The `NDB` storage engine uses a recovery scheme based on checkpoint consistency in conjunction with an operational REDO log. To produce a consistent checkpoint without blocking the entire system for writes, UNDO logging is done while performing the local checkpoint. UNDO logging is activated on a single table fragment at a time. This optimization is possible because tables are stored entirely in main memory.

The UNDO index buffer is used for the updates on the primary key hash index. Inserts and deletes rearrange the hash index; the NDB storage engine writes UNDO log records that map all physical changes to an index page so that they can be undone at system restart. It also logs all active insert operations for each fragment at the start of a local checkpoint.

Reads and updates set lock bits and update a header in the hash index entry. These changes are handled by the page-writing algorithm to ensure that these operations need no UNDO logging.

This buffer is 2MB by default. The minimum value is 1MB, which is sufficient for most applications. For applications doing extremely large or numerous inserts and deletes together with large transactions and large primary keys, it may be necessary to increase the size of this buffer. If this buffer is too small, the NDB storage engine issues internal error code 677 (`Index UNDO buffers overloaded`).

> ⚠️ **Important**
>
> It is not safe to decrease the value of this parameter during a rolling restart.

- `UndoDataBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	16M	1M - 4294967039 (0xFFFFFEFF)	N

This parameter sets the size of the UNDO data buffer, which performs a function similar to that of the UNDO index buffer, except the UNDO data buffer is used with regard to data memory rather than index memory. This buffer is used during the local checkpoint phase of a fragment for inserts, deletes, and updates.

Because UNDO log entries tend to grow larger as more operations are logged, this buffer is also larger than its index memory counterpart, with a default value of 16MB.

This amount of memory may be unnecessarily large for some applications. In such cases, it is possible to decrease this size to a minimum of 1MB.

It is rarely necessary to increase the size of this buffer. If there is such a need, it is a good idea to check whether the disks can actually handle the load caused by database update activity. A lack of sufficient disk space cannot be overcome by increasing the size of this buffer.

If this buffer is too small and gets congested, the NDB storage engine issues internal error code 891 (`Data UNDO buffers overloaded`).

> **Important**
>
> It is not safe to decrease the value of this parameter during a rolling restart.

- `RedoBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	8M	1M - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.4	bytes	32M	1M - 4294967039 (0xFFFFFEFF)	N

All update activities also need to be logged. The REDO log makes it possible to replay these updates whenever the system is restarted. The NDB recovery algorithm uses a "fuzzy" checkpoint of the data together with the UNDO log, and then applies the REDO log to play back all changes up to the restoration point.

`RedoBuffer` sets the size of the buffer in which the REDO log is written. In MySQL Cluster NDB 6.4.3 and earlier, the default value is 8MB; beginning with MySQL Cluster NDB 7.0.4, the default is 32MB. The minimum value is 1MB.

If this buffer is too small, the `NDB` storage engine issues error code 1221 (`REDO log buffers overloaded`). For this reason, you should exercise care if you attempt to decrease the value of `RedoBuffer` as part of an online change in the cluster's configuration.

`ndbmtd` allocates a separate buffer for each LDM thread (see `ThreadConfig`). For example, with 4 LDM threads, an `ndbmtd` data node actually has 4 buffers and allocates `RedoBuffer` bytes to each one, for a total of `4 * RedoBuffer` bytes.

- `EventLogBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.4	bytes	8192	0 - 64K	S

Controls the size of the circular buffer used for NDB log events within data nodes.

Added in MySQL Cluster NDB 7.0.4.

Controlling log messages.   In managing the cluster, it is very important to be able to control the number of log messages sent for various event types to `stdout`. For each event category, there are 16

possible event levels (numbered 0 through 15). Setting event reporting for a given event category to level 15 means all event reports in that category are sent to `stdout`; setting it to 0 means that there will be no event reports made in that category.

By default, only the startup message is sent to `stdout`, with the remaining event reporting level defaults being set to 0. The reason for this is that these messages are also sent to the management server's cluster log.

An analogous set of levels can be set for the management client to determine which event levels to record in the cluster log.

- `LogLevelStartup`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	1	0 - 15	N

The reporting level for events generated during startup of the process.

The default level is 1.

- `LogLevelShutdown`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	0	0 - 15	N

The reporting level for events generated as part of graceful shutdown of a node.

The default level is 0.

- `LogLevelStatistic`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	0	0 - 15	N

The reporting level for statistical events such as number of primary key reads, number of updates, number of inserts, information relating to buffer usage, and so on.

The default level is 0.

- `LogLevelCheckpoint`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	log level	0	0 - 15	N

The reporting level for events generated by local and global checkpoints.

The default level is 0.

- `LogLevelNodeRestart`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	0	0 - 15	N

The reporting level for events generated during node restart.

The default level is 0.

- `LogLevelConnection`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	0	0 - 15	N

The reporting level for events generated by connections between cluster nodes.

The default level is 0.

- `LogLevelError`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	0	0 - 15	N

The reporting level for events generated by errors and warnings by the cluster as a whole. These errors do not cause any node failure but are still considered worth reporting.

The default level is 0.

- `LogLevelCongestion`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	levelr	0	0 - 15	N

The reporting level for events generated by congestion. These errors do not cause node failure but are still considered worth reporting.

The default level is 0.

- `LogLevelInfo`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	integer	0	0 - 15	N

The reporting level for events generated for information about the general state of the cluster.

The default level is 0.

- `MemReportFrequency`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N
MySQL 5.1.16	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter controls how often data node memory usage reports are recorded in the cluster log; it is an integer value representing the number of seconds between reports.

Each data node's data memory and index memory usage is logged as both a percentage and a number of 32 KB pages of the `DataMemory` and `IndexMemory`, respectively, set in the `config.ini` file. For

example, if `DataMemory` is equal to 100 MB, and a given data node is using 50 MB for data memory storage, the corresponding line in the cluster log might look like this:

```
2006-12-24 01:18:16 [MgmSrvr] INFO -- Node 2: Data usage is 50%(1280 32K pages of total 2560)
```

`MemReportFrequency` is not a required parameter. If used, it can be set for all cluster data nodes in the `[ndbd default]` section of `config.ini`, and can also be set or overridden for individual data nodes in the corresponding `[ndbd]` sections of the configuration file. The minimum value—which is also the default value—is 0, in which case memory reports are logged only when memory usage reaches certain percentages (80%, 90%, and 100%), as mentioned in the discussion of statistics events in Section 17.5.6.2, "MySQL Cluster Log Events".

This parameter was added in MySQL Cluster 5.1.16 and MySQL Cluster NDB 6.1.0.

- `StartupStatusReportFrequency`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	seconds	0	0 - 4294967039 (0xFFFFFEFF)	N

When a data node is started with the `--initial`, it initializes the redo log file during Start Phase 4 (see Section 17.5.1, "Summary of MySQL Cluster Start Phases"). When very large values are set for `NoOfFragmentLogFiles`, `FragmentLogFileSize`, or both, this initialization can take a long time. Previous to MySQL Cluster NDB 6.4.0, only the beginning and end of the redo log file initialization process were logged. Beginning with this version, it is possible to force reports on the progress of this process to be logged periodically, by means of the `StartupStatusReportFrequency` configuration parameter. In this case, progress is reported in the cluster log, in terms of both the number of files and the amount of space that have been initialized, as shown here:

```
2009-06-20 16:39:23 [MgmSrvr] INFO -- Node 1: Local redo log file initialization status:
#Total files: 80, Completed: 60
#Total MBytes: 20480, Completed: 15557
2009-06-20 16:39:23 [MgmSrvr] INFO -- Node 2: Local redo log file initialization status:
#Total files: 80, Completed: 60
#Total MBytes: 20480, Completed: 15570
```

These reports are logged each `StartupStatusReportFrequency` seconds during Start Phase 4. If `StartupStatusReportFrequency` is 0 (the default), then reports are written to the cluster log only when at the beginning and at the completion of the redo log file initialization process.

Debugging Parameters.   Beginning with MySQL Cluster NDB 6.3.36, MySQL Cluster NDB 7.0.17, and MySQL Cluster NDB 7.1.6, it is possible to cause logging of traces for events generated by creating and dropping tables using `DictTrace`. This parameter is useful only in debugging NDB kernel code. `DictTrace` takes an integer value; currently, 0 (default - no logging) and 1 (logging enabled) are the only supported values.

Backup parameters.   The `[ndbd]` parameters discussed in this section define memory buffers set aside for execution of online backups.

- `BackupDataBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	2M	0 - 4294967039 (0xFFFFFEFF)	N

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.23	bytes	16M	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.4	bytes	16M	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.5.1	bytes	16M	512K - 4294967039 (0xFFFFFEFF)	N

In creating a backup, there are two buffers used for sending data to the disk. The backup data buffer is used to fill in data recorded by scanning a node's tables. Once this buffer has been filled to the level specified as `BackupWriteSize`, the pages are sent to disk. While flushing data to disk, the backup process can continue filling this buffer until it runs out of space. When this happens, the backup process pauses the scan and waits until some disk writes have completed freeing up memory so that scanning may continue.

In MySQL Cluster NDB 6.4.3 and earlier, the default value is 2MB; in MySQL Cluster NDB 7.0.4 and later, it is 16MB.

- `BackupLogBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	2M	0 - 4294967039 (0xFFFFFEFF)	N
NDB 6.3.23	bytes	16M	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.4	bytes	16M	0 - 4294967039 (0xFFFFFEFF)	N

The backup log buffer fulfills a role similar to that played by the backup data buffer, except that it is used for generating a log of all table writes made during execution of the backup. The same principles apply for writing these pages as with the backup data buffer, except that when there is no more space in the backup log buffer, the backup fails. For that reason, the size of the backup log buffer must be large enough to handle the load caused by write activities while the backup is being made. See Section 17.5.3.3, "Configuration for MySQL Cluster Backups".

The default value for this parameter should be sufficient for most applications. In fact, it is more likely for a backup failure to be caused by insufficient disk write speed than it is for the backup log buffer to become full. If the disk subsystem is not configured for the write load caused by applications, the cluster is unlikely to be able to perform the desired operations.

It is preferable to configure cluster nodes in such a manner that the processor becomes the bottleneck rather than the disks or the network connections.

In MySQL Cluster NDB 6.4.3 and earlier, the default value is 2MB; in MySQL Cluster NDB 7.0.4 and later, it is 16MB.

- `BackupMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	4M	0 - 4294967039 (0xFFFFFEFF)	N

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.4	bytes	32M	0 - 4294967039 (0xFFFFFEFF)	N

This parameter is simply the sum of `BackupDataBufferSize` and `BackupLogBufferSize`.

In MySQL Cluster NDB 7.0.4 and later, the default value is 16MB + 16MB = 32MB. (Previously, it was 2MB + 2MB = 4MB.)

> **Important**
>
> If `BackupDataBufferSize` and `BackupLogBufferSize` taken together exceed the default value for `BackupMemory`, then this parameter must be set explicitly in the `config.ini` file to their sum.

- `BackupReportFrequency`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.3	seconds	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter controls how often backup status reports are issued in the management client during a backup, as well as how often such reports are written to the cluster log (provided cluster event logging is configured to permit it—see Logging and checkpointing). `BackupReportFrequency` represents the time in seconds between backup status reports.

The default value is 0.

This parameter was added in MySQL Cluster NDB 6.2.3.

- `BackupWriteSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	32K	2K - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.4	bytes	256K	2K - 4294967039 (0xFFFFFEFF)	N

This parameter specifies the default size of messages written to disk by the backup log and backup data buffers.

In MySQL Cluster 6.4.3 and earlier, the default value for this parameter was 32KB; beginning with MySQL Cluster NDB 7.0.4, it is 256KB.

- `BackupMaxWriteSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	256K	2K - 4294967039 (0xFFFFFEFF)	N
MySQL 5.1.32	bytes	1M	2K - 4294967039 (0xFFFFFEFF)	N

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	bytes	1M	2K - 4294967039 (0xFFFFFEFF)	N

This parameter specifies the maximum size of messages written to disk by the backup log and backup data buffers.

In MySQL Cluster 6.4.3 and earlier, the default value for this parameter was 256KB; beginning with MySQL Cluster NDB 7.0.4, it is 1MB.

> **Important**
>
> When specifying these parameters, the following relationships must hold true. Otherwise, the data node will be unable to start.

- `BackupDataBufferSize >= BackupWriteSize + 188KB`

- `BackupLogBufferSize >= BackupWriteSize + 16KB`

- `BackupMaxWriteSize >= BackupWriteSize`

MySQL Cluster Realtime Performance Parameters

The `[ndbd]` parameters discussed in this section are used in scheduling and locking of threads to specific CPUs on multiprocessor data node hosts. They were introduced in MySQL Cluster NDB 6.3.4.

> **Note**
>
> To make use of these parameters, the data node process must be run as system root.

- `LockExecuteThreadToCPU`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.4	CPU ID	64K	0 - 64K	N

Previous to MySQL Cluster NDB 7.0. This parameter specifies the ID of the CPU assigned to handle the `NDBCLUSTER` execution thread. The value of this parameter is an integer in the range 0 to 65535 (inclusive). The default is 65535.

MySQL Cluster NDB 7.0 and later (beginning with MySQL Cluster NDB 6.4.0). When used with `ndbd`, this parameter (now a string) specifies the ID of the CPU assigned to handle the `NDBCLUSTER` execution thread.

When used with `ndbmtd`, the value of this parameter is a comma-separated list of CPU IDs assigned to handle execution threads. Each CPU ID in the list should be an integer in the range 0 to 65535 (inclusive). The number of IDs specified should match the number of execution threads determined by `MaxNoOfExecutionThreads`. However, there is no guarantee that threads are assigned to CPUs in any given order when using this parameter; beginning with in MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, you can obtain more finely-grained control of this type using `ThreadConfig`.

`LockExecuteThreadToCPU` has no default value.

Prior to MySQL Cluster NDB 7.0.18 and MySQL Cluster NDB 7.1.7, the effective maximum value recognized by this parameter as a valid CPU ID was 255; using a greater value caused thread locking to be disabled. (Bug #56185)

- LockMaintThreadsToCPU

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.4	CPU ID	64K	0 - 64K	N
NDB 6.4.0	CPU ID	[none]	0 - 64K	N

This parameter specifies the ID of the CPU assigned to handle NDBCLUSTER maintenance threads.

The value of this parameter is an integer in the range 0 to 65535 (inclusive). This parameter was added in MySQL Cluster NDB 6.3.4. Prior to MySQL Cluster NDB 6.4.0, the default is 65535; in MySQL Cluster NDB 7.0 and later MySQL Cluster release series, there is no default value.

- RealtimeScheduler

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.4	boolean	false	true, false	N

Setting this parameter to 1 enables real-time scheduling of data node threads.

Prior to MySQL Cluster NDB 7.0.40 and MySQL Cluster NDB 7.1.29, this parameter did not work correctly with data nodes running ndbmtd. (Bug #16961971)

The default is 0 (scheduling disabled).

- SchedulerExecutionTimer

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.4	µs	50	0 - 11000	N

This parameter specifies the time in microseconds for threads to be executed in the scheduler before being sent. Setting it to 0 minimizes the response time; to achieve higher throughput, you can increase the value at the expense of longer response times.

The default is 50 µsec, which our testing shows to increase throughput slightly in high-load cases without materially delaying requests.

This parameter was added in MySQL Cluster NDB 6.3.4.

- SchedulerSpinTimer

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.4	µs	0	0 - 500	N

This parameter specifies the time in microseconds for threads to be executed in the scheduler before sleeping.

The default value is 0.

- BuildIndexThreads

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.30	numeric	0	0 - 128	S
NDB 7.0.11	numeric	0	0 - 128	S

This parameter determines the number of threads to create when rebuilding ordered indexes during a system or node start, as well as when running `ndb_restore --rebuild-indexes`. It is supported only when there is more than one fragment for the table per data node (for example, when the `MAX_ROWS` option has been used with `CREATE TABLE`).

Setting this parameter to 0 (the default) disables multi-threaded building of ordered indexes.

This parameter was added in MySQL Cluster NDB 6.3.30 and MySQL Cluster NDB 7.0.11. Prior to MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5, it was supported only when using `ndbd`; in these and later MySQL Cluster releases, `BuildIndexThreads` is also supported for data nodes running `ndbmtd` (see Bug #54521).

You can enable multi-threaded builds during data node initial restarts by setting the `TwoPassInitialNodeRestartCopy` data node configuration parameter to `TRUE`.

- `TwoPassInitialNodeRestartCopy`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.1.11	boolean	false	true, false	N

In MySQL Cluster NDB 7.1.11 and later, multi-threaded building of ordered indexes can be enabled for initial restarts of data nodes by setting this configuration parameter to `TRUE`, which enables two-pass copying of data during initial node restarts.

You must also set `BuildIndexThreads` to a nonzero value.

- `Numa`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.20	boolean	1	...	N
NDB 7.1.9	boolean	1	...	N

This parameter determines whether Non-Uniform Memory Access (NUMA) is controlled by the operating or by the data node process, whether the data node uses `ndbd` or `ndbmtd`. By default, `NDB` attempts to use an interleaved NUMA memory allocation policy on any data node where the host operating system provides NUMA support.

Setting `Numa = 0` means that the datanode process does not itself attempt to set a policy for memory allocation, and permits this behavior to be determined by the operating system, which may be further guided by the separate `numactl` tool. That is, `Numa = 0` yields the system default behavior, which can be customised by `numactl`. For many Linux systems, the system default behavior is to allocate socket-local memory to any given process at allocation time. This can be problematic when using `ndbmtd`; this is because `nbdmtd` allocates all memory at startup, leading to an imbalance, giving different access speeds for different sockets, especially when locking pages in main memory.

Setting `Numa = 1` means that the data node process uses `libnuma` to request interleaved memory allocation. (This can also be accomplished manually, on the operating system level, using `numactl`.) Using interleaved allocation in effect tells the data node process to ignore non-uniform memory access but does not attempt to take any advantage of fast local memory; instead, the data node process tries to avoid imbalances due to slow remote memory. If interleaved allocation is not desired, set `Numa` to 0 so that the desired behavior can be determined on the operating system level.

The `Numa` configuration parameter is supported only on Linux systems where `libnuma.so` is available.

Multi-Threading Configuration Parameters (ndbmtd). `ndbmtd` runs by default as a single-threaded process and must be configured to use multiple threads, using either of two methods, both of which require setting configuration parameters in the `config.ini` file. The first method is simply to set an appropriate value for the `MaxNoOfExecutionThreads` configuration parameter. In MySQL Cluster NDB 7.1.17 and later, a second method is also supported, whereby it is possible to set up more complex rules for `ndbmtd` multi-threading using `ThreadConfig`. The next few paragraphs provide information about these parameters and their use with multi-threaded data nodes.

- `MaxNoOfExecutionThreads`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	integer	[none]	2 - 8	IS
NDB 7.0.4	integer	2	2 - 8	IS

This parameter controls the number of execution threads used by `ndbmtd`, up to a maximum of 8 threads, 4 of which can be LDM (LQH) threads. Although this parameter is set in the `[ndbd]` or `[ndbd default]` sections of the `config.ini` file, it is exclusive to `ndbmtd` and does not apply to `ndbd`.

Setting `MaxNoOfExecutionThreads` sets the number of threads by type as determined in the following table:

`MaxNoOfExecutionThreads` Value	LDM Threads	TC Threads	Send Threads	Receive Threads
0 .. 3	1	1	0	1
4 .. 6	2	1	0	1
7 .. 8	4	1	0	1

There is always one SUMA (replication) thread.

The thread types are described later in this section (see `ThreadConfig`).

Setting this parameter outside the permitted range of values causes the management server to abort on startup with the error `Error line` *number*`: Illegal value` *value* `for parameter MaxNoOfExecutionThreads`.

For `MaxNoOfExecutionThreads`, a value of 0 or 1 is rounded up internally by `NDB` to 2, so that 2 is considered this parameter's default and minimum value.

`MaxNoOfExecutionThreads` is generally intended to be set equal to the number of CPU threads available, and to allocate a number of threads of each type suitable to typical workloads. It does not assign particular threads to specified CPUs. For cases where it is desirable to vary from the settings provided, or to bind threads to CPUs, you should use `ThreadConfig` instead, which allows you to allocate each thread directly to a desired type, CPU, or both.

The multi-threaded data node process always spawns at least 4 threads, listed here:

- 1 local query handler (LDM) thread

- 1 transaction coordinator (TC) thread

- 1 receive thread

- 1 subscription manager (SUMA or replication) thread

Changing the number of LDM threads always requires a system restart, whether it is changed using this parameter or `ThreadConfig`. If the cluster's `IndexMemory` usage is greater than 50%, changing this requires an initial restart of the cluster. (A maximum of 30-35% `IndexMemory` usage is recommended in such cases.) Otherwise, resource usage and LDM thread allocation cannot be balanced between nodes, which can result in underutilized and overutilized LDM threads, and ultimately data node failures.

In MySQL Cluster NDB 7.1 and earlier, it is not possible to cause `ndbmtd` to use more than 1 TC thread. (This is possible in MySQL Cluster NDB 7.2.)

- `ThreadConfig`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.1.17	string	''	...	IS
NDB 7.2.3	string	''	...	IS

This parameter is used with `ndbmtd` to assign threads of different types to different CPUs. Its value is a string whose format has the following syntax:

```
ThreadConfig := entry[,entry[,...]]

entry := type={param[,param[,...]]}

type := ldm | main | recv | rep | io | tc | watchdog

param := count=number
   | cpubind=cpu_list
   | cpuset=cpu_list
   | spintime=number
   | realtime={0|1}
```

The curly braces ({...}) surrounding the list of parameters are required, even if there is only one parameter in the list.

A _param_ (parameter) specifies any or all of the following information:

- The number of threads of the given type (`count`).

- The set of CPUs to which the threads of the given type are to be nonexclusively bound. Thsi is determined by either one of `cpubind` or `cpuset`). `cpubind` causes each thread to be bound (nonexclusively) to a CPU in the set; `cpuset` means that each thread is bound (nonexclusively) to the set of CPUs specified.

  Only one of `cpubind` or `cpuset` can be provided in a single configuration.

- `spintime` determines the wait time in microseconds the thread spins before going to sleep.

  The default value for `spintime` is the value of the `SchedulerSpinTimer` data node configuration parameter.

  `spintime` does not apply to I/O threads or watchdog threads and so cannot be set for these thread types.

- `realtime` can be set to 0 or 1. If it is set to 1, the threads run with real-time priority. This also means that `thread_prio` cannot be set.

The `realtime` parameter is set by default to the value of the `RealtimeScheduler` data node configuration parameter.

The *type* attribute represents an NDB thread type. The thread types supported in MySQL Cluster NDB 7.1 and the range of permitted `count` values for each are provided in the following list:

- `ldm`: Local query handler (`DBLQH` kernel block) that handles data. The more LDM threads that are used, the more highly partitioned the data becomes. Each LDM thread maintains its own sets of data and index partitions, as well as its own redo log. In MySQL Cluster NDB 7.1, the maximum is 4 such threads.

> ⚠️ **Important**
>
> Changing the number of LDM threads requires a system restart to be effective and safe for cluster operations. (This is also true when this is done using `MaxNoOfExecutionThreads`.) If `IndexMemory` usage is in excess of 50%, an initial restart of the cluster is required; a maximum of 30-35% `IndexMemory` usage is recommended in such cases. Otherwise, `IndexMemory` and `DataMemory` usage as well as the allocation of LDM threads cannot be balanced between nodes, which can ultimately lead to data node failures.

- `tc`: Transaction coordinator thread (`DBTC` kernel block) containing the state of an ongoing transaction. In MySQL Cluster NDB 7.1, there can be only 1 TC thread. (In MySQL Cluster NDB 7.2, this number is configurable.)

  Range: 1 only.

- `main`: Data dictionary and transaction coordinator (`DBDIH` and `DBTC` kernel blocks), providing schema management. This is always handled by a single dedicated thread.

  Range: 1 only.

- `recv`: Receive thread (`CMVMI` kernel block). Each receive thread handles one or more sockets for communicating with other nodes in a MySQL Cluster, with one socket per node. Previously, this was limited to a single thread, but MySQL Cluster 7.2 implements multiple receive threads (up to 8).

  Range: 1 only.

- `rep`: Replication thread (`SUMA` kernel block). Asynchronous replication operations are always handled by a single, dedicated thread.

  Range: 1 only.

- `io`: File system and other miscellaneous operations. These are not demanding tasks, and are always handled as a group by a single, dedicated I/O thread.

  Range: 1 only.

Simple examples:

```
# Example 1.

ThreadConfig=ldm={count=2,cpubind=1,2},main={cpubind=12},rep={cpubind=11}

# Example 2.
```

```
Threadconfig=main={cpubind=0},ldm={count=4,cpubind=1,2,5,6},io={cpubind=3}
```

It is usually desirable when configuring thread usage for a data node host to reserve one or more CPUs for operating system and other tasks. Thus, for a host machine with 8 CPUs, you might want to use 8 CPU threads bound to 7 CPUs (leaving one for operating system and other functions), with 4 LDM threads, 1 TC thread, 1 receive thread, and 1 thread each for schema management, asynchronous replication, and I/O operations. (This is almost the same distribution of threads used when `MaxNoOfExecutionThreads` is set equal to 8.) The following `ThreadConfig` setting performs these assignments, additionally binding all of these threads to specific CPUs:

```
ThreadConfig=ldm{count=4,cpubind=1,2,3,4},main={cpubind=5}, \
io={cpubind=5},rep={cpubind=6},tc{cpubind=7},recv={cpubind=8}
```

It should be possible in most cases to bind the main (schema management) thread and the I/O thread to the same CPU, as we have done in the example just shown.

In order to take advantage of the enhanced stability that the use of `ThreadConfig` offers, it is necessary to insure that CPUs are isolated, and that they not subject to interrupts, or to being scheduled for other tasks by the operating system. On many Linux systems, you can do this by setting `IRQBALANCE_BANNED_CPUS` in `/etc/sysconfig/irqbalance` to `0xFFFFF0`, and by using the `isolcpus` boot option in `grub.conf`. For specific information, see your operating system or platform documentation.

In MySQL Cluster NDB 7.1 and earlier, it is not possible to cause `ndbmtd` to use more than 1 TC thread; this capability is introduced in MySQL Cluster NDB 7.2.

Disk Data Configuration Parameters.   Configuration parameters affecting Disk Data behavior include the following:

- `DiskPageBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.6	bytes	64M	4M - 1T	N

This determines the amount of space used for caching pages on disk, and is set in the `[ndbd]` or `[ndbd default]` section of the `config.ini` file. It is measured in bytes. Each page takes up 32 KB. This means that Cluster Disk Data storage always uses N * 32 KB memory where N is some nonnegative integer.

The default value for this parameter is `64M` (2000 pages of 32 KB each).

This parameter was added in MySQL 5.1.6.

Beginning with MySQL Cluster NDB 7.1.9, you can query the `ndbinfo.diskpagebuffer` table to help determine whether the value for this parameter should be increased to minimize unnecessary disk seeks. See Section 17.5.10.8, "The ndbinfo diskpagebuffer Table", for more information.

- `SharedGlobalMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	128M	0 - 64T	N
MySQL 5.1.6	bytes	20M	0 - 64T	N

This parameter determines the amount of memory that is used for log buffers, disk operations (such as page requests and wait queues), and metadata for tablespaces, log file groups, `UNDO` files, and

data files. The shared global memory pool also provides memory used for satisfying the memory requirements of the `UNDO_BUFFER_SIZE` option used with `CREATE LOGFILE GROUP` and `ALTER LOGFILE GROUP` statements, including any default value implied for this options by the setting of the `InitialLogFileGroup` data node configuration parameter. `SharedGlobalMemory` can be set in the `[ndbd]` or `[ndbd default]` section of the `config.ini` configuration file, and is measured in bytes.

As of MySQL Cluster NDB 7.2.0, the default value is `128M`. (Previously, this was `20M`.)

This parameter was added in MySQL 5.1.6.

- `DiskIOThreadPool`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.3	threads	8	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.7	threads	2	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.0	threads	2	0 - 4294967039 (0xFFFFFEFF)	N

This parameter determines the number of unbound threads used for Disk Data file access. Before `DiskIOThreadPool` was introduced, exactly one thread was spawned for each Disk Data file, which could lead to performance issues, particularly when using very large data files. With `DiskIOThreadPool`, you can—for example—access a single large data file using several threads working in parallel.

This parameter applies to Disk Data I/O threads only.

The optimum value for this parameter depends on your hardware and configuration, and includes these factors:

- **Physical distribution of Disk Data files.**   You can obtain better performance by placing data files, undo log files, and the data node file system on separate physical disks. If you do this with some or all of these sets of files, then you can set `DiskIOThreadPool` higher to enable separate threads to handle the files on each disk.

- **Disk performance and types.**   The number of threads that can be accommodated for Disk Data file handling is also dependent on the speed and throughput of the disks. Faster disks and higher throughput allow for more disk I/O threads. Our test results indicate that solid-state disk drives can handle many more disk I/O threads than conventional disks, and thus higher values for `DiskIOThreadPool`.

This parameter was added in MySQL Cluster NDB 6.4.0. Previous to MySQL Cluster NDB 6.4.3, it was named `IOThreadPool`. Previous to MySQL Cluster NDB 7.0.7, the default value was 8. Beginning with MySQL Cluster NDB 7.0.7 and MySQL Cluster NDB 7.1.0, the default is 2.

- **Disk Data file system parameters.**   The parameters in the following list were added in MySQL Cluster NDB 6.2.17, 6.3.22, and 6.4.3 to make it possible to place MySQL Cluster Disk Data files in specific directories without the need for using symbolic links.

  - `FileSystemPathDD`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.22	filename	[see text]	...	IN

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.2.17	filename	[see text]	...	IN
NDB 6.4.3	filename	[see text]	...	IN

If this parameter is specified, then MySQL Cluster Disk Data data files and undo log files are placed in the indicated directory. This can be overridden for data files, undo log files, or both, by specifying values for `FileSystemPathDataFiles`, `FileSystemPathUndoFiles`, or both, as explained for these parameters. It can also be overridden for data files by specifying a path in the `ADD DATAFILE` clause of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement, and for undo log files by specifying a path in the `ADD UNDOFILE` clause of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement. If `FileSystemPathDD` is not specified, then `FileSystemPath` is used.

If a `FileSystemPathDD` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

- `FileSystemPathDataFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.22	filename	[see text]	...	IN
NDB 6.2.17	filename	[see text]	...	IN
NDB 6.4.3	filename	[see text]	...	IN

If this parameter is specified, then MySQL Cluster Disk Data data files are placed in the indicated directory. This overrides any value set for `FileSystemPathDD`. This parameter can be overridden for a given data file by specifying a path in the `ADD DATAFILE` clause of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement used to create that data file. If `FileSystemPathDataFiles` is not specified, then `FileSystemPathDD` is used (or `FileSystemPath`, if `FileSystemPathDD` has also not been set).

If a `FileSystemPathDataFiles` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

- `FileSystemPathUndoFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.22	filename	[see text]	...	IN
NDB 6.2.17	filename	[see text]	...	IN
NDB 6.4.3	filename	[see text]	...	IN

If this parameter is specified, then MySQL Cluster Disk Data undo log files are placed in the indicated directory. This overrides any value set for `FileSystemPathDD`. This parameter can be overridden for a given data file by specifying a path in the `ADD UNDO` clause of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement used to create that data file. If `FileSystemPathUndoFiles` is not specified, then `FileSystemPathDD` is used (or `FileSystemPath`, if `FileSystemPathDD` has also not been set).

If a `FileSystemPathUndoFiles` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

For more information, see Section 17.5.12.1, "MySQL Cluster Disk Data Objects".

- **Disk Data object creation parameters.**   The next two parameters enable you—when starting the cluster for the first time—to cause a Disk Data log file group, tablespace, or both, to be created without the use of SQL statements.

  - `InitialLogFileGroup`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.22	string	[see text]	...	S
NDB 6.2.17	string	[see text]	...	S
NDB 6.4.3	string	[see text]	...	S

    This parameter can be used to specify a log file group that is created when performing an initial start of the cluster. `InitialLogFileGroup` is specified as shown here:

    ```
    InitialLogFileGroup = [name=name;] [undo_buffer_size=size;] file-specification-list

    file-specification-list:
        file-specification[; file-specification[; ...]]

    file-specification:
        filename:size
    ```

    The `name` of the log file group is optional and defaults to `DEFAULT-LG`. The `undo_buffer_size` is also optional; if omitted, it defaults to `64M`. Each `file-specification` corresponds to an undo log file, and at least one must be specified in the `file-specification-list`. Undo log files are placed according to any values that have been set for `FileSystemPath`, `FileSystemPathDD`, and `FileSystemPathUndoFiles`, just as if they had been created as the result of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement.

    Consider the following:

    ```
    InitialLogFileGroup = name=LG1; undo_buffer_size=128M; undo1.log:250M; undo2.log:150M
    ```

    This is equivalent to the following SQL statements:

    ```
    CREATE LOGFILE GROUP LG1
        ADD UNDOFILE 'undo1.log'
        INITIAL_SIZE 250M
        UNDO_BUFFER_SIZE 128M
        ENGINE NDBCLUSTER;

    ALTER LOGFILE GROUP LG1
        ADD UNDOFILE 'undo2.log'
        INITIAL_SIZE 150M
        ENGINE NDBCLUSTER;
    ```

    This logfile group is created when the data nodes are started with `--initial`.

    Resources for the initial log file group are taken from the global memory pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter; if this parameter is set too low and the values set in `InitialLogFileGroup` for the logfile group's initial size or undo buffer size are too high, the cluster may fail to create the default log file group when starting, or fail to start altogether.

This parameter, if used, should always be set in the `[ndbd default]` section of the `config.ini` file. The behavior of a MySQL Cluster when different values are set on different data nodes is not defined.

- `InitialTablespace`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.22	string	[see text]	...	S
NDB 6.2.17	string	[see text]	...	S
NDB 6.4.3	string	[see text]	...	S

This parameter can be used to specify a MySQL Cluster Disk Data tablespace that is created when performing an initial start of the cluster. `InitialTablespace` is specified as shown here:

```
InitialTablespace = [name=name;] [extent_size=size;] file-specification-list
```

The `name` of the tablespace is optional and defaults to `DEFAULT-TS`. The `extent_size` is also optional; it defaults to `1M`. The `file-specification-list` uses the same syntax as shown with the `InitialLogfileGroup` parameter, the only difference being that each `file-specification` used with `InitialTablespace` corresponds to a data file. At least one must be specified in the `file-specification-list`. Data files are placed according to any values that have been set for `FileSystemPath`, `FileSystemPathDD`, and `FileSystemPathDataFiles`, just as if they had been created as the result of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement.

For example, consider the following line specifying `InitialTablespace` in the `[ndbd default]` section of the `config.ini` file (as with `InitialLogfileGroup`, this parameter should always be set in the `[ndbd default]` section, as the behavior of a MySQL Cluster when different values are set on different data nodes is not defined):

```
InitialTablespace = name=TS1; extent_size=8M; data1.dat:2G; data2.dat:4G
```

This is equivalent to the following SQL statements:

```
CREATE TABLESPACE TS1
    ADD DATAFILE 'data1.dat'
    EXTENT_SIZE 8M
    INITIAL_SIZE 2G
    ENGINE NDBCLUSTER;

ALTER TABLESPACE TS1
    ADD DATAFILE 'data2.dat'
    INITIAL_SIZE 4G
    ENGINE NDBCLUSTER;
```

This tablespace is created when the data nodes are started with `--initial`, and can be used whenever creating MySQL Cluster Disk Data tables thereafter.

Disk Data and GCP Stop errors. Errors encountered when using Disk Data tables such as `Node nodeid killed this node because GCP stop was detected` (error 2303) are often referred to as "GCP stop errors". Such errors occur when the redo log is not flushed to disk quickly enough; this is usually due to slow disks and insufficient disk throughput.

You can help prevent these errors from occurring by using faster disks, and by placing Disk Data files on a separate disk from the data node file system. Reducing the value of `TimeBetweenGlobalCheckpoints`

tends to decrease the amount of data to be written for each global checkpoint, and so may provide some protection against redo log buffer overflows when trying to write a global checkpoint; however, reducing this value also permits less time in which to write the GCP, so this must be done with caution.

In addition, adjusting the cluster configuration as discussed here can also help:

- **MySQL Cluster NDB 6.2 and 6.3.** When working with large amounts of data on disk under high load, the default value for `DiskPageBufferMemory` may not be large enough. In such cases, you should increase its value to include most of the memory available to the data nodes after accounting for index memory, data memory, internal buffers, and memory needed by the data node host operating system.

  You can use this formula as a guide:

  ```
  DiskPageBufferMemory
    = 0.8
      x (
          [total memory]
            - ([operating system memory] + [buffer memory] + DataMemory + IndexMemory)
        )
  ```

  Once you have established that sufficient memory is reserved for `DataMemory`, `IndexMemory`, NDB internal buffers, and operating system overhead, it is possible (and sometimes desirable) to allocate more than the above amount of the remainder to `DiskPageBufferMemory`.

- **MySQL Cluster NDB 7.X.** In addition to the considerations given for `DiskPageBufferMemory` as explained previously, it is also very important that the `DiskIOThreadPool` configuration parameter be set correctly; having `DiskIOThreadPool` set too high is very likely to cause GCP stop errors (Bug #37227).

GCP stops can be caused by save or commit timeouts; the `TimeBetweenEpochsTimeout` data node configuration parameter determines the timeout for commits. However, beginning with MySQL Cluster NDB 7.0.21 and MySQL Cluster NDB 7.1.10, it is possible to disable both types of timeouts by setting this parameter to 0.

Parameters for configuring send buffer memory allocation (MySQL Cluster NDB 7.0 and later).
Beginning with MySQL Cluster NDB 6.4.0, send buffer memory is allocated dynamically from a memory pool shared between all transporters, which means that the size of the send buffer can be adjusted as necessary. (Previously, the NDB kernel used a fixed-size send buffer for every node in the cluster, which was allocated when the node started and could not be changed while the node was running.) The following data node configuration parameters were added in MySQL Cluster NDB 6.4.0 to permit the setting of limits on this memory allocation; this change is reflected by the addition of the configuration parameters `TotalSendBufferMemory` and `OverLoadLimit`, as well as a change in how the existing `SendBufferMemory` configuration parameter is used. For more information, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

- `ExtraSendBufferMemory`

  This parameter specifies the amount of transporter send buffer memory to allocate in addition to any set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

  This parameter was added in MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20. (Bug #13633845, Bug #11760629, Bug #53053)

- `TotalSendBufferMemory`

This parameter is available beginning with MySQL Cluster NDB 6.4.0. It is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

Prior to MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, this parameter did not work correctly with `ndbmtd`. (Bug #13633845)

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

- `ReservedSendBufferMemory`

  This parameter is present in `NDBCLUSTER` source code beginning with MySQL Cluster NDB 6.4.0. However, it is not currently enabled.

  As of MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, this parameter is deprecated, and is subject to removal in a future release of MySQL Cluster (Bug #11760629, Bug #53053).

For more detailed information about the behavior and use of `TotalSendBufferMemory` and `ReservedSendBufferMemory`, and about configuring send buffer memory parameters in MySQL Cluster NDB 6.4.0 and later, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

> **Note**
>
> Previous to MySQL Cluster NDB 7.0, to add new data nodes to a MySQL Cluster, it was necessary to shut down the cluster completely, update the `config.ini` file, and then restart the cluster (that is, you had to perform a system restart). All data node processes had to be started with the `--initial` option.
>
> Beginning with MySQL Cluster NDB 7.0, it is possible to add new data node groups to a running cluster online. See Section 17.5.13, "Adding MySQL Cluster Data Nodes Online", for more information.

Redo log over-commit handling. Beginning with MySQL Cluster NDB 7.1.10, it is possible to control the data node's handling of operations when too much time is taken flushing redo logs to disk. This occurs when a given redo log flush takes longer than `RedoOverCommitLimit` seconds, more than `RedoOverCommitCounter` times, causing any pending transactions to be aborted. When this happens, the API node that sent the transaction can handle the operations that should have been committed either by queuing the operations and re-trying them, or by aborting them, as determined by `DefaultOperationRedoProblemAction`. The data node configuration parameters for setting the timeout and number of times it may be exceeded before the API node takes this action are described in the following list:

- `RedoOverCommitCounter`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.1.10	numeric	3	0 - 4294967039 (0xFFFFFEFF)	N

  When `RedoOverCommitLimit` is exceeded when trying to write a given redo log to disk this many times or more, any transactions that were not committed as a result are aborted, and an API node where any of these transactions originated handles the operations making up those transactions according to its value for `DefaultOperationRedoProblemAction` (by either queuing the operations to be re-tried, or aborting them).

`RedoOverCommitCounter` defaults to 3. Set it to 0 to disable the limit. This parameter was added in MySQL Cluster NDB 7.1.10.

- `RedoOverCommitLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.1.10	seconds	20	0 - 4294967039 (0xFFFFFEFF)	N

This parameter sets an upper limit in seconds for trying to write a given redo log to disk before timing out. The number of times the data node tries to flush this redo log, but takes longer than `RedoOverCommitLimit`, is kept and compared with `RedoOverCommitCounter`, and when flushing takes too long more times than the value of that parameter, any transactions that were not committed as a result of the flush timeout are aborted. When this occurs, the API node where any of these transactions originated handles the operations making up those transactions according to its `DefaultOperationRedoProblemAction` setting (it either queues the operations to be re-tried, or aborts them).

By default, `RedoOverCommitLimit` is 20 seconds. Set to 0 to disable checking for redo log flush timeouts. This parameter was added in MySQL Cluster NDB 7.1.10.

Controlling restart attempts.   Beginning in MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.37, MySQL Cluster NDB 7.0.18, and MySQL Cluster NDB 7.1.7, it is possible to exercise more finely-grained control over restart attempts by data nodes when they fail to start using two data node configuration parameters added in these releases. `MaxStartFailRetries` limits the total number of retries made before giving up on starting the data node; `StartFailRetryDelay` sets the number of seconds between retry attempts, as described in the following list:

- `StartFailRetryDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.37	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.18	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.7	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N
NDB 6.2.19	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

Beginning in MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.37, MySQL Cluster NDB 7.0.18, and MySQL Cluster NDB 7.1.7, it is possible to set the number of seconds between restart attempts by the data node in the event on failure on startup. The default is 0 (no delay).

Note

This parameter is ignored unless `StopOnError` is equal to 0.

- `MaxStartFailRetries`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.37	unsigned	3	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.18	unsigned	3	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.7	unsigned	3	0 - 4294967039 (0xFFFFFEFF)	N
NDB 6.2.19	unsigned	3	0 - 4294967039 (0xFFFFFEFF)	N

Beginning in MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.37, MySQL Cluster NDB 7.0.18, and MySQL Cluster NDB 7.1.7, it is possible to limit the number restart attempts made by the data node in the event that it fails on startup. The default is 3 attempts.

Note

This parameter is ignored unless `StopOnError` is equal to 0.

17.3.3.7 Defining SQL and Other API Nodes in a MySQL Cluster

The `[mysqld]` and `[api]` sections in the `config.ini` file define the behavior of the MySQL servers (SQL nodes) and other applications (API nodes) used to access cluster data. None of the parameters shown is required. If no computer or host name is provided, any host can use this SQL or API node.

Generally speaking, a `[mysqld]` section is used to indicate a MySQL server providing an SQL interface to the cluster, and an `[api]` section is used for applications other than `mysqld` processes accessing cluster data, but the two designations are actually synonymous; you can, for instance, list parameters for a MySQL server acting as an SQL node in an `[api]` section.

Note

For a discussion of MySQL server options for MySQL Cluster, see MySQL Server Options for MySQL Cluster; for information about MySQL server system variables relating to MySQL Cluster, see MySQL Cluster System Variables.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 63	IS
NDB 6.1.1	unsigned	[none]	1 - 255	IS

The `Id` is an integer value used to identify the node in all cluster internal messages. Prior to MySQL Cluster NDB 6.1.1, the permitted range of values for this parameter was 1 to 63 inclusive. Beginning with MySQL Cluster NDB 6.1.1, the permitted range is 1 to 255 inclusive. This value must be unique for each node in the cluster, regardless of the type of node.

Note

Data node IDs must be less than 49, regardless of the MySQL Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for API nodes (and management nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying management nodes beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.39, MySQL Cluster NDB 7.0.20, and MySQL Cluster NDB 7.1.9. Although `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used.

- `ConnectionMap`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.0	string	[none]	...	N

Specifies which data nodes to connect. Introduced in MySQL Cluster NDB 6.1.0.

- `NodeId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	1 - 63	IS
NDB 6.1.1	unsigned	[none]	1 - 255	IS

The `NodeId` is an integer value used to identify the node in all cluster internal messages. Prior to MySQL Cluster NDB 6.1.1, the permitted range of values for this parameter was 1 to 63 inclusive. Beginning with MySQL Cluster NDB 6.1.1, the permitted range is 1 to 255 inclusive. This value must be unique for each node in the cluster, regardless of the type of node.

> **Note**
>
> Data node IDs must be less than 49, regardless of the MySQL Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for API nodes (and management nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying management nodes beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.39, MySQL Cluster NDB 7.0.20, and MySQL Cluster NDB 7.1.9. Although `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used.

- `ExecuteOnComputer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name	[none]	...	S

This refers to the `Id` set for one of the computers (hosts) defined in a `[computer]` section of the configuration file.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

Specifying this parameter defines the hostname of the computer on which the SQL node (API node) is to reside. To specify a hostname, either this parameter or `ExecuteOnComputer` is required.

If no `HostName` or `ExecuteOnComputer` is specified in a given `[mysql]` or `[api]` section of the `config.ini` file, then an SQL or API node may connect using the corresponding "slot" from any host which can establish a network connection to the management server host machine. *This differs from*

the default behavior for data nodes, where `localhost` is assumed for `HostName` unless otherwise specified.

- `ArbitrationRank`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	0-2	0	0 - 2	N

This parameter defines which nodes can act as arbitrators. Both management nodes and SQL nodes can be arbitrators. A value of 0 means that the given node is never used as an arbitrator, a value of 1 gives the node high priority as an arbitrator, and a value of 2 gives it low priority. A normal configuration uses the management server as arbitrator, setting its `ArbitrationRank` to 1 (the default for management nodes) and those for all SQL nodes to 0 (the default for SQL nodes).

Beginning with MySQL 5.1.16 and MySQL Cluster NDB 6.1.3, it is possible to disable arbitration completely by setting `ArbitrationRank` to 0 on all management and SQL nodes. In MySQL Cluster NDB 7.0.7 and later releases, you can also control arbitration by overriding this parameter; to do this, set the `Arbitration` parameter in the `[ndbd default]` section of the `config.ini` global configuration file.

- `ArbitrationDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

Setting this parameter to any other value than 0 (the default) means that responses by the arbitrator to arbitration requests will be delayed by the stated number of milliseconds. It is usually not necessary to change this value.

- `BatchByteSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	32K	1024 - 1M	N
NDB 7.2.1	bytes	16K	1024 - 1M	N

For queries that are translated into full table scans or range scans on indexes, it is important for best performance to fetch records in properly sized batches. It is possible to set the proper size both in terms of number of records (`BatchSize`) and in terms of bytes (`BatchByteSize`). The actual batch size is limited by both parameters.

The speed at which queries are performed can vary by more than 40% depending upon how this parameter is set.

This parameter is measured in bytes. The default value is 32K.

- `BatchSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	records	64	1 - 992	N
NDB 7.2.1	records	256	1 - 992	N

This parameter is measured in number of records and is by default set to 64. The maximum size is 992.

- `ExtraSendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.39	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.1.28	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter specifies the amount of transporter send buffer memory to allocate in addition to any that has been set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

This parameter was added in MySQL Cluster NDB 7.0.39 and MySQL Cluster NDB 7.1.28. (Bug #14555359)

- `HeartbeatThreadPriority`

Beginning with MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2, it is possible to use this parameter to set the scheduling policy and priority of heartbeat threads for management and API nodes.

The syntax for setting this parameter is shown here:

```
HeartbeatThreadPriority = policy[, priority]

policy:
  {FIFO | RR}
```

When setting this parameter, you must specify a policy. This is one of `FIFO` (first in, first in) or `RR` (round robin). This followed optionally by the priority (an integer).

- `MaxScanBatchSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	256K	32K - 16M	N

The batch size is the size of each batch sent from each data node. Most scans are performed in parallel to protect the MySQL Server from receiving too much data from many nodes in parallel; this parameter sets a limit to the total batch size over all nodes.

The default value of this parameter is set to 256KB. Its maximum size is 16MB.

- `TotalSendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	bytes	0	256K - 4294967039 (0xFFFFFEFF)	N

This parameter is available beginning with MySQL Cluster NDB 6.4.0. It is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

- `AutoReconnect`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.3.26	boolean	false	true, false	N
NDB 7.0.7	boolean	false	true, false	N

This parameter is available beginning with MySQL Cluster NDB 6.3.26 and MySQL Cluster NDB 7.0.7. By default, its value is `false`, which forces disconnected API nodes (including MySQL Servers acting as SQL nodes) the use a new connection to the cluster rather than attempting to re-use an existing one, which can cause problems when using dynamically-allocated node IDs. (Bug #45921)

Note

This parameter can be overridden using the NDB API. For more information, see Ndb_cluster_connection::set_auto_reconnect(), and Ndb_cluster_connection::get_auto_reconnect().

- `DefaultOperationRedoProblemAction`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.1.10	enumeration	ABORT	ABORT, QUEUE	S
NDB 7.2.1	enumeration	ABORT	ABORT, QUEUE	S

This parameter was introduced in MySQL Cluster NDB 7.1.10 (along with `RedoOverCommitLimit` and `RedoOverCommitCounter`) for controlling the data node's handling of operations when too much time is taken flushing redo logs to disk. This occurs when a given redo log flush takes longer than `RedoOverCommitLimit` seconds, more than `RedoOverCommitCounter` times, causing any pending transactions to be aborted.

When this happens, the node can respond in either of two ways, according to the value of `DefaultOperationRedoProblemAction`, listed here:

- `ABORT`: Any pending operations from aborted transactions are also aborted.

- `QUEUE`: Pending operations from transactions that were aborted are queued up to be re-tried.

Prior to MySQL Cluster NDB 7.1.26, setting this parameter did not have any effect. (Bug #15855588)

- `DefaultHashMapSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.0.38	buckets	240	0 - 3840	N
NDB 7.1.27	buckets	240	0 - 3840	N

Beginning with MySQL Cluster NDB 7.0.38 and MySQL Cluster NDB 7.1.26, the size of the table hash maps used by `NDB` is configurable using this parameter; previously this value was hard-coded. `DefaultHashMapSize` can take any of three possible values (0, 240, 3840). These values and their effects are described in the following table.

Value	Description / Effect
0	Use the lowest value set, if any, for this parameter among all data nodes and API nodes in the cluster; if it is not set on any data or API node, use the default value.

Value	Description / Effect
240	Original hash map size used by default in all MySQL Cluster NDB 7.1 and MySQL Cluster NDB 7.0 (and earlier) releases; effectively the only value prior to versions 7.0.38 and 7.1.26 (when this parameter was introduced).
3840	Larger hash map size available beginning with MySQL Cluster NDB 7.0.38 and MySQL Cluster NDB 7.1.26

The primary intended use for this parameter is to facilitate upgrades and especially downgrades between MySQL Cluster NDB 7.1 and later MySQL Cluster versions in which the larger hash map size (3840) is the default; by setting this parameter to 240 prior to performing an upgrade, you can cause the cluster to continue using the smaller size for table hash maps, in which case the tables remain compatible with earlier versions. `DefaultHashMapSize` can be set for individual data nodes, API nodes, or both, but setting it once only, in the `[ndbd default]` section of the `config.ini` file, is the recommended practice. You can also set this parameter to 0, in which case the default value is used.

After increasing this parameter, to have existing tables to take advantage of the new size, you can run `ALTER TABLE ... REORGANIZE PARTITION` on them, after which they can use the larger hash map size. This is in addition to performing a rolling restart, which makes the larger hash maps available to new tables, but does not enable existing tables to use them.

Decreasing this parameter online after any tables have been created or modified with `DefaultHashMapSize` equal to 3840 is not currently supported.

- Wan

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.1	boolean	false	true, false	N

Use WAN TCP setting as default. Introduced in MySQL Cluster NDB 6.1.1.

You can also obtain information from a MySQL server running as a MySQL Cluster SQL node using `SHOW STATUS` in the `mysql` client, as shown here:

```
mysql> SHOW STATUS LIKE 'ndb%';
+-----------------------------+---------------+
| Variable_name               | Value         |
+-----------------------------+---------------+
| Ndb_cluster_node_id         | 5             |
| Ndb_config_from_host        | 192.168.0.112 |
| Ndb_config_from_port        | 1186          |
| Ndb_number_of_storage_nodes | 4             |
+-----------------------------+---------------+
4 rows in set (0.02 sec)
```

For information about the status variables appearing in the output from this statement, see MySQL Cluster Status Variables.

> **Note**
>
> To add new SQL or API nodes to the configuration of a running MySQL Cluster, it is necessary to perform a rolling restart of all cluster nodes after adding new `[mysqld]` or `[api]` sections to the `config.ini` file (or files, if you are using more than one management server). This must be done before the new SQL or API nodes can connect to the cluster.

> It is *not* necessary to perform any restart of the cluster if new SQL or API nodes can employ previously unused API slots in the cluster configuration to connect to the cluster.

17.3.3.8 MySQL Server Options and Variables for MySQL Cluster

This section provides information about MySQL server options, server and status variables that are specific to MySQL Cluster. For general information on using these, and for other options and variables not specific to MySQL Cluster, see Section 5.1, "The MySQL Server".

For MySQL Cluster configuration parameters used in the cluster configuration file (usually named `config.ini`), see Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1".

MySQL Server Options for MySQL Cluster

This section provides descriptions of `mysqld` server options relating to MySQL Cluster. For information about `mysqld` options not specific to MySQL Cluster, and for general information about the use of options with `mysqld`, see Section 5.1.3, "Server Command Options".

For information about command-line options used with other MySQL Cluster processes (`ndbd`, `ndb_mgmd`, and `ndb_mgm`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs". For information about command-line options used with NDB utility programs (such as `ndb_desc`, `ndb_size.pl`, and `ndb_show_tables`), see Section 17.4, "MySQL Cluster Programs".

- `--ndb-batch-size=#`

Table 17.10 Type and value information for ndb-batch-size

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-batch-size`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	integer	32768 / 0 - 31536000
DESCRIPTION: Size (in bytes) to use for NDB transaction batches		

This sets the size in bytes that is used for NDB transaction batches.

- `--ndb-blob-read-batch-bytes=bytes`

Table 17.11 Type and value information for ndb-blob-read-batch-bytes

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-blob-read-batch-bytes`		

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	65536 / 0 - 4294967295
DESCRIPTION: Specifies size in bytes that large BLOB reads should be batched into. 0 = no limit.		

This option can be used to set the size (in bytes) for batching of `BLOB` data reads in MySQL Cluster applications. When this batch size is exceeded by the amount of `BLOB` data to be read within the current transaction, any pending `BLOB` read operations are immediately executed.

The maximum value for this option is 4294967295; the default is 65536. Setting it to 0 has the effect of disabling `BLOB` read batching.

> **Note**
>
> In NDB API applications, you can control `BLOB` write batching with the `setMaxPendingBlobReadBytes()` and `getMaxPendingBlobReadBytes()` methods.

This option was introduced in MySQL Cluster NDB 7.0.21 and MySQL Cluster NDB 7.1.10.

- `--ndb-blob-write-batch-bytes=bytes`

Table 17.12 Type and value information for ndb-blob-write-batch-bytes

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-blob-write-batch-bytes`		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	65536 / 0 - 4294967295
DESCRIPTION: Specifies size in bytes that large BLOB writes should be batched into. 0 = no limit.		

This option can be used to set the size (in bytes) for batching of `BLOB` data writes in MySQL Cluster applications. When this batch size is exceeded by the amount of `BLOB` data to be written within the current transaction, any pending `BLOB` write operations are immediately executed.

The maximum value for this option is 4294967295; the default is 65536. Setting it to 0 has the effect of disabling `BLOB` write batching.

> **Note**
>
> In NDB API applications, you can control `BLOB` write batching with the `setMaxPendingBlobWriteBytes()` and `getMaxPendingBlobWriteBytes()` methods.

This option was introduced in MySQL Cluster NDB 7.0.21 and MySQL Cluster NDB 7.1.10.

- `--ndb-cluster-connection-pool=#`

Table 17.13 Type and value information for ndb-cluster-connection-pool

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-cluster-connection-pool`		
Yes	Yes	Yes
Yes	Global	No
MySQL 5.1	integer	1 / 1 - 63
DESCRIPTION: Number of connections to the cluster used by MySQL		

By setting this option to a value greater than 1 (the default), a `mysqld` process can use multiple connections to the cluster, effectively mimicking several SQL nodes. Each connection requires its own `[api]` or `[mysqld]` section in the cluster configuration (`config.ini`) file, and counts against the maximum number of API connections supported by the cluster.

Suppose that you have 2 cluster host computers, each running an SQL node whose `mysqld` process was started with `--ndb-cluster-connection-pool=4`; this means that the cluster must have 8 API slots available for these connections (instead of 2). All of these connections are set up when the SQL node connects to the cluster, and are allocated to threads in a round-robin fashion.

This option is useful only when running `mysqld` on host machines having multiple CPUs, multiple cores, or both. For best results, the value should be smaller than the total number of cores available on the host machine. Setting it to a value greater than this is likely to degrade performance severely.

> **Important**
>
> Because each SQL node using connection pooling occupies multiple API node slots—each slot having its own node ID in the cluster—you must *not* use a node ID as part of the cluster connection string when starting any `mysqld` process that employs connection pooling.
>
> Setting a node ID in the connection string when using the `--ndb-cluster-connection-pool` option causes node ID allocation errors when the SQL node attempts to connect to the cluster.

This option was introduced in MySQL Cluster NDB 6.2.2. Beginning with MySQL Cluster NDB 6.2.16 and MySQL Cluster NDB 6.3.13, the value used for this option is available as a system variable (Bug #35573).

Prior to MySQL Cluster NDB 7.0.23 and MySQL Cluster NDB 7.1.12, there was also a status variable corresponding to this option; however, the status variable was removed as redundant as of these versions. (Bug #60119)

- `--ndb-connectstring=connection_string`

Table 17.14 Type and value information for ndb-connectstring

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-connectstring`		
Yes	No	No
Yes		No
MySQL 5.1	string	
DESCRIPTION: Point to the management server that distributes the cluster configuration		

When using the `NDBCLUSTER` storage engine, this option specifies the management server that distributes cluster configuration data. See Section 17.3.3.3, "MySQL Cluster Connection Strings", for syntax.

- `--ndb-deferred-constraints=[0|1]`

Table 17.15 Type and value information for ndb-deferred-constraints

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-deferred-constraints`		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	0 / 0 - 1
DESCRIPTION: Specifies that constraint checks on unique indexes (where these are supported) should be deferred until commit time. Not normally needed or used; for testing purposes only.		

Controls whether or not constraint checks on unique indexes are deferred until commit time, where such checks are supported. `0` is the default.

This option is not normally needed for operation of MySQL Cluster or MySQL Cluster Replication, and is intended primarily for use in testing.

This option was added in MySQL Cluster NDB 7.0.28 and MySQL Cluster NDB 7.1.14.

- `--ndb-distribution=[KEYHASH|LINHASH]`

Table 17.16 Type and value information for ndb-distribution

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb-distribution		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	enumeration	KEYHASH / LINHASH, KEYHASH
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH)		

Controls the default distribution method for NDB tables. Can be set to either of KEYHASH (key hashing) or LINHASH (linear hashing). KEYHASH is the default.

- `--ndb-mgmd-host=host[:port]`

Table 17.17 Type and value information for ndb-mgmd-host

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb-mgmd-host		
Yes	No	No
Yes		No
MySQL 5.1	string	localhost:1186
DESCRIPTION: Set the host (and port, if desired) for connecting to management server		

Can be used to set the host and port number of a single management server for the program to connect to. If the program requires node IDs or references to multiple management servers (or both) in its connection information, use the `--ndb-connectstring` option instead.

- `--ndbcluster`

Table 17.18 Type and value information for ndbcluster

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndbcluster		
Yes	No	No

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
Yes		No
MySQL 5.1	boolean	FALSE
DESCRIPTION: Enable NDB Cluster (if this version of MySQL supports it)		
Disabled by `--skip-ndbcluster`		

The `NDBCLUSTER` storage engine is necessary for using MySQL Cluster. If a `mysqld` binary includes support for the `NDBCLUSTER` storage engine, the engine is disabled by default. Use the `--ndbcluster` option to enable it. Use `--skip-ndbcluster` to explicitly disable the engine.

- `--ndb-log-apply-status`

Table 17.19 Type and value information for ndb-log-apply-status

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-log-apply-status`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	boolean	OFF
DESCRIPTION: Cause a MySQL server acting as a slave to log mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID. Effective only if the server is started with the --ndbcluster option.		

Causes a slave `mysqld` to log any updates received from its immediate master to the `mysql.ndb_apply_status` table in its own binary log using its own server ID rather than the server ID of the master. In a circular or chain replication setting, this allows such updates to propagate to the `mysql.ndb_apply_status` tables of any MySQL servers configured as slaves of the current `mysqld`.

In a chain replication setup, using this option allows downstream (slave) clusters to be aware of their positions relative to all of their upstream contributors (masters).

In a circular replication setup, this option causes changes to `ndb_apply_status` tables to complete the entire circuit, eventually propagating back to the originating MySQL Cluster. This also allows a cluster acting as a master to see when its changes (epochs) have been applied to the other clusters in the circle.

This option was added in MySQL Cluster NDB 7.0.21 and MySQL Cluster NDB 7.1.10. It has no effect unless the MySQL server is started with the `--ndbcluster` option.

- `--ndb-log-empty-epochs=[0|1]`

Table 17.20 Type and value information for ndb-log-empty-epochs

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-log-empty-epochs`		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	boolean	OFF
DESCRIPTION: When enabled, causes epochs in which there were no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled.		

Causes epochs during which there were no changes to be written to the `ndb_apply_status` and `ndb_binlog_index` tables, even when `--log-slave-updates` is enabled.

By default this option is disabled. Disabling `--ndb-log-empty-epochs` causes epoch transactions with no changes not to be written to the binary log, although a row is still written even for an empty epoch in `ndb_binlog_index` (Bug #49559, Bug #11757505).

Because `--ndb-log-empty-epochs=1` causes the size of `ndb_binlog_index` table to increase independently of the size of the binary log, users should be prepared to manage the growth of this table, even if they expect the cluster to be idle a large part of the time.

This option was introduced in MySQL Cluster NDB 6.3.21 and MySQL Cluster NDB 6.4.1. Prior to MySQL Cluster NDB 6.3.33, MySQL Cluster NDB 7.0.14, and MySQL Cluster NDB 7.1.3, setting `--ndb-log-empty-epochs=0` also caused no row to be written in `ndb_binlog_index` for an empty epoch.

- `--ndb-log-orig`

Table 17.21 Type and value information for ndb-log-orig

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-log-orig`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	boolean	OFF
DESCRIPTION: Log originating server id and epoch in mysql.ndb_binlog_index table.		

Log the originating server ID and epoch in the `ndb_binlog_index` table.

Note that this makes it possible for a given epoch to have multiple rows in `ndb_binlog_index`, one for each originating epoch.

For more information, see Section 17.6.4, "MySQL Cluster Replication Schema and Tables".

- `--ndb-log-transaction-id`

Table 17.22 Type and value information for ndb-log-transaction-id

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb-log-transaction-id		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	boolean	OFF
DESCRIPTION: Write NDB transaction IDs in the binary log. Requires --log-bin-v1-events=OFF.		

Causes a slave `mysqld` to write the NDB transaction ID in each row of the binary log. Such logging requires the use of the Version 2 event format for the binary log; thus, `--log-bin-use-v1-row-events` must be set to `FALSE` in order to use this option.

This option is available beginning with MySQL Cluster NDB 7.1.16 (and is not supported in mainline MySQL Server 5.1). It is required to enable MySQL Cluster Replication conflict detection and resolution using the `NDB$EPOCH_TRANS()` function introduced in the same MySQL Cluster release.

The default value is `FALSE`.

For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `--ndb-nodeid=#`

Table 17.23 Type and value information for ndb-nodeid

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb-nodeid		
Yes	No	Yes
Yes	Global	No
5.0.45	integer	/ 1 - 63
5.1.5	integer	/ 1 - 255
DESCRIPTION: MySQL Cluster node ID for this MySQL server		

Set this MySQL server's node ID in a MySQL Cluster.

Prior to MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, this option can be used *instead* of specifying the node ID as part of the connection string or in the `config.ini` file, or permitting the cluster to determine an arbitrary node ID. If you use this option, then `--ndb-nodeid` must be specified

before `--ndb-connectstring`. If `--ndb-nodeid` is used *and* a node ID is specified in the connection string, then the MySQL server cannot connect to the cluster.

Beginning with MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, the `--ndb-nodeid` option *overrides* any node ID set with `--ndb-connectstring`, regardless of the order in which the two options are used.

In addition (regardless of the MySQL Cluster version), if `--ndb-nodeid` is used, then either a matching node ID must be found in a `[mysqld]` or `[api]` section of `config.ini`, or there must be an "open" `[mysqld]` or `[api]` section in the file (that is, a section without a `NodeId` or `Id` parameter specified). This is also true if the node ID is specified as part of the connection string.

Regardless of how the node ID is determined, its is shown as the value of the global status variable `Ndb_cluster_node_id` in the output of `SHOW STATUS`, and as `cluster_node_id` in the `connection` row of the output of `SHOW ENGINE NDBCLUSTER STATUS`.

For more information about node IDs for MySQL Cluster SQL nodes, see Section 17.3.3.7, "Defining SQL and Other API Nodes in a MySQL Cluster".

- `--ndb_optimization_delay=milliseconds`

Table 17.24 Type and value information for ndb_optimization_delay

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_optimization_delay`		
No	Yes	No
No	Global	Yes
MySQL 5.1	integer	10 / 0 - 100000
DESCRIPTION: Sets the number of milliseconds to wait between processing sets of rows by OPTIMIZE TABLE on NDB tables.		

Set the number of milliseconds to wait between sets of rows by `OPTIMIZE TABLE` statements on `NDB` tables. The default is 10.

- `ndb-transid-mysql-connection-map=state`

Table 17.25 Type and value information for ndb-transid-mysql-connection-map

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-transid-mysql-connection-map`		
Yes	No	No
No		No
MySQL 5.1	enumeration	ON / ON, OFF, FORCE

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
DESCRIPTION: Enable or disable the ndb_transid_mysql_connection_map plugin; that is, enable or disable the INFORMATION_SCHEMA table having that name.		

Enables or disables the plugin that handles the `ndb_transid_mysql_connection_map` table in the `INFORMATION_SCHEMA` database. Takes one of the values `ON`, `OFF`, or `FORCE`. `ON` (the default) enables the plugin. `OFF` disables the plugin, which makes `ndb_transid_mysql_connection_map` inaccessible. `FORCE` keeps the MySQL Server from starting if the plugin fails to load and start.

You can see whether the `ndb_transid_mysql_connection_map` table plugin is running by checking the output of `SHOW PLUGINS`.

This option was added in MySQL Cluster NDB 7.1.17.

- `--ndb-wait-connected=`*seconds*

Table 17.26 Type and value information for ndb-wait-connected

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-wait-connected`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	integer	0 / 0 - 31536000
5.1.56-ndb-7.1.16, 5.1.56-ndb-7.0.27	integer	30 / 0 - 31536000
DESCRIPTION: Time (in seconds) for the MySQL server to wait for connection to cluster management and data nodes before accepting MySQL client connections.		

This option sets the period of time that the MySQL server waits for connections to MySQL Cluster management and data nodes to be established before accepting MySQL client connections. The time is specified in seconds.

Prior to MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, there existed a hard-coded 30-second timeout (which was removed in these versions), and the default value for this option was `0`. Starting with these releases, the default value is `30`, and user-supplied values are handled correctly. (Bug #12543299)

- `--ndb-wait-setup=`*seconds*

Table 17.27 Type and value information for ndb-wait-setup

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb-wait-setup		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	integer	15 / 0 - 31536000
5.1.56-ndb-7.0.27, 5.1.56-ndb-7.1.16	integer	30 / 0 - 31536000
DESCRIPTION: Time (in seconds) for the MySQL server to wait for NDB engine setup to complete.		

This variable shows the period of time that the MySQL server waits for the NDB storage engine to complete setup before timing out and treating NDB as unavailable. The time is specified in seconds.

Prior to MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, the default value for this option was 15. In these and later releases, the default value is 30. (Bug #12543299)

- --server-id-bits=#

Table 17.28 Type and value information for server-id-bits

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
server-id-bits		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	integer	32 / 7 - 32
DESCRIPTION: Sets the number of least significant bits in the server_id actually used for identifying the server, permitting NDB API applications to store application data in the most significant bits. server_id must be less than 2 to the power of this value.		

This option indicates the number of least significant bits within the 32-bit server_id which actually identify the server. Indicating that the server is actually identified by fewer than 32 bits makes it possible for some of the remaining bits to be used for other purposes, such as storing user data generated by applications using the NDB API's Event API within the AnyValue of an OperationOptions structure (MySQL Cluster uses the AnyValue to store the server ID).

When extracting the effective server ID from server_id for purposes such as detection of replication loops, the server ignores the remaining bits. The --server-id-bits option is used to mask out any irrelevant bits of server_id in the IO and SQL threads when deciding whether an event should be ignored based on the server ID.

This data can be read from the binary log by `mysqlbinlog`, provided that it is run with its own `--server-id-bits` option set to 32 (the default).

The value of `server_id` must be less than 2 ^ `server_id_bits`; otherwise, `mysqld` refuses to start.

This system variable was added in MySQL Cluster NDB 7.0.17 and MySQL Cluster NDB 7.1.6; it is supported only in these and later releases of MySQL Cluster. It is not supported by the standard MySQL Server.

- `--skip-ndbcluster`

Table 17.29 Type and value information for skip-ndbcluster

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`skip-ndbcluster`		
Yes	No	No
Yes		No
DESCRIPTION: Disable the NDB Cluster storage engine		

Disable the `NDBCLUSTER` storage engine. This is the default for binaries that were built with `NDBCLUSTER` storage engine support; the server allocates memory and other resources for this storage engine only if the `--ndbcluster` option is given explicitly. See Section 17.3.1, "Quick Test Setup of MySQL Cluster", for an example.

MySQL Cluster System Variables

This section provides detailed information about MySQL server system variables that are specific to MySQL Cluster and the `NDB` storage engine. For system variables not specific to MySQL Cluster, see Section 5.1.4, "Server System Variables". For general information on using system variables, see Section 5.1.5, "Using System Variables".

- `have_ndbcluster`

Table 17.30 Type and value information for have_ndbcluster

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`have_ndbcluster`		
No	Yes	No
No	Global	No
MySQL 5.1	boolean	
DESCRIPTION: Whether mysqld supports NDB Cluster tables (set by --ndbcluster option)		

`YES` if `mysqld` supports `NDBCLUSTER` tables. `DISABLED` if `--skip-ndbcluster` is used.

This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `ndb_autoincrement_prefetch_sz`

Table 17.31 Type and value information for ndb_autoincrement_prefetch_sz

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_autoincrement_prefetch_sz`		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	32 / 1 - 256
5.0.56	integer	1 / 1 - 256
5.1.1	integer	32 / 1 - 256
5.1.23	integer	1 / 1 - 256
5.1.16-ndb-6.2.0	integer	32 / 1 - 256
5.1.23-ndb-6.2.10	integer	1 / 1 - 256
5.1.19-ndb-6.3.0	integer	32 / 1 - 256
5.1.23-ndb-6.3.7	integer	1 / 1 - 256
5.1.41-ndb-6.3.31	integer	1 / 1 - 65536
5.1.30-ndb-6.4.0	integer	32 / 1 - 256
5.1.41-ndb-7.0.11	integer	1 / 1 - 65536
DESCRIPTION: NDB auto-increment prefetch size		

Determines the probability of gaps in an autoincremented column. Set it to `1` to minimize this. Setting it to a high value for optimization makes inserts faster, but decreases the likelihood that consecutive autoincrement numbers will be used in a batch of inserts. The minimum value is 1. Prior to MySQL 5.1.23, MySQL Cluster NDB 6.2.9, and MySQL Cluster NDB 6.3.7, the default value was 32; in these and all later versions, the default is 1. Prior to MySQL Cluster NDB 6.3.31 and MySQL Cluster NDB 7.0.11, the maximum value was 256; in these and all later versions of MySQL Cluster (including all MySQL Cluster NDB 7.1 releases), the maximum is 65536 (Bug #50621).

Beginning with MySQL Cluster NDB 6.2.10, MySQL Cluster NDB 6.3.7, and MySQL 5.1.23, this variable affects the number of `AUTO_INCREMENT` IDs that are fetched between statements only. Within a statement, at least 32 IDs are now obtained at a time. Also beginning with these releases, the default value is 1. (Bug #31956)

> **Important**
>
> This variable does not affect inserts performed using `INSERT ... SELECT`.

- `ndb_cache_check_time`

Table 17.32 Type and value information for ndb_cache_check_time

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_cache_check_time		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	integer	0 / -
DESCRIPTION: Number of milliseconds between checks of cluster SQL nodes made by the MySQL query cache		

The number of milliseconds that elapse between checks of MySQL Cluster SQL nodes by the MySQL query cache. Setting this to 0 (the default and minimum value) means that the query cache checks for validation on every query.

The recommended maximum value for this variable is 1000, which means that the check is performed once per second. A larger value means that the check is performed and possibly invalidated due to updates on different SQL nodes less often. It is generally not desirable to set this to a value greater than 2000.

- ndb_deferred_constraints

Table 17.33 Type and value information for ndb_deferred_constraints

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_deferred_constraints		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	0 / 0 - 1
DESCRIPTION: Specifies that constraint checks should be deferred (where these are supported). Not normally needed or used; for testing purposes only.		

Controls whether or not constraint checks are deferred, where these are supported. 0 is the default.

This variable was added in MySQL Cluster NDB 7.0.28 and MySQL Cluster NDB 7.1.14.

This variable is not normally needed for operation of MySQL Cluster or MySQL Cluster Replication, and is intended primarily for use in testing.

- ndb_distribution

Table 17.34 Type and value information for ndb_distribution

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_distribution		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	enumeration	KEYHASH / LINHASH, KEYHASH
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH)		

Controls the default distribution method for NDB tables. Can be set to either of KEYHASH (key hashing) or LINHASH (linear hashing). KEYHASH is the default.

- ndb_eventbuffer_max_alloc

Table 17.35 Type and value information for ndb_eventbuffer_max_alloc

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_eventbuffer_max_alloc		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	integer	0 / 0 - 4294967295
DESCRIPTION: Maximum memory that can be allocated for buffering events by the NDB API. Defaults to 0 (no limit).		

Sets the maximum amount memory (in bytes) that can be allocated for buffering events by the NDB API. 0 means that no limit is imposed, and is the default.

This variable was added in MySQL Cluster NDB 7.1.29.

- ndb_extra_logging

Table 17.36 Type and value information for ndb_extra_logging

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_extra_logging		

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	integer	0 / -
5.1.19-ndb-6.3.0	integer	1 / -
DESCRIPTION: Controls logging of MySQL Cluster schema, connection, and data distribution events in the MySQL error log		

This variable enables recording in the MySQL error log of information specific to the NDB storage engine.

When this variable is set to 0, the only information specific to NDB that is written to the MySQL error log relates to transaction handling. If it set to a value greater than 0 but less than 10, NDB table schema and connection events are also logged, as well as whether or not conflict resolution is in use, and other NDB errors and information. If the value is set to 10 or more, information about NDB internals, such as the progress of data distribution among cluster nodes, is also written to the MySQL error log.

This variable was added in MySQL 5.1.6. Prior to MySQL Cluster NDB 6.3, the default value was 0; in MySQL Cluster NDB 6.3.0 and later, the default is 1.

- ndb_force_send

Table 17.37 Type and value information for ndb_force_send

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_force_send		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	boolean	TRUE
DESCRIPTION: Forces sending of buffers to NDB immediately, without waiting for other threads		

Forces sending of buffers to NDB immediately, without waiting for other threads. Defaults to ON.

- ndb_index_stat_cache_entries

Table 17.38 Type and value information for ndb_index_stat_cache_entries

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_index_stat_cache_entries		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	32 / 0 - 4294967295
DESCRIPTION: Sets the granularity of the statistics by determining the number of starting and ending keys		

Sets the granularity of the statistics by determining the number of starting and ending keys to store in the statistics memory cache. Zero means no caching takes place; in this case, the data nodes are always queried directly. Default value: `32`.

> **Note**
>
> If `ndb_index_stat_enable` is `OFF`, then setting this variable has no effect.

This variable is deprecated as of MySQL 5.1.19, and is removed from MySQL Cluster NDB 7.1.31 and later.

- ndb_index_stat_enable

Table 17.39 Type and value information for ndb_index_stat_enable

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_index_stat_enable		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	boolean	OFF
DESCRIPTION: Use NDB index statistics in query optimization		

Use NDB index statistics in query optimization. Defaults to `OFF` prior to MySQL Cluster NDB 7.2; `ON` is the default in MySQL Cluster NDB 7.2 and later.

- ndb_index_stat_option

Table 17.40 Type and value information for ndb_index_stat_option

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_index_stat_option		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	string	loop_enable=1000ms,loop_idle=1000ms,loop_b update_batch=1,read_batch=4,idle_batch=32,c check_delay=10m,delete_batch=8, clean_delay=1m,error_batch=4, error_delay=1m,evict_batch=8,evict_delay=1m, cache_lowpct=90,zero_total=0
5.1.56-ndb-7.1.17	string	loop_checkon=1000ms,loop_idle=1000ms,loop_ update_batch=1,read_batch=4,idle_batch=32,c check_delay=1m,delete_batch=8,clean_delay= error_delay=1m,evict_batch=8,evict_delay=1m, cache_lowpct=90
DESCRIPTION: Comma-separated list of tunable options for NDB index statistics; the list should contain no spaces		

This variable is used for providing tuning options for NDB index statistics generation. The list consist of comma-separated name-value pairs of option names and values. Note that this list must not contain any space characters.

Options not used when setting ndb_index_stat_option are not changed from their default values. For example, you can set ndb_index_stat_option = 'loop_idle=1000ms,cache_limit=32M'.

Time values can be optionally suffixed with h (hours), m (minutes), or s (seconds). Millisecond values can optionally be specified using ms; millisecond values cannot be specified using h, m, or s.) Integer values can be suffixed with K, M, or G.

The names of the options that can be set using this variable are shown in the table that follows. The table also provides brief descriptions of the options, their default values, and (where applicable) their minimum and maximum values.

Name	Description	Default/Units	Minimum/Maximum
loop_enable		1000 ms	0/4G
loop_idle	Time to sleep when idle	1000 ms	0/4G
loop_busy	Time to sleep when more work is waiting	100 ms	0/4G
update_batch		1	0/4G
read_batch		4	1/4G
idle_batch		32	1/4G

Name	Description	Default/Units	Minimum/Maximum
check_batch		8	1/4G
check_delay	How often to check for new statistics	10 m	1/4G
delete_batch		8	0/4G
clean_delay		1 m	0/4G
error_batch		4	1/4G
error_delay		1 m	1/4G
evict_batch		8	1/4G
evict_delay	Clean LRU cache, from read time	1 m	0/4G
cache_limit	Maximum amount of memory in bytes used for cached index statistics by this mysqld; clean up the cache when this is exceeded.	32 M	0/4G
cache_lowpct		90	0/100
zero_total	Setting this to 1 causes all accumulating counters in ndb_index_stat_status to be reset to 0. Note that the option value is also reset to 0 when this is done.	0	0/1

ndb_index_stat_option was added in MySQL Cluster NDB 7.1.15.

- ndb_index_stat_update_freq

Table 17.41 Type and value information for ndb_index_stat_update_freq

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_index_stat_update_freq		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	integer	20 / 0 - 4294967295
DESCRIPTION: How often to query data nodes instead of the statistics cache		

How often to query data nodes instead of the statistics cache. For example, a value of 20 (the default) means to direct every 20th query to the data nodes.

> **Note**
>
> If `ndb_index_stat_cache_entries` is `0`, then setting this variable has no effect; in this case, every query is sent directly to the data nodes.

This variable is deprecated as of MySQL 5.1.19, and is removed from MySQL Cluster NDB 7.1.31 and later.

- `ndb_join_pushdown`

Table 17.42 Type and value information for ndb_join_pushdown

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_join_pushdown`		
No	Yes	No
No	Both	Yes
5.1.51-ndb-7.2.0	boolean	TRUE
DESCRIPTION: Enables pushing down of joins to data nodes		

Added in MySQL Cluster NDB 7.2.0, this variable controls whether joins on `NDB` tables are pushed down to the NDB kernel (data nodes). Previously, a join was handled using multiple accesses of `NDB` by the SQL node; however, when `ndb_join_pushdown` is enabled, a pushable join is sent in its entirety to the data nodes, where it can be distributed among the data nodes and executed in parallel on multiple copies of the data, with a single, merged result being returned to `mysqld`. This can reduce greatly the number of round trips between an SQL node and the data nodes required to handle such a join.

By default, `ndb_join_pushdown` is enabled.

Conditions for NDB pushdown joins.   In order for a join to be pushable, it must meet the following conditions:

1. Only columns can be compared, and all columns to be joined must use *exactly* the same data type.

    This means that expressions such as `t1.a = t2.a + constant` cannot be pushed down, and that (for example) a join on an `INT` column and a `BIGINT` column also cannot be pushed down.

2. Queries referencing `BLOB` or `TEXT` columns are not supported.

3. Explicit locking is not supported; however, the `NDB` storage engine's characteristic implicit row-based locking is enforced.

    This means that a join using `FOR UPDATE` cannot be pushed down.

4. In order for a join to be pushed down, child tables in the join must be accessed using one of the `ref`, `eq_ref`, or `const` access methods, or some combination of these methods.

    Outer joined child tables can only be pushed using `eq_ref`.

If the root of the pushed join is an `eq_ref` or `const`, only child tables joined by `eq_ref` can be appended. (A table joined by `ref` is likely to become the root of another pushed join.)

If the query optimizer decides on `Using join cache` for a candidate child table, that table cannot be pushed as a child. However, it may be the root of another set of pushed tables.

5. Joins referencing tables explicitly partitioned by `[LINEAR] HASH`, `LIST`, or `RANGE` currently cannot be pushed down.

You can see whether a given join can be pushed down by checking it with `EXPLAIN`; when the join can be pushed down, you can see references to the `pushed join` in the `Extra` column of the output, as shown in this example:

```
mysql> EXPLAIN
    ->       SELECT e.first_name, e.last_name, t.title, d.dept_name
    ->           FROM employees e
    ->           JOIN dept_emp de ON e.emp_no=de.emp_no
    ->           JOIN departments d ON d.dept_no=de.dept_no
    ->           JOIN titles t ON e.emp_no=t.emp_no\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: d
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 9
        Extra: Parent of 4 pushed join@1
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: de
         type: ref
possible_keys: PRIMARY,emp_no,dept_no
          key: dept_no
      key_len: 4
          ref: employees.d.dept_no
         rows: 5305
        Extra: Child of 'd' in pushed join@1
*************************** 3. row ***************************
           id: 1
  select_type: SIMPLE
        table: e
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: employees.de.emp_no
         rows: 1
        Extra: Child of 'de' in pushed join@1
*************************** 4. row ***************************
           id: 1
  select_type: SIMPLE
        table: t
         type: ref
possible_keys: PRIMARY,emp_no
          key: emp_no
      key_len: 4
          ref: employees.de.emp_no
         rows: 19
        Extra: Child of 'e' in pushed join@1
```

```
4 rows in set (0.00 sec)
```

> **Note**
>
> If inner joined child tables are joined by `ref`, *and* the result is ordered or grouped by a sorted index, this index cannot provide sorted rows, which forces writing to a sorted tempfile.

Two additional sources of information about pushed join performance are available:

1. The status variables `Ndb_pushed_queries_defined`, `Ndb_pushed_queries_dropped`, `Ndb_pushed_queries_executed`, and `Ndb_pushed_reads` (all introduced in MySQL Cluster NDB 7.2.0).

2. The counters in the `ndbinfo.counters` table that belong to the `DBSPJ` kernel block. (These counters and the `DBSPJ` block were also introduced in MySQL Cluster NDB 7.2.0). See Section 17.5.10.7, "The ndbinfo counters Table", for information about these counters. See also The DBSPJ Block, in the *MySQL Cluster API Developer Guide*.

- `ndb_log_apply_status`

Table 17.43 Type and value information for ndb_log_apply_status

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_log_apply_status`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	boolean	OFF
DESCRIPTION: Whether or not a MySQL server acting as a slave logs mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID.		

A read-only variable which shows whether the server was started with the `--ndb-log-apply-status` option.

This variable was added in MySQL Cluster NDB 7.0.21 and MySQL Cluster NDB 7.1.10.

- `ndb_log_bin`

Table 17.44 Type and value information for ndb_log_bin

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_log_bin`		
Yes	Yes	No
No	Both	Yes

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
MySQL 5.1	boolean	ON
DESCRIPTION: Write updates to NDB tables in the binary log. Effective only if binary logging is enabled with --log-bin.		

Causes updates to `NDB` tables to be written to the binary log. Setting this variable has no effect if binary logging is not already enabled for the server using `log_bin`. `ndb_log_bin` defaults to 1 (ON); normally, there is never any need to change this value in a production environment.

This variable was added in MySQL 5.1.6.

- `ndb_log_binlog_index`

Table 17.45 Type and value information for ndb_log_binlog_index

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_log_binlog_index`		
Yes	Yes	No
No	Global	Yes
MySQL 5.1	boolean	ON
DESCRIPTION: Insert mapping between epochs and binary log positions into the ndb_binlog_index table. Defaults to ON. Effective only if binary logging is enabled on the server.		

Causes a mapping of epochs to positions in the binary log to be inserted into the `ndb_binlog_index` table. Setting this variable has no effect if binary logging is not already enabled for the server using `log_bin`. (In addition, `ndb_log_bin` must not be disabled.) `ndb_log_binlog_index` defaults to `1` (`ON`); normally, there is never any need to change this value in a production environment.

This variable was added in MySQL 5.1.6.

- `ndb_log_empty_epochs`

Table 17.46 Type and value information for ndb_log_empty_epochs

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_log_empty_epochs`		
Yes	Yes	No
Yes	Global	Yes

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
MySQL 5.1	boolean	OFF
DESCRIPTION: When enabled, epochs in which there were no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.		

When this variable is set to 0, epoch transactions with no changes are not written to the binary log, although a row is still written even for an empty epoch in `ndb_binlog_index` (Bug #49559, Bug #11757505).

- `ndb_log_orig`

Table 17.47 Type and value information for ndb_log_orig

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_log_orig`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	boolean	OFF
DESCRIPTION: Whether the id and epoch of the originating server are recorded in the mysql.ndb_binlog_index table. Set using the --ndb-log-orig option when starting mysqld.		

Shows whether the originating server ID and epoch are logged in the `ndb_binlog_index` table. Set using the `--ndb-log-orig` server option.

This variable was added in MySQL Cluster NDB 6.3.2.

- `ndb_log_transaction_id`

Table 17.48 Type and value information for ndb_log_transaction_id

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_log_transaction_id`		
No	Yes	No
No	Global	No
MySQL 5.1	boolean	OFF
DESCRIPTION: Whether NDB transaction IDs are written into the binary log. (Read-only.)		

This read-only, Boolean system variable shows whether a slave `mysqld` writes NDB transaction IDs in the binary log (required to use "active-active" MySQL Cluster Replication with `NDB$EPOCH_TRANS()` conflict detection). To change the setting, use the `--ndb-log-transaction-id` option.

`ndb_log_transaction_id` is available in MySQL Cluster NDB 7.1.16 and later. It is not supported in mainline MySQL Server 5.1.

For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `ndb_optimized_node_selection`

Table 17.49 Type and value information for ndb_optimized_node_selection

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_optimized_node_selection`		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	boolean	ON
5.1.22-ndb-6.3.4	integer	3 / 0 - 3
DESCRIPTION: Determines how an SQL node chooses a cluster data node to use as transaction coordinator		

Prior to MySQL Cluster NDB 6.3.4.   Causes an SQL node to use the "closest" data node as transaction coordinator. Enabled by default. Set to `0` or `OFF` to disable, in which case the SQL node uses each data node in the cluster in succession. When this option is disabled each SQL thread attempts to use a given data node 8 times before proceeding to the next one.

Beginning with MySQL Cluster NDB 6.3.4.   There are two forms of optimized node selection, described here:

1. The SQL node uses *promixity* to determine the transaction coordinator; that is, the "closest" data node to the SQL node is chosen as the transaction coordinator. For this purpose, a data node having a shared memory connection with the SQL node is considered to be "closest" to the SQL node; the next closest (in order of decreasing proximity) are: TCP connection to `localhost`; SCI connection; TCP connection from a host other than `localhost`.

2. The SQL thread uses *distribution awareness* to select the data node. That is, the data node housing the cluster partition accessed by the first statement of a given transaction is used as the transaction coordinator for the entire transaction. (This is effective only if the first statement of the transaction accesses no more than one cluster partition.)

This option takes one of the integer values `0`, `1`, `2`, or `3`. `3` is the default. These values affect node selection as follows:

- `0`: Node selection is not optimized. Each data node is employed as the transaction coordinator 8 times before the SQL thread proceeds to the next data node. (This is the same "round-robin" behavior as caused by setting this option to `0` or `OFF` in previous versions of MySQL Cluster.)

- 1: Proximity to the SQL node is used to determine the transaction coordinator. (This is the same behavior as caused by setting this option to 1 or ON in previous MySQL versions.)

- 2: Distribution awareness is used to select the transaction coordinator. However, if the first statement of the transaction accesses more than one cluster partition, the SQL node reverts to the round-robin behavior seen when this option is set to 0.

- 3: If distribution awareness can be employed to determine the transaction coordinator, then it is used; otherwise proximity is used to select the transaction coordinator. (This is the default behavior in MySQL Cluster NDB 6.3.4 and later.)

> **Important**
>
> Beginning with MySQL Cluster NDB 6.3.4, it is no longer possible to set --ndb_optimized_node_selection to ON or OFF; attempting to do so causes mysqld to abort with an error.

- ndb_report_thresh_binlog_epoch_slip

Table 17.50 Type and value information for ndb_report_thresh_binlog_epoch_slip

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_report_thresh_binlog_epoch_slip		
Yes	No	No
Yes		No
MySQL 5.1	integer	3 / 0 - 256
DESCRIPTION: This is a threshold on the number of epochs to be behind before reporting binary log status		

This is a threshold on the number of epochs to be behind before reporting binary log status. For example, a value of 3 (the default) means that if the difference between which epoch has been received from the storage nodes and which epoch has been applied to the binary log is 3 or more, a status message is sent to the cluster log.

- ndb_report_thresh_binlog_mem_usage

Table 17.51 Type and value information for ndb_report_thresh_binlog_mem_usage

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_report_thresh_binlog_mem_usage		
Yes	No	No
Yes		No

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
MySQL 5.1	integer	10 / 0 - 10
DESCRIPTION: This is a threshold on the percentage of free memory remaining before reporting binary log status		

This is a threshold on the percentage of free memory remaining before reporting binary log status. For example, a value of `10` (the default) means that if the amount of available memory for receiving binary log data from the data nodes falls below 10%, a status message is sent to the cluster log.

- ndb_table_no_logging

Table 17.52 Type and value information for ndb_table_no_logging

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_table_no_logging		
No	Yes	No
No	Session	Yes
MySQL 5.1	boolean	FALSE
DESCRIPTION: NDB tables created when this setting is enabled are not checkpointed to disk (although table schema files are created). The setting in effect when the table is created with or altered to use NDBCLUSTER persists for the lifetime of the table.		

When this variable is set to `ON` or `1`, it causes `NDB` tables not to be checkpointed to disk. More specifically, this setting applies to tables which are created or altered using `ENGINE NDB` when ndb_table_no_logging is enabled, and continues to apply for the lifetime of the table, even if ndb_table_no_logging is later changed. Suppose that `A`, `B`, `C`, and `D` are tables that we create (and perhaps also alter), and that we also change the setting for ndb_table_no_logging as shown here:

```
SET @@ndb_table_no_logging = 1;

CREATE TABLE A ... ENGINE NDB;

CREATE TABLE B ... ENGINE MYISAM;
CREATE TABLE C ... ENGINE MYISAM;

ALTER TABLE B ENGINE NDB;

SET @@ndb_table_no_logging = 0;

CREATE TABLE D ... ENGINE NDB;
ALTER TABLE C ENGINE NDB;

SET @@ndb_table_no_logging = 1;
```

After the previous sequence of events, tables `A` and `B` are not checkpointed; `A` was created with `ENGINE NDB` and B was altered to use `NDB`, both while `ndb_table_no_logging` was enabled. However, tables `C` and `D` are logged; `C` was altered to use `NDB` and `D` was created using `ENGINE NDB`, both while `ndb_table_no_logging` was disabled. Setting `ndb_table_no_logging` back to `1` or `ON` does *not* cause table `C` or `D` to be checkpointed.

> **Note**
>
> `ndb_table_no_logging` has no effect on the creation of `NDB` table schema files; to suppress these, use `ndb_table_temporary` instead.

- `ndb_table_temporary`

Table 17.53 Type and value information for ndb_table_temporary

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_table_temporary`		
No	Yes	No
No	Session	Yes
MySQL 5.1	boolean	FALSE
DESCRIPTION: NDB tables are not persistent on disk: no schema files are created and the tables are not logged		

When set to `ON` or `1`, this variable causes `NDB` tables not to be written to disk: This means that no table schema files are created, and that the tables are not logged.

> **Note**
>
> Setting this variable currently has no effect in MySQL Cluster NDB 7.0 and later. This is a known issue; see Bug #34036.

- `ndb_use_copying_alter_table`

Table 17.54 Type and value information for ndb_use_copying_alter_table

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_use_copying_alter_table`		
No	Yes	No
No	Both	No
DESCRIPTION: Use copying ALTER TABLE operations in MySQL Cluster		

Forces `NDB` to use copying of tables in the event of problems with online `ALTER TABLE` operations. The default value is `OFF`.

This variable was added in MySQL 5.1.12.

- ndb_version

Table 17.55 Type and value information for ndb_version

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_version		
No	Yes	No
No	Global	No
MySQL 5.1	string	
DESCRIPTION: Shows build and NDB engine version as an integer.		

NDB engine version, as a composite integer.

This variable was added in MySQL Cluster NDB 7.1.19.

- ndb_version_string

Table 17.56 Type and value information for ndb_version_string

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_version_string		
No	Yes	No
No	Global	No
MySQL 5.1	string	
DESCRIPTION: Shows build information including NDB engine version in ndb-x.y.z format.		

NDB engine version in ndb-*x.y.z* format.

This variable was added in MySQL Cluster NDB 7.1.19.

- ndb_use_exact_count

Table 17.57 Type and value information for ndb_use_exact_count

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_use_exact_count		

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
No	Yes	No
No	Both	Yes
MySQL 5.1	boolean	ON
5.1.47-ndb-7.1.8	boolean	OFF
DESCRIPTION: Use exact row count when planning queries		

Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query. Prior to MySQL Cluster NDB 7.1.7, the default value for this variable was ON. Starting with MySQL Cluster NDB 7.1.8, the value of ndb_use_exact_count defaults to OFF, which allows for faster queries overall.

- ndb_use_transactions

Table 17.58 Type and value information for ndb_use_transactions

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_use_transactions		
Yes	Yes	No
Yes	Both	Yes
MySQL 5.1	boolean	ON
DESCRIPTION: Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query		

You can disable NDB transaction support by setting this variable's values to OFF (not recommended). The default is ON.

> **Note**
>
> The setting for this variable was not honored in MySQL Cluster NDB 6.4.3 and MySQL Cluster NDB 7.0.4. (Bug #43236)

- server_id_bits

Table 17.59 Type and value information for server_id_bits

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
server_id_bits		
Yes	Yes	No
Yes	Global	No
MySQL 5.1	integer	32 / 7 - 32
DESCRIPTION: The effective value of server_id if the server was started with the --server-id-bits option set to a nondefault value.		

The effective value of `server_id` if the server was started with the `--server-id-bits` option set to a nondefault value.

If the value of `server_id` is greater than or equal to 2 to the power of `server_id_bits`, `mysqld` refuses to start.

This system variable was added in MySQL Cluster NDB 7.0.17 and MySQL Cluster NDB 7.1.6; it is supported only in these and later releases of MySQL Cluster. `server_id_bits` is not supported by the standard MySQL Server.

- `slave_allow_batching`

Table 17.60 Type and value information for slave_allow_batching

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
slave_allow_batching		
Yes	Yes	No
Yes	Global	Yes
MySQL 5.1	boolean	off
DESCRIPTION: Turns update batching on and off for a replication slave		

Whether or not batched updates are enabled on MySQL Cluster replication slaves.

This variable is available beginning with MySQL Cluster NDB 6.2.3. It is available for `mysqld` only as supplied with MySQL Cluster or built from the MySQL Cluster sources. For more information, see Section 17.6.6, "Starting MySQL Cluster Replication (Single Replication Channel)".

- `transaction_allow_batching`

Table 17.61 Type and value information for transaction_allow_batching

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
transaction_allow_batching		
No	Yes	No
No	Session	Yes
MySQL 5.1	boolean	FALSE
DESCRIPTION: Allows batching of statements within a transaction. Disable AUTOCOMMIT to use.		

When set to `1` or `ON`, this variable enables batching of statements within the same transaction. To use this variable, `autocommit` must first be disabled by setting it to `0` or `OFF`; otherwise, setting `transaction_allow_batching` has no effect.

It is safe to use this variable with transactions that performs writes only, as having it enabled can lead to reads from the "before" image. You should ensure that any pending transactions are committed (using an explicit `COMMIT` if desired) before issuing a `SELECT`.

> **Important**
>
> `transaction_allow_batching` should not be used whenever there is the possibility that the effects of a given statement depend on the outcome of a previous statement within the same transaction.

This variable was added in MySQL Cluster NDB 6.3.7, and is currently supported in MySQL Cluster only.

The system variables in the following list all relate to the `ndbinfo` information database. They were added in MySQL Cluster NDB 7.1.1.

- `ndbinfo_database`

Table 17.62 Type and value information for ndbinfo_database

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndbinfo_database		
No	Yes	No
No	Global	No
MySQL 5.1	string	ndbinfo
DESCRIPTION: The name used for the NDB information database; read only.		

Shows the name used for the `NDB` information database; the default is `ndbinfo`. This is a read-only variable whose value is determined at compile time; you can set it by starting the server using `--`

`ndbinfo-database=`*name*, which sets the value shown for this variable but does not actually change the name used for the NDB information database.

- `ndbinfo_max_bytes`

Table 17.63 Type and value information for ndbinfo_max_bytes

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndbinfo_max_bytes`		
Yes	Yes	No
No	Both	Yes
MySQL 5.1	integer	0 / -
DESCRIPTION: Used for debugging only.		

Used in testing and debugging only.

- `ndbinfo_max_rows`

Table 17.64 Type and value information for ndbinfo_max_rows

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndbinfo_max_rows`		
Yes	Yes	No
No	Both	Yes
MySQL 5.1	integer	10 / -
DESCRIPTION: Used for debugging only.		

Used in testing and debugging only.

- `ndbinfo_offline`

Table 17.65 Type and value information for ndbinfo_offline

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndbinfo_offline`		
No	Yes	No
No	Global	Yes

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Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
MySQL 5.1	boolean	OFF
DESCRIPTION: Put the ndbinfo database into offline mode, in which no rows are returned from tables or views.		

Place the `ndbinfo` database into offline mode, in which tables and views can be opened even when they do not actually exist, or when they exist but have different definitions in `NDB`. No rows are returned from such tables (or views).

- `ndbinfo_show_hidden`

Table 17.66 Type and value information for ndbinfo_show_hidden

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndbinfo_show_hidden`		
Yes	Yes	No
No	Both	Yes
MySQL 5.1	boolean	OFF
DESCRIPTION: Whether to show ndbinfo internal base tables in the mysql client. The default is OFF.		

Whether or not the `ndbinfo` database's underlying internal tables are shown in the `mysql` client. The default is `OFF`.

- `ndbinfo_table_prefix`

Table 17.67 Type and value information for ndbinfo_table_prefix

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndbinfo_table_prefix`		
Yes	Yes	No
No	Both	Yes
MySQL 5.1	string	ndb$
DESCRIPTION: The prefix to use for naming ndbinfo internal base tables		

The prefix used in naming the ndbinfo database's base tables (normally hidden, unless exposed by setting `ndbinfo_show_hidden`). This is a read-only variable whose default value is "`ndb$`". You can start the server with the `--ndbinfo-table-prefix` option, but this merely sets the variable and

does not change the actual prefix used to name the hidden base tables; the prefix itself is determined at compile time.

- `ndbinfo_version`

  Table 17.68 Type and value information for ndbinfo_version

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndbinfo_version`		
No	Yes	No
No	Global	No
MySQL 5.1	string	
DESCRIPTION: The version of the ndbinfo engine; read only.		

  Shows the version of the `ndbinfo` engine in use; read-only.

MySQL Cluster Status Variables

This section provides detailed information about MySQL server status variables that relate to MySQL Cluster and the `NDB` storage engine. For status variables not specific to MySQL Cluster, and for general information on using status variables, see Section 5.1.6, "Server Status Variables".

- `Handler_discover`

  The MySQL server can ask the `NDBCLUSTER` storage engine if it knows about a table with a given name. This is called discovery. `Handler_discover` indicates the number of times that tables have been discovered using this mechanism.

- `Ndb_api_event_bytes_count`

  The number of bytes of events received by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_bytes_sent_count_session`

  Amount of data (in bytes) sent to the data nodes in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_bytes_sent_count_slave`

  Amount of data (in bytes) sent to the data nodes by this slave.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_bytes_sent_count`

  Amount of data (in bytes) sent to the data nodes by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_bytes_received_count_session`

  Amount of data (in bytes) received from the data nodes in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_bytes_received_count_slave`

  Amount of data (in bytes) received from the data nodes by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_bytes_received_count`

  Amount of data (in bytes) received from the data nodes by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_event_bytes_count_injector`

  The number of bytes of events received by the NDB binlog injector thread.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_event_data_count_injector`

  The number of row change events received by the NDB binlog injector thread.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_event_data_count`

  The number of row change events received by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_event_nondata_count_injector`

  The number of events received, other than row change events, by the NDB binary log injector thread.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_event_nondata_count`

  The number of events received, other than row change events, by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_pk_op_count_session`

  The number of operations in this client session based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_pk_op_count_slave`

  The number of operations by this slave based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_pk_op_count`

  The number of operations by this MySQL Server (SQL node) based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_pruned_scan_count_session`

  The number of scans in this client session that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_pruned_scan_count_slave`

  The number of scans by this slave that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_pruned_scan_count`

  The number of scans by this MySQL Server (SQL node) that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_range_scan_count_session`

  The number of range scans that have been started in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_range_scan_count_slave`

  The number of range scans that have been started by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_range_scan_count`

  The number of range scans that have been started by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_read_row_count_session`

  The total number of rows that have been read in this client session. This includes all rows read by any primary key, unique key, or scan operation made in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_read_row_count_slave`

  The total number of rows that have been read by this slave. This includes all rows read by any primary key, unique key, or scan operation made by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_read_row_count`

  The total number of rows that have been read by this MySQL Server (SQL node). This includes all rows read by any primary key, unique key, or scan operation made by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_scan_batch_count_session`

  The number of batches of rows received in this client session. 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_scan_batch_count_slave`

  The number of batches of rows received by this slave. 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_scan_batch_count`

  The number of batches of rows received by this MySQL Server (SQL node). 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_table_scan_count_session`

  The number of table scans that have been started in this client session, including scans of internal tables,.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_table_scan_count_slave`

  The number of table scans that have been started by this slave, including scans of internal tables,.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_table_scan_count`

The number of table scans that have been started by this MySQL Server (SQL node), including scans of internal tables,.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_abort_count_session`

The number of transactions aborted in this client session.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_abort_count_slave`

The number of transactions aborted by this slave.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_abort_count`

The number of transactions aborted by this MySQL Server (SQL node).

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_close_count_session`

The number of transactions closed in this client session. This value may be greater than the sum of `Ndb_api_trans_commit_count_session` and `Ndb_api_trans_abort_count_session`, since some transactions may have been rolled back.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_close_count_slave`

The number of transactions closed by this slave. This value may be greater than the sum of `Ndb_api_trans_commit_count_slave` and `Ndb_api_trans_abort_count_slave`, since some transactions may have been rolled back.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_close_count`

  The number of transactions closed by this MySQL Server (SQL node). This value may be greater than the sum of `Ndb_api_trans_commit_count` and `Ndb_api_trans_abort_count`, since some transactions may have been rolled back.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_commit_count_session`

  The number of transactions committed in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_commit_count_slave`

  The number of transactions committed by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_commit_count`

  The number of transactions committed by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_local_read_row_count_session`

  The total number of rows that have been read in this client session. This includes all rows read by any primary key, unique key, or scan operation made in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_local_read_row_count_slave`

  The total number of rows that have been read by this slave. This includes all rows read by any primary key, unique key, or scan operation made by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_local_read_row_count`

  The total number of rows that have been read by this MySQL Server (SQL node). This includes all rows read by any primary key, unique key, or scan operation made by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_start_count_session`

  The number of transactions started in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_start_count_slave`

  The number of transactions started by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_trans_start_count`

  The number of transactions started by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_uk_op_count_session`

  The number of operations in this client session based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_uk_op_count_slave`

  The number of operations by this slave based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_uk_op_count`

  The number of operations by this MySQL Server (SQL node) based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_exec_complete_count_session`

  The number of times a thread has been blocked in this client session while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit implicit executes for blob and auto-increment operations not visible to clients.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_exec_complete_count_slave`

  The number of times a thread has been blocked by this slave while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit implicit executes for blob and auto-increment operations not visible to clients.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_exec_complete_count`

The number of times a thread has been blocked by this MySQL Server (SQL node) while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit implicit executes for blob and auto-increment operations not visible to clients.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_meta_request_count_session`

The number of times a thread has been blocked in this client session waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_meta_request_count_slave`

The number of times a thread has been blocked by this slave waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_meta_request_count`

The number of times a thread has been blocked by this MySQL Server (SQL node) waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_nanos_count_session`

Total time (in nanoseconds) spent in this client session waiting for any type of signal from the data nodes.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_nanos_count_slave`

Total time (in nanoseconds) spent by this slave waiting for any type of signal from the data nodes.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_nanos_count`

Total time (in nanoseconds) spent by this MySQL Server (SQL node) waiting for any type of signal from the data nodes.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_scan_result_count_session`

The number of times a thread has been blocked in this client session while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_scan_result_count_slave`

The number of times a thread has been blocked by this slave while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_api_wait_scan_result_count`

The number of times a thread has been blocked by this MySQL Server (SQL node) while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

This variable was added in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11. For more information, see Section 17.5.15, "NDB API Statistics Counters and Variables".

- `Ndb_cluster_node_id`

If the server is acting as a MySQL Cluster node, then the value of this variable its node ID in the cluster.

If the server is not part of a MySQL Cluster, then the value of this variable is 0.

- `Ndb_config_from_host`

  If the server is part of a MySQL Cluster, the value of this variable is the host name or IP address of the Cluster management server from which it gets its configuration data.

  If the server is not part of a MySQL Cluster, then the value of this variable is an empty string.

  Prior to MySQL 5.1.12, this variable was named `Ndb_connected_host`.

- `Ndb_config_from_port`

  If the server is part of a MySQL Cluster, the value of this variable is the number of the port through which it is connected to the Cluster management server from which it gets its configuration data.

  If the server is not part of a MySQL Cluster, then the value of this variable is 0.

  Prior to MySQL 5.1.12, this variable was named `Ndb_connected_port`.

- `Ndb_conflict_fn_max`

  Used in MySQL Cluster Replication conflict resolution, this variable shows the number of times that a row was not applied on the current SQL node due to "greatest timestamp wins" conflict resolution since the last time that this `mysqld` was started.

  This variable was added in MySQL Cluster NDB 6.3.3. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_fn_old`

  Used in MySQL Cluster Replication conflict resolution, this variable shows the number of times that a row was not applied as the result of "same timestamp wins" conflict resolution on a given `mysqld` since the last time it was restarted.

  This variable was added in MySQL Cluster NDB 6.3.4. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_fn_epoch`

  Used in MySQL Cluster Replication conflict resolution, this variable shows the number of rows found to be in conflict using `NDB$EPOCH()` conflict resolution on a given `mysqld` since the last time it was restarted.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_fn_epoch_trans`

  Used in MySQL Cluster Replication conflict resolution, this variable shows the number of rows found to be in conflict using `NDB$EPOCH_TRANS()` conflict resolution on a given `mysqld` since the last time it was restarted.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_trans_row_conflict_count`

  Used in MySQL Cluster Replication conflict resolution, this status variable shows the number of rows found to be directly in-conflict by a transactional conflict function on a given `mysqld` since the last time it was restarted.

  Currently, the only transactional conflict detection function supported by MySQL Cluster is NDB$EPOCH_TRANS(), so this status variable is effectively the same as `Ndb_conflict_fn_epoch_trans`.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_trans_row_reject_count`

  Used in MySQL Cluster Replication conflict resolution, this status variable shows the total number of rows realigned due to being determined as conflicting by a transactional conflict detection function. This includes not only `Ndb_conflict_trans_row_conflict_count`, but any rows in or dependent on conflicting transactions.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_trans_reject_count`

  Used in MySQL Cluster Replication conflict resolution, this status variable shows the number of transactions found to be in conflict by a transactional conflict detection function.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_trans_detect_iter_count`

  Used in MySQL Cluster Replication conflict resolution, this shows the number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to `Ndb_conflict_trans_conflict_commit_count`.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_conflict_trans_conflict_commit_count`

  Used in MySQL Cluster Replication conflict resolution, this shows the number of epoch transactions committed after they required transactional conflict handling.

  This variable was added in MySQL Cluster NDB 7.1.16. For more information, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

- `Ndb_execute_count`

  Provides the number of round trips to the `NDB` kernel made by operations. Added in MySQL Cluster NDB 6.3.6.

- `Ndb_number_of_data_nodes`

  If the server is part of a MySQL Cluster, the value of this variable is the number of data nodes in the cluster.

If the server is not part of a MySQL Cluster, then the value of this variable is 0.

Prior to MySQL 5.1.12, this variable was named `Ndb_number_of_storage_nodes`.

- `Ndb_pushed_queries_defined`

  The total number of joins pushed down to the NDB kernel for distributed handling on the data nodes. Note that joins tested using `EXPLAIN` that can be pushed down contribute to this number. Added in MySQL Cluster NDB 7.2.0.

- `Ndb_pushed_queries_dropped`

  The number of joins that were pushed down to the NDB kernel but that could not be handled there. Added in MySQL Cluster NDB 7.2.0.

- `Ndb_pushed_queries_executed`

  The number of joins successfully pushed down to `NDB` and executed there. Added in MySQL Cluster NDB 7.2.0.

- `Ndb_pushed_reads`

  The number of rows returned to `mysqld` from the NDB kernel by joins that were pushed down. Note that executing `EXPLAIN` on joins that can be pushed down to `NDB` does not add to this number. Added in MySQL Cluster NDB 7.2.0.

- `Ndb_pruned_scan_count`

  This variable holds a count of the number of scans executed by `NDBCLUSTER` since the MySQL Cluster was last started where `NDBCLUSTER` was able to use partition pruning.

  Using this variable together with `Ndb_scan_count` can be helpful in schema design to maximize the ability of the server to prune scans to a single table partition, thereby involving only a single data node.

  This variable was added in MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.5.

- `Ndb_scan_count`

  This variable holds a count of the total number of scans executed by `NDBCLUSTER` since the MySQL Cluster was last started.

  This variable was added in MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.5.

- `Slave_heartbeat_period`

  Shows the replication heartbeat interval (in seconds) on a replication slave.

  This variable was added in MySQL Cluster NDB 6.3.4.

- `Slave_received_heartbeats`

  This counter increments with each replication heartbeat received by a replication slave since the last time that the slave was restarted or reset, or a `CHANGE MASTER TO` statement was issued.

  This variable was added in MySQL Cluster NDB 6.3.4.

17.3.3.9 MySQL Cluster TCP/IP Connections

TCP/IP is the default transport mechanism for all connections between nodes in a MySQL Cluster. Normally it is not necessary to define TCP/IP connections; MySQL Cluster automatically sets up such connections for all data nodes, management nodes, and SQL or API nodes.

> **Note**
>
> For an exception to this rule, see Section 17.3.3.10, "MySQL Cluster TCP/IP Connections Using Direct Connections".

To override the default connection parameters, it is necessary to define a connection using one or more `[tcp]` sections in the `config.ini` file. Each `[tcp]` section explicitly defines a TCP/IP connection between two MySQL Cluster nodes, and must contain at a minimum the parameters `NodeId1` and `NodeId2`, as well as any connection parameters to override.

It is also possible to change the default values for these parameters by setting them in the `[tcp default]` section.

> **Important**
>
> Any `[tcp]` sections in the `config.ini` file should be listed *last*, following all other sections in the file. However, this is not required for a `[tcp default]` section. This requirement is a known issue with the way in which the `config.ini` file is read by the MySQL Cluster management server.

Connection parameters which can be set in `[tcp]` and `[tcp default]` sections of the `config.ini` file are listed here:

*   `NodeId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide their node IDs in the `[tcp]` section of the configuration file as the values of `NodeId1` and `NodeId2`. These are the same unique `Id` values for each of these nodes as described in Section 17.3.3.7, "Defining SQL and Other API Nodes in a MySQL Cluster".

*   `NodeId2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide their node IDs in the `[tcp]` section of the configuration file as the values of `NodeId1` and `NodeId2`. These are the same unique `Id` values for each of these nodes as described in Section 17.3.3.7, "Defining SQL and Other API Nodes in a MySQL Cluster".

*   `HostName1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given TCP connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `HostName2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given TCP connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `OverloadLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

Beginning in MySQL Cluster NDB 6.4.0, this parameter can be used to determine the amount of unsent data that must be present in the send buffer before the connection is considered overloaded. See Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters", for more information.

Prior to MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, the effective value of this parameter was limited by the size of `SendBufferMemory`; beginning with these releases, the actual value for `OverloadLimit` (up to the stated maximum of 4G) is used instead.

- `SendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	256K	64K - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.4	unsigned	2M	256K - 4294967039 (0xFFFFFEFF)	N

TCP transporters use a buffer to store all messages before performing the send call to the operating system. When this buffer reaches 64KB its contents are sent; these are also sent when a round of messages have been executed. To handle temporary overload situations it is also possible to define a bigger send buffer.

Prior to MySQL Cluster NDB 7.0, this parameter determines a fixed amount of memory allocated at startup for each configured TCP connection. Beginning with MySQL Cluster NDB 6.4.0, if this parameter is set explicitly, then the memory is not dedicated to each transporter; instead, the value used denotes the hard limit for how much memory (out of the total available memory—that is, `TotalSendBufferMemory`) that may be used by a single transporter. For more information about configuring dynamic transporter send buffer memory allocation in MySQL Cluster NDB 7.0 and later, see Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters".

In MySQL Cluster NDB 6.4.3 and earlier, the default size of the send buffer was 256 KB; in MySQL Cluster NDB 7.0.4 and later, it is 2MB, which is the size recommended in most situations. The minimum size is 64 KB; the theoretical maximum is 4 GB.

- `SendSignalId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	[see text]	true, false	N

To be able to retrace a distributed message datagram, it is necessary to identify each message. When this parameter is set to `Y`, message IDs are transported over the network. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- Checksum

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	false	true, false	N

This parameter is a boolean parameter (enabled by setting it to `Y` or `1`, disabled by setting it to `N` or `0`). It is disabled by default. When it is enabled, checksums for all messages are calculated before they placed in the send buffer. This feature ensures that messages are not corrupted while waiting in the send buffer, or by the transport mechanism.

- PortNumber (*OBSOLETE*)

This formerly specified the port number to be used for listening for connections from other nodes. This parameter is deprecated as of MySQL 5.1.3 and should no longer be used; use the `ServerPort` data node configuration parameter for this purpose instead.

- ReceiveBufferMemory

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	64K	16K - 4294967039 (0xFFFFFEFF)	N
NDB 7.0.4	bytes	2M	16K - 4294967039 (0xFFFFFEFF)	N

Specifies the size of the buffer used when receiving data from the TCP/IP socket.

In MySQL Cluster NDB 6.4.3 and earlier, the default value of this parameter was 64 KB; beginning with MySQL Cluster NDB 7.0.4, 2MB is the default. The minimum possible value is 16KB; the theoretical maximum is 4GB.

- TCP_RCV_BUF_SIZE

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.1	unsigned	70080	1 - 2G	N

Determines the size of the receive buffer set during TCP transporter initialization. The default is recommended for most common usage cases.

`TCP_RCV_BUF_SIZE` was added in MySQL Cluster NDB 6.1.1.

- TCP_SND_BUF_SIZE

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.1.1	unsigned	71540	1 - 2G	N

Determines the size of the send buffer set during TCP transporter initialization. The default is recommended for most common usage cases.

`TCP_SND_BUF_SIZE` was added in MySQL Cluster NDB 6.1.1.

- `TCP_MAXSEG_SIZE`

Effective Version	Type/Units	Default	Range/Values	**Restart Type**
NDB 6.1.1	unsigned	0	0 - 2G	N

Determines the size of the memory set during TCP transporter initialization. The default is recommended for most common usage cases.

`TCP_MAXSEG_SIZE` was added in MySQL Cluster NDB 6.1.1.

- `TcpBind_INADDR_ANY`

Setting this parameter to `TRUE` or `1` binds `IP_ADDR_ANY` so that connections can be made from anywhere (for autogenerated connections). The default is `FALSE` (`0`).

This parameter was added in MySQL Cluster NDB 6.2.0.

17.3.3.10 MySQL Cluster TCP/IP Connections Using Direct Connections

Setting up a cluster using direct connections between data nodes requires specifying explicitly the crossover IP addresses of the data nodes so connected in the `[tcp]` section of the cluster `config.ini` file.

In the following example, we envision a cluster with at least four hosts, one each for a management server, an SQL node, and two data nodes. The cluster as a whole resides on the `172.23.72.*` subnet of a LAN. In addition to the usual network connections, the two data nodes are connected directly using a standard crossover cable, and communicate with one another directly using IP addresses in the `1.1.0.*` address range as shown:

```
# Management Server
[ndb_mgmd]
Id=1
HostName=172.23.72.20

# SQL Node
[mysqld]
Id=2
HostName=172.23.72.21

# Data Nodes
[ndbd]
Id=3
HostName=172.23.72.22

[ndbd]
Id=4
HostName=172.23.72.23

# TCP/IP Connections
[tcp]
NodeId1=3
NodeId2=4
HostName1=1.1.0.1
```

```
HostName2=1.1.0.2
```

The `HostName1` and `HostName2` parameters are used only when specifying direct connections.

The use of direct TCP connections between data nodes can improve the cluster's overall efficiency by enabling the data nodes to bypass an Ethernet device such as a switch, hub, or router, thus cutting down on the cluster's latency. It is important to note that to take the best advantage of direct connections in this fashion with more than two data nodes, you must have a direct connection between each data node and every other data node in the same node group.

17.3.3.11 MySQL Cluster Shared-Memory Connections

MySQL Cluster attempts to use the shared memory transporter and configure it automatically where possible. `[shm]` sections in the `config.ini` file explicitly define shared-memory connections between nodes in the cluster. When explicitly defining shared memory as the connection method, it is necessary to define at least `NodeId1`, `NodeId2`, and `ShmKey`. All other parameters have default values that should work well in most cases.

> **Important**
>
> *SHM functionality is considered experimental only.* It is not officially supported in any current MySQL Cluster release, and testing results indicate that SHM performance is not appreciably greater than when using TCP/IP for the transporter.
>
> For these reasons, you must determine for yourself or by using our free resources (forums, mailing lists) whether SHM can be made to work correctly in your specific case.

- `NodeId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `NodeId2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `HostName1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SHM connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `HostName2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SHM connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `OverloadLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

Beginning in MySQL Cluster NDB 6.4.0, this parameter can be used to determine the amount of unsent data that must be present in the send buffer before the connection is considered overloaded. See Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters", for more information.

Prior to MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, the effective value of this parameter was limited by the size of `SendBufferMemory`; beginning with these releases, the actual value for `OverloadLimit` (up to the stated maximum) is used instead.

- `ShmKey`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

When setting up shared memory segments, a node ID, expressed as an integer, is used to identify uniquely the shared memory segment to use for the communication. There is no default value.

- `ShmSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	bytes	1M	64K - 4294967039 (0xFFFFFEFF)	N

Each SHM connection has a shared memory segment where messages between nodes are placed by the sender and read by the reader. The size of this segment is defined by `ShmSize`. The default value is 1MB.

- `SendSignalId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	false	true, false	N

To retrace the path of a distributed message, it is necessary to provide each message with a unique identifier. Setting this parameter to `Y` causes these message IDs to be transported over the network as well. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- `Checksum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	true	true, false	N

This parameter is a boolean (`Y`/`N`) parameter which is disabled by default. When it is enabled, checksums for all messages are calculated before being placed in the send buffer.

This feature prevents messages from being corrupted while waiting in the send buffer. It also serves as a check against data being corrupted during transport.

- `SigNum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

When using the shared memory transporter, a process sends an operating system signal to the other process when there is new data available in the shared memory. Should that signal conflict with an existing signal, this parameter can be used to change it. This is a possibility when using SHM due to the fact that different operating systems use different signal numbers.

The default value of `SigNum` is 0; therefore, it must be set to avoid errors in the cluster log when using the shared memory transporter. Typically, this parameter is set to 10 in the `[shm default]` section of the `config.ini` file.

17.3.3.12 SCI Transport Connections in MySQL Cluster

`[sci]` sections in the `config.ini` file explicitly define SCI (Scalable Coherent Interface) connections between cluster nodes. Using SCI transporters in MySQL Cluster is supported only when the MySQL binaries are built using `--with-ndb-sci=/your/path/to/SCI`. The `path` should point to a directory that contains at a minimum `lib` and `include` directories containing SISCI libraries and header files. (See Section 17.3.4, "Using High-Speed Interconnects with MySQL Cluster" for more information about SCI.)

In addition, SCI requires specialized hardware.

It is strongly recommended to use SCI Transporters only for communication between `ndbd` processes. Note also that using SCI Transporters means that the `ndbd` processes never sleep. For this reason, SCI Transporters should be used only on machines having at least two CPUs dedicated for use by `ndbd` processes. There should be at least one CPU per `ndbd` process, with at least one CPU left in reserve to handle operating system activities.

- `NodeId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `NodeId2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

* `Host1SciId0`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

This identifies the SCI node ID on the first Cluster node (identified by `NodeId1`).

* `Host1SciId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

It is possible to set up SCI Transporters for failover between two SCI cards which then should use separate networks between the nodes. This identifies the node ID and the second SCI card to be used on the first node.

* `Host2SciId0`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

This identifies the SCI node ID on the second Cluster node (identified by `NodeId2`).

* `Host2SciId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

When using two SCI cards to provide failover, this parameter identifies the second SCI card to be used on the second node.

* `HostName1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SCI connection between two nodes. The values used for these parameters can be host names or IP addresses.

* `HostName2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SCI connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `SharedBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	10M	64K - 4294967039 (0xFFFFFEFF)	N

Each SCI transporter has a shared memory segment used for communication between the two nodes. Setting the size of this segment to the default value of 1MB should be sufficient for most applications. Using a smaller value can lead to problems when performing many parallel inserts; if the shared buffer is too small, this can also result in a crash of the `ndbd` process.

- `SendLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	unsigned	8K	128 - 32K	N

A small buffer in front of the SCI media stores messages before transmitting them over the SCI network. By default, this is set to 8KB. Our benchmarks show that performance is best at 64KB but 16KB reaches within a few percent of this, and there was little if any advantage to increasing it beyond 8KB.

- `SendSignalId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	true	true, false	N

To trace a distributed message it is necessary to identify each message uniquely. When this parameter is set to `Y`, message IDs are transported over the network. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- `Checksum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
MySQL 5.1.0	boolean	false	true, false	N

This parameter is a boolean value, and is disabled by default. When `Checksum` is enabled, checksums are calculated for all messages before they are placed in the send buffer. This feature prevents messages from being corrupted while waiting in the send buffer. It also serves as a check against data being corrupted during transport.

- `OverloadLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 6.4.0	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded. See Section 17.3.3.14, "Configuring MySQL Cluster Send Buffer Parameters", for more information.

17.3.3.13 Configuring MySQL Cluster Parameters for Local Checkpoints

The parameters discussed in Logging and Checkpointing and in Data Memory, Index Memory, and String Memory that are used to configure local checkpoints for a MySQL Cluster do not exist in isolation, but rather are very much interdepedent on each other. In this section, we illustrate how these parameters—including `DataMemory`, `IndexMemory`, `NoOfDiskPagesToDiskAfterRestartTUP`, `NoOfDiskPagesToDiskAfterRestartACC`, and `NoOfFragmentLogFiles`—relate to one another in a working Cluster.

> **Important**
>
> The parameters `NoOfDiskPagesToDiskAfterRestartTUP` and `NoOfDiskPagesToDiskAfterRestartACC` were deprecated in MySQL 5.1.6. From MySQL 5.1.6 through 5.1.11, disk writes during LCPs took place at the maximum speed possible. Beginning with MySQL 5.1.12, the speed and throughput for LCPs are controlled using the parameters `DiskSyncSize`, `DiskCheckpointSpeed`, and `DiskCheckpointSpeedInRestart`. See Section 17.3.3.6, "Defining MySQL Cluster Data Nodes".

In this example, we assume that our application performs the following numbers of types of operations per hour:

- 50000 selects

- 15000 inserts

- 15000 updates

- 15000 deletes

We also make the following assumptions about the data used in the application:

- We are working with a single table having 40 columns.

- Each column can hold up to 32 bytes of data.

- A typical `UPDATE` run by the application affects the values of 5 columns.

- No `NULL` values are inserted by the application.

A good starting point is to determine the amount of time that should elapse between local checkpoints (LCPs). It is worth noting that, in the event of a system restart, it takes 40-60 percent of this interval to execute the REDO log—for example, if the time between LCPs is 5 minutes (300 seconds), then it should take 2 to 3 minutes (120 to 180 seconds) for the REDO log to be read.

The maximum amount of data per node can be assumed to be the size of the `DataMemory` parameter. In this example, we assume that this is 2 GB. The `NoOfDiskPagesToDiskAfterRestartTUP` parameter represents the amount of data to be checkpointed per unit time—however, this parameter is actually expressed as the number of 8K memory pages to be checkpointed per 100 milliseconds. 2 GB per 300 seconds is approximately 6.8 MB per second, or 700 KB per 100 milliseconds, which works out to roughly 85 pages per 100 milliseconds.

Similarly, we can calculate `NoOfDiskPagesToDiskAfterRestartACC` in terms of the time for local checkpoints and the amount of memory required for indexes—that is, the `IndexMemory`. Assuming that we permit 512 MB for indexes, this works out to approximately 20 8-KB pages per 100 milliseconds for this parameter.

Next, we need to determine the number of REDO log files required—that is, fragment log files—the corresponding parameter being `NoOfFragmentLogFiles`. We need to make sure that there are sufficient

REDO log files for keeping records for at least 3 local checkpoints (in MySQL Cluster NDB 6.3.8 and later, we need only allow for 2 local checkpoints). In a production setting, there are always uncertainties—for instance, we cannot be sure that disks always operate at top speed or with maximum throughput. For this reason, it is best to err on the side of caution, so we double our requirement and calculate a number of fragment log files which should be enough to keep records covering 6 local checkpoints (in MySQL Cluster NDB 6.3.8 and later, a number of fragment log files accommodating 4 local checkpoints should be sufficient).

It is also important to remember that the disk also handles writes to the REDO log, so if you find that the amount of data being written to disk as determined by the values of `NoOfDiskPagesToDiskAfterRestartACC` and `NoOfDiskPagesToDiskAfterRestartTUP` is approaching the amount of disk bandwidth available, you may wish to increase the time between local checkpoints.

Given 5 minutes (300 seconds) per local checkpoint, this means that we need to support writing log records at maximum speed for 6 * 300 = 1800 seconds (*MySQL Cluster NDB 6.3.8 and later*: 4 * 300 = 1200 seconds). The size of a REDO log record is 72 bytes plus 4 bytes per updated column value plus the maximum size of the updated column, and there is one REDO log record for each table record updated in a transaction, on each node where the data reside. Using the numbers of operations set out previously in this section, we derive the following:

- 50000 select operations per hour yields 0 log records (and thus 0 bytes), since `SELECT` statements are not recorded in the REDO log.

- 15000 `DELETE` statements per hour is approximately 5 delete operations per second. (Since we wish to be conservative in our estimate, we round up here and in the following calculations.) No columns are updated by deletes, so these statements consume only 5 operations * 72 bytes per operation = 360 bytes per second.

- 15000 `UPDATE` statements per hour is roughly the same as 5 updates per second. Each update uses 72 bytes, plus 4 bytes per column * 5 columns updated, plus 32 bytes per column * 5 columns—this works out to 72 + 20 + 160 = 252 bytes per operation, and multiplying this by 5 operation per second yields 1260 bytes per second.

- 15000 `INSERT` statements per hour is equivalent to 5 insert operations per second. Each insert requires REDO log space of 72 bytes, plus 4 bytes per record * 40 columns, plus 32 bytes per column * 40 columns, which is 72 + 160 + 1280 = 1512 bytes per operation. This times 5 operations per second yields 7560 bytes per second.

So the total number of REDO log bytes being written per second is approximately 0 + 360 + 1260 + 7560 = 9180 bytes. Multiplied by 1800 seconds, this yields 16524000 bytes required for REDO logging, or approximately 15.75 MB. The unit used for `NoOfFragmentLogFiles` represents a set of 4 16-MB log files—that is, 64 MB. Thus, the minimum value (3) for this parameter is sufficient for the scenario envisioned in this example, since 3 times 64 = 192 MB, or about 12 times what is required; the default value of 8 (or 512 MB) is more than ample in this case.

17.3.3.14 Configuring MySQL Cluster Send Buffer Parameters

Formerly, the NDB kernel used a send buffer whose size was fixed at 2MB for every node in the cluster, which was allocated when the node started. Because the size of this buffer could not be changed after the cluster was started, it was necessary to make it large enough in advance to accommodate the maximum possible load on any transporter socket. However, this was an inefficient use of memory, since much of it often went unused, and could result in large amounts of resources being wasted when scaling up to many API nodes.

Beginning with MySQL Cluster NDB 7.0, this problem is solved by employing a unified send buffer whose memory is allocated dynamically from a pool shared by all transporters. This means that the size of the

send buffer can be adjusted as necessary. Configuration of the unified send buffer can accomplished by setting the following parameters:

- **TotalSendBufferMemory.** This parameter can be set for all types of MySQL Cluster nodes—that is, it can be set in the `[ndbd]`, `[mgm]`, and `[api]` (or `[mysql]`) sections of the `config.ini` file. It represents the total amount of memory (in bytes) to be allocated by each node for which it is set for use among all configured transporters. If set, its minimum is 256KB; the maximum is 4294967039.

  To be backward-compatible with existing configurations, this parameter takes as its default value the sum of the maximum send buffer sizes of all configured transporters, plus an additional 32KB (one page) per transporter. The maximum depends on the type of transporter, as shown in the following table:

Transporter	Maximum Send Buffer Size (bytes)
TCP	`SendBufferMemory` (default = 2M)
SCI	`SendLimit` (default = 8K) plus 16K
SHM	20K

  This enables existing configurations to function in close to the same way as they did with MySQL Cluster NDB 6.3 and earlier, with the same amount of memory and send buffer space available to each transporter. However, memory that is unused by one transporter is not available to other transporters.

- **OverloadLimit.** This parameter is used in the `config.ini` file `[tcp]` section, and denotes the amount of unsent data (in bytes) that must be present in the send buffer before the connection is considered overloaded. When such an overload condition occurs, transactions that affect the overloaded connection fail with NDB API Error 1218 (`Send Buffers overloaded in NDB kernel`) until the overload status passes. The default value is 0, in which case the effective overload limit is calculated as `SendBufferMemory * 0.8` for a given connection. The maximum value for this parameter is 4G.

- **SendBufferMemory.** In MySQL Cluster NDB 6.3 and earlier, this TCP configuration parameter represented the amount of memory allocated at startup for each configured TCP connection. Beginning with MySQL Cluster NDB 7.0, this value denotes a hard limit for the amount of memory that may be used by a single transporter out of the entire pool specified by `TotalSendBufferMemory`. However, the sum of `SendBufferMemory` for all configured transporters may be greater than the `TotalSendBufferMemory` that is set for a given node. This is a way to save memory when many nodes are in use, as long as the maximum amount of memory is never required by all transporters at the same time.

- **ReservedSendBufferMemory.** This optional data node parameter, if set, gives an amount of memory (in bytes) that is reserved for connections between data nodes; this memory is not allocated to send buffers used for communications with management servers or API nodes. This provides a way to protect the cluster against misbehaving API nodes that use excess send memory and thus cause failures in communications internally in the NDB kernel. If set, its the minimum permitted value for this parameters is 256KB; the maximum is 4294967039.

17.3.4 Using High-Speed Interconnects with MySQL Cluster

Even before design of `NDBCLUSTER` began in 1996, it was evident that one of the major problems to be encountered in building parallel databases would be communication between the nodes in the network. For this reason, `NDBCLUSTER` was designed from the very beginning to permit the use of a number of different data transport mechanisms. In this Manual, we use the term *transporter* for these.

The MySQL Cluster codebase provides for four different transporters:

- *TCP/IP using 100 Mbps or gigabit Ethernet*, as discussed in Section 17.3.3.9, "MySQL Cluster TCP/IP Connections".

- *Direct (machine-to-machine) TCP/IP*; although this transporter uses the same TCP/IP protocol as mentioned in the previous item, it requires setting up the hardware differently and is configured differently as well. For this reason, it is considered a separate transport mechanism for MySQL Cluster. See Section 17.3.3.10, "MySQL Cluster TCP/IP Connections Using Direct Connections", for details.

- *Shared memory (SHM).* For more information about SHM, see Section 17.3.3.11, "MySQL Cluster Shared-Memory Connections".

> **Note**
>
> SHM is considered experimental only, and is not officially supported.

- *Scalable Coherent Interface (SCI)*, as described in the next section of this chapter, Section 17.3.3.12, "SCI Transport Connections in MySQL Cluster".

Most users today employ TCP/IP over Ethernet because it is ubiquitous. TCP/IP is also by far the best-tested transporter for use with MySQL Cluster.

We are working to make sure that communication with the `ndbd` process is made in "chunks" that are as large as possible because this benefits all types of data transmission.

For users who desire it, it is also possible to use cluster interconnects to enhance performance even further. There are two ways to achieve this: Either a custom transporter can be designed to handle this case, or you can use socket implementations that bypass the TCP/IP stack to one extent or another. We have experimented with both of these techniques using the SCI (Scalable Coherent Interface) technology developed by Dolphin Interconnect Solutions.

17.3.4.1 Configuring MySQL Cluster to use SCI Sockets

It is possible employing Scalable Coherent Interface (SCI) technology to achieve a significant increase in connection speeds and throughput between MySQL Cluster data and SQL nodes. To use SCI, it is necessary to obtain and install Dolphin SCI network cards and to use the drivers and other software supplied by Dolphin. You can get information on obtaining these, from Dolphin Interconnect Solutions. SCI SuperSocket or SCI Transporter support is available for 32-bit and 64-bit Linux, Solaris, Windows, and other platforms. See the Dolphin documentation referenced later in this section for more detailed information regarding platforms supported for SCI.

> **Note**
>
> Prior to MySQL 5.1.20, there were issues with building MySQL Cluster with SCI support (see Bug #25470), but these have been resolved due to work contributed by Dolphin. SCI Sockets are now correctly supported for MySQL Cluster hosts running recent versions of Linux using the `-max` builds, and versions of MySQL Cluster with SCI Transporter support can be built using either of `compile-amd64-max-sci` or `compile-pentium64-max-sci`. Both of these build scripts can be found in the `BUILD` directory of the MySQL Cluster source trees; it should not be difficult to adapt them for other platforms. Generally, all that is necessary is to compile MySQL Cluster with SCI Transporter support is to configure the MySQL Cluster build using `--with-ndb-sci=/opt/DIS`.

Once you have acquired the required Dolphin hardware and software, you can obtain detailed information on how to adapt a MySQL Cluster configured for normal TCP/IP communication to use SCI from the from the Dolphin SCI online documentation.

17.3.4.2 MySQL Cluster Interconnects and Performance

The `ndbd` process has a number of simple constructs which are used to access the data in a MySQL Cluster. We have created a very simple benchmark to check the performance of each of these and the effects which various interconnects have on their performance.

There are four access methods:

- **Primary key access.**   This is access of a record through its primary key. In the simplest case, only one record is accessed at a time, which means that the full cost of setting up a number of TCP/IP messages and a number of costs for context switching are borne by this single request. In the case where multiple primary key accesses are sent in one batch, those accesses share the cost of setting up the necessary TCP/IP messages and context switches. If the TCP/IP messages are for different destinations, additional TCP/IP messages need to be set up.

- **Unique key access.**   Unique key accesses are similar to primary key accesses, except that a unique key access is executed as a read on an index table followed by a primary key access on the table. However, only one request is sent from the MySQL Server, and the read of the index table is handled by `ndbd`. Such requests also benefit from batching.

- **Full table scan.**   When no indexes exist for a lookup on a table, a full table scan is performed. This is sent as a single request to the `ndbd` process, which then divides the table scan into a set of parallel scans on all cluster `ndbd` processes. In future versions of MySQL Cluster, an SQL node will be able to filter some of these scans.

- **Range scan using ordered index.**   When an ordered index is used, it performs a scan in the same manner as the full table scan, except that it scans only those records which are in the range used by the query transmitted by the MySQL server (SQL node). All partitions are scanned in parallel when all bound index attributes include all attributes in the partitioning key.

With benchmarks developed internally by MySQL for testing simple and batched primary and unique key accesses, we have found that using SCI sockets improves performance by approximately 100% over TCP/IP, except in rare instances when communication performance is not an issue. This can occur when scan filters make up most of processing time or when very large batches of primary key accesses are achieved. In that case, the CPU processing in the `ndbd` processes becomes a fairly large part of the overhead.

Using the SCI transporter instead of SCI Sockets is only of interest in communicating between `ndbd` processes. Using the SCI transporter is also only of interest if a CPU can be dedicated to the `ndbd` process because the SCI transporter ensures that this process will never go to sleep. It is also important to ensure that the `ndbd` process priority is set in such a way that the process does not lose priority due to running for an extended period of time, as can be done by locking processes to CPUs in Linux 2.6. If such a configuration is possible, the `ndbd` process will benefit by 10−70% as compared with using SCI sockets. (The larger figures will be seen when performing updates and probably on parallel scan operations as well.)

There are several other optimized socket implementations for computer clusters, including Myrinet, Gigabit Ethernet, Infiniband and the VIA interface. However, we have tested MySQL Cluster so far only with SCI sockets. See Section 17.3.4.1, "Configuring MySQL Cluster to use SCI Sockets", for information on how to set up SCI sockets using ordinary TCP/IP for MySQL Cluster.

17.4 MySQL Cluster Programs

Using and managing a MySQL Cluster requires several specialized programs, which we describe in this chapter. We discuss the purposes of these programs in a MySQL Cluster, how to use the programs, and what startup options are available for each of them.

These programs include the MySQL Cluster data, management, and SQL node processes (`ndbd`, `ndbmtd`, `ndb_mgmd`, and `mysqld`) and the management client (`ndb_mgm`).

For information about using `mysqld` as a MySQL Cluster process, see Section 17.5.4, "MySQL Server Usage for MySQL Cluster".

Other `NDB` utility, diagnostic, and example programs are included with the MySQL Cluster distribution. These include `ndb_restore`, `ndb_show_tables`, and `ndb_config`. These programs are also covered in this section.

The final portion of this section contains tables of options that are common to all the various MySQL Cluster programs.

17.4.1 `ndbd` — The MySQL Cluster Data Node Daemon

`ndbd` is the process that is used to handle all the data in tables using the NDB Cluster storage engine. This is the process that empowers a data node to accomplish distributed transaction handling, node recovery, checkpointing to disk, online backup, and related tasks.

In a MySQL Cluster, a set of `ndbd` processes cooperate in handling data. These processes can execute on the same computer (host) or on different computers. The correspondences between data nodes and Cluster hosts is completely configurable.

The following table includes command options specific to the MySQL Cluster data node program `ndbd`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndbd`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.69 This table describes command-line options for the ndbd program

Format	Description	Added or Removed
`--initial`	Perform initial start of ndbd, including cleaning the file system. Consult the documentation before using this option	All MySQL 5.1 based releases
`--nostart`, `-n`	Don't start ndbd immediately; ndbd waits for command to start from ndb_mgmd	All MySQL 5.1 based releases
`--daemon`, `-d`	Start ndbd as daemon (default); override with --nodaemon	All MySQL 5.1 based releases
`--nodaemon`	Do not start ndbd as daemon; provided for testing purposes	All MySQL 5.1 based releases
`--foreground`	Run ndbd in foreground, provided for debugging purposes (implies --nodaemon)	All MySQL 5.1 based releases
`--nowait-nodes=list`	Do not wait for these data nodes to start (takes comma-separated list of node IDs). Also requires --ndb-nodeid to be used.	ADDED: 5.1.9
`--initial-start`	Perform partial initial start (requires --nowait-nodes)	ADDED: 5.1.11
`--bind-address=name`	Local bind address	ADDED: 5.1.12
`--install[=name]`	Used to install the data node process as a Windows service.	ADDED: NDB 7.0.16, NDB 7.1.5

Format	Description	Added or Removed
	Does not apply on non-Windows platforms.	
`--remove[=name]`	Used to remove a data node process that was previously installed as a Windows service. Does not apply on non-Windows platforms.	ADDED: NDB 7.0.16, NDB 7.1.5
`--connect-retries=#`	Set the number of times to retry a connection before giving up; 0 means 1 attempt only (and no retries)	ADDED: NDB 7.0.36, NDB 7.1.25
`--connect-delay=#`	Time to wait between attempts to contact a management server, in seconds; 0 means do not wait between attempts	ADDED: NDB 7.0.36, NDB 7.1.25

> **Note**
>
> All of these options also apply to the multi-threaded version of this program (`ndbmtd`, available in MySQL Cluster NDB 7.0 and later) and you may substitute "`ndbmtd`" for "`ndbd`" wherever the latter occurs in this section.

- `--bind-address`

Introduced	5.1.12	
Command-Line Format	`--bind-address=name`	
Permitted Values	**Type**	`string`
	Default	

Causes `ndbd` to bind to a specific network interface (host name or IP address). This option has no default value.

This option was added in MySQL 5.1.12.

- `--daemon`, `-d`

Command-Line Format	`--daemon`	
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

Instructs `ndbd` or `ndbmtd` to execute as a daemon process. This is the default behavior. `--nodaemon` can be used to prevent the process from running as a daemon.

This option has no effect when running `ndbd` or `ndbmtd` on Windows platforms.

- `--nodaemon`

Command-Line Format	`--nodaemon`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Prevents `ndbd` or `ndbmtd` from executing as a daemon process. This option overrides the `--daemon` option. This is useful for redirecting output to the screen when debugging the binary.

As of MySQL Cluster NDB 7.0.8, the default behavior for `ndbd` and `ndbmtd` on Windows is to run in the foreground, making this option unnecessary on Windows platforms, where it has no effect. (Bug #45588)

- `--foreground`

Command-Line Format	`--foreground`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Causes `ndbd` or `ndbmtd` to execute as a foreground process, primarily for debugging purposes. This option implies the `--nodaemon` option.

This option has no effect when running `ndbd` or `ndbmtd` on Windows platforms.

- `--initial`

Command-Line Format	`--initial`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Instructs `ndbd` to perform an initial start. An initial start erases any files created for recovery purposes by earlier instances of `ndbd`. It also re-creates recovery log files. Note that on some operating systems this process can take a substantial amount of time.

An `--initial` start is to be used *only* when starting the `ndbd` process under very special circumstances; this is because this option causes all files to be removed from the MySQL Cluster file system and all redo log files to be re-created. These circumstances are listed here:

- When performing a software upgrade which has changed the contents of any files.

- When restarting the node with a new version of `ndbd`.

- As a measure of last resort when for some reason the node restart or system restart repeatedly fails. In this case, be aware that this node can no longer be used to restore data due to the destruction of the data files.

Use of this option prevents the `StartPartialTimeout` and `StartPartitionedTimeout` configuration parameters from having any effect.

Important

This option does *not* affect either of the following types of files:

- Backup files that have already been created by the affected node

- MySQL Cluster Disk Data files (see Section 17.5.12, "MySQL Cluster Disk Data Tables").

This option also has no effect on recovery of data by a data node that is just starting (or restarting) from data nodes that are already running. This recovery of

> data occurs automatically, and requires no user intervention in a MySQL Cluster that is running normally.

It is permissible to use this option when starting the cluster for the very first time (that is, before any data node files have been created); however, it is *not* necessary to do so.

- `--initial-start`

Introduced	5.1.11	
Command-Line Format	`--initial-start`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This option is used when performing a partial initial start of the cluster. Each node should be started with this option, as well as `--nowait-nodes`.

Suppose that you have a 4-node cluster whose data nodes have the IDs 2, 3, 4, and 5, and you wish to perform a partial initial start using only nodes 2, 4, and 5—that is, omitting node 3:

```
shell> ndbd --ndb-nodeid=2 --nowait-nodes=3 --initial-start
shell> ndbd --ndb-nodeid=4 --nowait-nodes=3 --initial-start
shell> ndbd --ndb-nodeid=5 --nowait-nodes=3 --initial-start
```

Prior to MySQL 5.1.19, it was not possible to perform DDL operations involving Disk Data tables on a partially started cluster. (See Bug #24631.)

When using this option, you must also specify the node ID for the data node being started with the `--ndb-nodeid` option.

This option was added in MySQL 5.1.11.

> **Important**
>
> Do not confuse this option with the `--nowait-nodes` option added for `ndb_mgmd` in MySQL Cluster NDB 7.0.10, which can be used to enable a cluster configured with multiple management servers to be started without all management servers being online.

- `--nowait-nodes=node_id_1[, node_id_2[, ...]]`

Introduced	5.1.9	
Command-Line Format	`--nowait-nodes=list`	
Permitted Values	**Type**	`string`
	Default	

This option takes a list of data nodes which for which the cluster will not wait for before starting.

This can be used to start the cluster in a partitioned state. For example, to start the cluster with only half of the data nodes (nodes 2, 3, 4, and 5) running in a 4-node cluster, you can start each `ndbd` process with `--nowait-nodes=3,5`. In this case, the cluster starts as soon as nodes 2 and 4 connect, and does *not* wait `StartPartitionedTimeout` milliseconds for nodes 3 and 5 to connect as it would otherwise.

If you wanted to start up the same cluster as in the previous example without one `ndbd` (say, for example, that the host machine for node 3 has suffered a hardware failure) then start nodes 2, 4, and 5 with `--nowait-nodes=3`. Then the cluster will start as soon as nodes 2, 4, and 5 connect and will not wait for node 3 to start.

This option was added in MySQL 5.1.9.

- `--nostart`, `-n`

Command-Line Format	`--nostart`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Instructs `ndbd` not to start automatically. When this option is used, `ndbd` connects to the management server, obtains configuration data from it, and initializes communication objects. However, it does not actually start the execution engine until specifically requested to do so by the management server. This can be accomplished by issuing the proper `START` command in the management client (see Section 17.5.2, "Commands in the MySQL Cluster Management Client").

- `--install[=name]`

Introduced	5.1.47-ndb-7.1.5	
Command-Line Format	`--install[=name]`	
Platform Specific	Windows	
Permitted Values	**Type**	`string`
	Default	`ndbd`

Causes `ndbd` to be installed as a Windows service. Optionally, you can specify a name for the service; if not set, the service name defaults to `ndbd`. Although it is preferable to specify other `ndbd` program options in a `my.ini` or `my.cnf` configuration file, it is possible to use together with `--install`. However, in such cases, the `--install` option must be specified first, before any other options are given, for the Windows service installation to succeed.

It is generally not advisable to use this option together with the `--initial` option, since this causes the data node file system to be wiped and rebuilt every time the service is stopped and started. Extreme care should also be taken if you intend to use any of the other `ndbd` options that affect the starting of data nodes—including `--initial-start`, `--nostart`, and `--nowait-nodes`—together with `--install`, and you should make absolutely certain you fully understand and allow for any possible consequences of doing so.

The `--install` option has no effect on non-Windows platforms.

This option became available in MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5.

- `--remove[=name]`

Introduced	5.1.47-ndb-7.1.5	
Command-Line Format	`--remove[=name]`	
Platform Specific	Windows	
Permitted Values	**Type**	`string`

	Default	ndbd

Causes an ndbd process that was previously installed as a Windows service to be removed. Optionally, you can specify a name for the service to be uninstalled; if not set, the service name defaults to ndbd.

The --remove option has no effect on non-Windows platforms.

This option became available in MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5.

- --connect-retries=#

Introduced	5.1.66-ndb-7.1.25	
Command-Line Format	--connect-retries=#	
Permitted Values	Type	numeric
	Default	12
	Min Value	0
	Max Value	65535

Determines the number of times that the data node attempts to contact a management server when starting. Setting this option to -1 causes the data node to keep trying to make contact indefinitely. The default is 12 attempts. The time to wait between attempts is controlled by the --connect-delay option.

This option was added in MySQL Cluster NDB 7.0.36 and MySQL Cluster 7.1.25.

- --connect-delay=#

Introduced	5.1.66-ndb-7.1.25	
Command-Line Format	--connect-delay=#	
Permitted Values	Type	numeric
	Default	5
	Min Value	0
	Max Value	3600

Determines the time to wait between attempts to contact a management server when starting (the time between attempts is controlled by the --connect-retries option). The default is 5 attempts.

This option was added in MySQL Cluster NDB 7.0.36 and MySQL Cluster 7.1.25.

ndbd generates a set of log files which are placed in the directory specified by DataDir in the config.ini configuration file.

These log files are listed below. node_id is the node's unique identifier. Note that node_id represents the node's unique identifier. For example, ndb_2_error.log is the error log generated by the data node whose node ID is 2.

- `ndb_node_id_error.log` is a file containing records of all crashes which the referenced `ndbd` process has encountered. Each record in this file contains a brief error string and a reference to a trace file for this crash. A typical entry in this file might appear as shown here:

```
Date/Time: Saturday 30 July 2004 - 00:20:01
Type of error: error
Message: Internal program error (failed ndbrequire)
Fault ID: 2341
Problem data: DbtupFixAlloc.cpp
Object of reference: DBTUP (Line: 173)
ProgramName: NDB Kernel
ProcessID: 14909
TraceFile: ndb_2_trace.log.2
***EOM***
```

Listings of possible `ndbd` exit codes and messages generated when a data node process shuts down prematurely can be found in ndbd Error Messages.

Important

The last entry in the error log file is not necessarily the newest one (nor is it likely to be). Entries in the error log are *not* listed in chronological order; rather, they correspond to the order of the trace files as determined in the `ndb_node_id_trace.log.next` file (see below). Error log entries are thus overwritten in a cyclical and not sequential fashion.

- `ndb_node_id_trace.log.trace_id` is a trace file describing exactly what happened just before the error occurred. This information is useful for analysis by the MySQL Cluster development team.

  It is possible to configure the number of these trace files that will be created before old files are overwritten. `trace_id` is a number which is incremented for each successive trace file.

- `ndb_node_id_trace.log.next` is the file that keeps track of the next trace file number to be assigned.

- `ndb_node_id_out.log` is a file containing any data output by the `ndbd` process. This file is created only if `ndbd` is started as a daemon, which is the default behavior.

- `ndb_node_id.pid` is a file containing the process ID of the `ndbd` process when started as a daemon. It also functions as a lock file to avoid the starting of nodes with the same identifier.

- `ndb_node_id_signal.log` is a file used only in debug versions of `ndbd`, where it is possible to trace all incoming, outgoing, and internal messages with their data in the `ndbd` process.

It is recommended not to use a directory mounted through NFS because in some environments this can cause problems whereby the lock on the `.pid` file remains in effect even after the process has terminated.

To start `ndbd`, it may also be necessary to specify the host name of the management server and the port on which it is listening. Optionally, one may also specify the node ID that the process is to use.

```
shell> ndbd --connect-string="nodeid=2;host=ndb_mgmd.mysql.com:1186"
```

See Section 17.3.3.3, "MySQL Cluster Connection Strings", for additional information about this issue. Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs", describes other command-line options which can be used with `ndbd`. For information about data node configuration parameters, see Section 17.3.3.6, "Defining MySQL Cluster Data Nodes".

When `ndbd` starts, it actually initiates two processes. The first of these is called the "angel process"; its only job is to discover when the execution process has been completed, and then to restart the `ndbd` process if it is configured to do so. Thus, if you attempt to kill `ndbd` using the Unix `kill` command, it is necessary to kill both processes, beginning with the angel process. The preferred method of terminating an `ndbd` process is to use the management client and stop the process from there.

The execution process uses one thread for reading, writing, and scanning data, as well as all other activities. This thread is implemented asynchronously so that it can easily handle thousands of concurrent actions. In addition, a watch-dog thread supervises the execution thread to make sure that it does not hang in an endless loop. A pool of threads handles file I/O, with each thread able to handle one open file. Threads can also be used for transporter connections by the transporters in the `ndbd` process. In a multi-processor system performing a large number of operations (including updates), the `ndbd` process can consume up to 2 CPUs if permitted to do so.

For a machine with many CPUs it is possible to use several `ndbd` processes which belong to different node groups; however, such a configuration is still considered experimental and is not supported for MySQL 5.1 in a production setting. See Section 17.1.6, "Known Limitations of MySQL Cluster".

17.4.2 `ndbinfo_select_all` — Select From ndbinfo Tables

`ndbinfo_select_all` is a client program that selects all rows and columns from one or more tables in the `ndbinfo` database. It is included with the MySQL Cluster distribution beginning with MySQL Cluster NDB 7.1.17.

Not all `ndbinfo` tables can be accessed by this program. `ndbinfo_select_all` can access the `counters`, `diskpagebuffer`, `logbuffers`, `logspaces`, `nodes`, `resources`, `threadblocks`, `threadstat`, and `transporters` tables.

To select from one or more `ndbinfo` tables using `ndbinfo_select_all`, it is necessary to supply the names of the tables when invoking the program as shown here:

```
shell> ndbinfo_select_all table_name1  [table_name2] [...]
```

For example:

```
shell> ndbinfo_select_all logbuffers logspaces
== logbuffers ==
node_id log_type        log_id  log_part        total   used    high
5       0       0       0       33554432        262144  0
6       0       0       0       33554432        262144  0
7       0       0       0       33554432        262144  0
8       0       0       0       33554432        262144  0
== logspaces ==
node_id log_type        log_id  log_part        total   used    high
5       0       0       0       268435456       0       0
5       0       0       1       268435456       0       0
5       0       0       2       268435456       0       0
5       0       0       3       268435456       0       0
6       0       0       0       268435456       0       0
6       0       0       1       268435456       0       0
6       0       0       2       268435456       0       0
6       0       0       3       268435456       0       0
7       0       0       0       268435456       0       0
7       0       0       1       268435456       0       0
7       0       0       2       268435456       0       0
7       0       0       3       268435456       0       0
8       0       0       0       268435456       0       0
8       0       0       1       268435456       0       0
```

```
8        0        0        2       268435456       0       0
8        0        0        3       268435456       0       0
shell>
```

The following table includes options that are specific to `ndbinfo_select_all`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndbinfo_select_all`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.70 This table describes command-line options for the ndbinfo_select_all program

Format	Description	Added or Removed
`--delay=#`	Set the delay in seconds between loops. Default is 5.	All MySQL 5.1 based releases

`--loops=#,`
 	
`-l`
	Set the number of times to perform the select. Default is 1.	All MySQL 5.1 based releases

`--database=db_name,`
 	
`-d`
	Name of the database where the table located.	All MySQL 5.1 based releases

`--parallelism=#,`
 	
`-p`
	Set the degree of parallelism.	All MySQL 5.1 based releases

- `--delay=seconds`

Command-Line Format	`--delay=#`	
Permitted Values	**Type**	`numeric`
	Default	5
	Min Value	0
	Max Value	`MAX_INT`

This option sets the number of seconds to wait between executing loops. Has no effect if `--loops` is set to 0 or 1.

- `--loops=number`, `-l` *number*

Command-Line Format	`--loops=#`	
Permitted Values	**Type**	`numeric`
	Default	1
	Min Value	0
	Max Value	`MAX_INT`

This option sets the number of times to execute the select. Use `--delay` to set the time between loops.

17.4.3 `ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)

`ndbmtd` is a multi-threaded version of `ndbd`, the process that is used to handle all the data in tables using the `NDBCLUSTER` storage engine. `ndbmtd` is intended for use on host computers having multiple CPU cores. Except where otherwise noted, `ndbmtd` functions in the same way as `ndbd`; therefore, in this section, we concentrate on the ways in which `ndbmtd` differs from `ndbd`, and you should consult Section 17.4.1, "ndbd — The MySQL Cluster Data Node Daemon", for additional information about running MySQL Cluster data nodes that apply to both the single-threaded and multi-threaded versions of the data node process.

Command-line options and configuration parameters used with `ndbd` also apply to `ndbmtd`. For more information about these options and parameters, see Section 17.4.1, "ndbd — The MySQL Cluster Data Node Daemon", and Section 17.3.3.6, "Defining MySQL Cluster Data Nodes", respectively.

`ndbmtd` is also file system-compatible with `ndbd`. In other words, a data node running `ndbd` can be stopped, the binary replaced with `ndbmtd`, and then restarted without any loss of data. (However, when doing this, you must make sure that `MaxNoOfExecutionThreads` is set to an apppriate value before restarting the node if you wish for `ndbmtd` to run in multi-threaded fashion.) Similarly, an `ndbmtd` binary can be replaced with `ndbd` simply by stopping the node and then starting `ndbd` in place of the multi-threaded binary. It is not necessary when switching between the two to start the data node binary using `--initial`.

Prior to MySQL Cluster NDB 7.0.6, there were known issues when using `ndbmtd` with MySQL Cluster Disk Data tables. If you wish to use multi-threaded data nodes with disk-based `NDB` tables, you should ensure that you are running MySQL Cluster NDB 7.0.6 or later (see Bug #41915 and Bug #44915)

Using `ndbmtd` differs from using `ndbd` in two key respects:

1. Because `ndbmtd` runs by default in single-threaded mode (that is, it behaves like `ndbd`), you must configure it to use multiple threads. This can be done by setting an appropriate value in the `config.ini` file for the `MaxNoOfExecutionThreads` configuration parameter. For more information about this parameter and its use, see Multi-Threading Configuration Parameters (ndbmtd).

2. Trace files are generated by critical errors in `ndbmtd` processes in a somewhat different fashion from how these are generated by `ndbd` failures. These differences are discussed in more detail in the next few paragraphs.

Like `ndbd`, `ndbmtd` generates a set of log files which are placed in the directory specified by `DataDir` in the `config.ini` configuration file. Except for trace files, these are generated in the same way and have the same names as those generated by `ndbd`.

In the event of a critical error, `ndbmtd` generates trace files describing what happened just prior to the error' occurrence. These files, which can be found in the data node's `DataDir`, are useful for analysis of problems by the MySQL Cluster Development and Support teams. One trace file is generated for each `ndbmtd` thread. The names of these files have the following pattern:

```
ndb_node_id_trace.log.trace_id_tthread_id,
```

In this pattern, `node_id` stands for the data node's unique node ID in the cluster, `trace_id` is a trace sequence number, and `thread_id` is the thread ID. For example, in the event of the failure of an `ndbmtd` process running as a MySQL Cluster data node having the node ID 3 and with `MaxNoOfExecutionThreads` equal to 4, four trace files are generated in the data node's data directory. If the is the first time this node has failed, then these files are named `ndb_3_trace.log.1_t1`, `ndb_3_trace.log.1_t2`, `ndb_3_trace.log.1_t3`, and `ndb_3_trace.log.1_t4`. Internally, these trace files follow the same format as `ndbd` trace files.

The `ndbd` exit codes and messages that are generated when a data node process shuts down prematurely are also used by `ndbmtd`. See ndbd Error Messages, for a listing of these.

> **Note**
>
> It is possible to use `ndbd` and `ndbmtd` concurrently on different data nodes in the same MySQL Cluster. However, such configurations have not been tested extensively; thus, we cannot recommend doing so in a production setting at this time.

17.4.4 `ndb_mgmd` — The MySQL Cluster Management Server Daemon

The management server is the process that reads the cluster configuration file and distributes this information to all nodes in the cluster that request it. It also maintains a log of cluster activities. Management clients can connect to the management server and check the cluster's status.

The following table includes options that are specific to the MySQL Cluster management server program `ndb_mgmd`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_mgmd`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.71 This table describes command-line options for the ndb_mgmd program

Format	Description	Added or Removed
`--config-file=file`, `-f`	Specify the cluster configuration file; in NDB-6.4.0 and later, needs --reload or --initial to override configuration cache if present	All MySQL 5.1 based releases
`--configdir=directory`, `--config-dir=directory`	Specify the cluster management server's configuration cache directory	ADDED: NDB 6.4.0
`--bind-address=ip_address`	Local bind address	ADDED: NDB 6.2.5, NDB 6.3.2
`--print-full-config`, `-P`	Print full configuration and exit	All MySQL 5.1 based releases
`--daemon`, `-d`	Run ndb_mgmd in daemon mode (default)	All MySQL 5.1 based releases
`--nodaemon`	Do not run ndb_mgmd as a daemon	ADDED: NDB 7.0.8
`--interactive`	Run ndb_mgmd in interactive mode (not officially supported in production; for testing purposes only)	All MySQL 5.1 based releases
`--log-name=name`	A name to use when writing messages applying to this node in the cluster log.	ADDED: NDB 7.0.8
`--no-nodeid-checks`	Do not provide any node id checks	All MySQL 5.1 based releases
`--mycnf`	Read cluster configuration data from the my.cnf file	All MySQL 5.1 based releases
`--reload`	Causes the management server to compare the configuration file with its configuration cache	ADDED: NDB 6.4.0

Format	Description	Added or Removed
`--initial`	Causes the management server reload its configuration data from the configuration file, bypassing the configuration cache	ADDED: NDB 6.4.0
`--nowait-nodes=list`	Do not wait for these management nodes when starting this management server. Also requires --ndb-nodeid to be used.	ADDED: NDB 7.0.10, NDB 7.1.0
`--config-cache[=TRUE|FALSE]`	Enable the management server configuration cache; TRUE by default.	ADDED: NDB 7.0.15, NDB 7.1.4
`--install[=name]`	Used to install the management server process as a Windows service. Does not apply on non-Windows platforms.	ADDED: NDB 7.0.16, NDB 7.1.5
`--remove[=name]`	Used to remove a management server process that was previously installed as a Windows service, optionally specifying the name of the service to be removed. Does not apply on non-Windows platforms.	ADDED: NDB 7.0.16, NDB 7.1.5

- `--bind-address=host[:port]`

Introduced	5.1.22-ndb-6.3.2	
Command-Line Format	`--bind-address=ip_address`	
Permitted Values	**Type**	`string`
	Default	`[none]`

When specified, this option limits management server connections by management clients to clients at the specified host name or IP address (and possibly port, if this is also specified). In such cases, a management client attempting to connect to the management server from any other address fails with the error `Unable to setup port: host:port!`

If the `port` is not specified, the management client attempts to use port 1186.

This option was added in MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2.

- `--no-nodeid-checks`

Command-Line Format	`--no-nodeid-checks`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Do not perform any checks of node IDs.

- `--configdir=dir_name`

Introduced	5.1.30-ndb-6.4.0

Command-Line Format	`--configdir=directory`	
	`--config-dir=directory` (>= 5.1.37-ndb-7.0.8)	
Permitted Values	**Type**	`file name`
	Default	`$INSTALLDIR/mysql-cluster`

In MySQL Cluster NDB 7.0 and later, specifies the cluster management server's configuration cache directory. Starting with MySQL Cluster NDB 7.0.8, `--config-dir` is accepted as an alias for this option.

- `--config-cache`

Introduced	5.1.44-ndb-7.1.4	
Command-Line Format	`--config-cache[=TRUE│FALSE]`	
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

This option, whose default value is `1` (or `TRUE`, or `ON`), can be used to disable the management server's configuration cache, so that it reads its configuration from `config.ini` every time it starts (see Section 17.3.3, "MySQL Cluster Configuration Files"). You can do this by starting the `ndb_mgmd` process with any one of the following options:

- `--config-cache=0`

- `--config-cache=FALSE`

- `--config-cache=OFF`

- `--skip-config-cache`

Using one of the options just listed is effective only if the management server has no stored configuration at the time it is started. If the management server finds any configuration cache files, then the `--config-cache` option or the `--skip-config-cache` option is ignored. Therefore, to disable configuration caching, the option should be used the *first* time that the management server is started. Otherwise—that is, if you wish to disable configuration caching for a management server that has *already* created a configuration cache—you must stop the management server, delete any existing configuration cache files manually, then restart the management server with `--skip-config-cache` (or with `--config-cache` set equal to 0, `OFF`, or `FALSE`).

Configuration cache files are normally created in a directory named `mysql-cluster` under the installation directory (unless this location has been overridden using the `--configdir` option). Each time the management server updates its configuration data, it writes a new cache file. The files are named sequentially in order of creation using the following format:

```
ndb_node-id_config.bin.seq-number
```

`node-id` is the management server's node ID; `seq-number` is a sequence number, beginning with 1. For example, if the management server's node ID is 5, then the first three configuration cache files would, when they are created, be named `ndb_5_config.bin.1`, `ndb_5_config.bin.2`, and `ndb_5_config.bin.3`.

If your intent is to purge or reload the configuration cache without actually disabling caching, you should start `ndb_mgmd` with one of the options `--reload` or `--initial` instead of `--skip-config-cache`.

To re-enable the configuration cache, simply restart the management server, but without the `--config-cache` or `--skip-config-cache` option that was used previously to disable the configuration cache.

This option was added in MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4.

Beginning with MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, `ndb_mgmd` no longer checks for the configuration directory (`--configdir`) or attempts to create one when `--skip-config-cache` is used. (Bug #13428853)

- `--config-file=filename`, `-f filename`

Command-Line Format	`--config-file=file`	
Permitted Values	**Type**	`file name`
	Default	`./config.ini`
Permitted Values (>= 5.1.30-ndb-6.4.0)	**Type**	`file name`
	Default	`[none]`

Instructs the management server as to which file it should use for its configuration file. By default, the management server looks for a file named `config.ini` in the same directory as the `ndb_mgmd` executable; otherwise the file name and location must be specified explicitly.

Beginning with MySQL Cluster NDB 6.4.0, this option has no default value, and is ignored unless the management server is forced to read the configuration file, either because `ndb_mgmd` was started with the `--reload` or `--initial` option, or because the management server could not find any configuration cache. Beginning with MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, this option is also read if `ndb_mgmd` was started with `--config-cache=OFF`. See Section 17.3.3, "MySQL Cluster Configuration Files", for more information.

Formerly, using this option together with `--initial` caused removal of the configuration cache even if the file was not found. This issue was resolved in MySQL Cluster NDB 7.0.38 and MySQL Cluster NDB 7.1.27. (Bug #1299289)

- `--mycnf`

Command-Line Format	`--mycnf`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Read configuration data from the `my.cnf` file.

- `--daemon`, `-d`

Command-Line Format	`--daemon`	
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

Instructs `ndb_mgmd` to start as a daemon process. This is the default behavior.

This option has no effect when running `ndb_mgmd` on Windows platforms.

- `--interactive`

Command-Line Format	`--interactive`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Starts `ndb_mgmd` in interactive mode; that is, an `ndb_mgm` client session is started as soon as the management server is running. This option does not start any other MySQL Cluster nodes.

- `--initial`

Introduced	5.1.30-ndb-6.4.0	
Command-Line Format	`--initial`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Beginning with MySQL Cluster NDB 6.4.0, configuration data is cached internally rather than being read from the cluster global configuration file each time the management server is started (see Section 17.3.3, "MySQL Cluster Configuration Files"). Using this option overrides this behavior, by forcing the management server to delete any existing cache files, and then to re-read the configuration data from the cluster configuration file and to build a new cache.

This differs in two ways from the `--reload` option. First, `--reload` forces the server to check the configuration file against the cache and reload its data only if the contents of the file are different from the cache. Second, `--reload` does not delete any existing cache files.

If `ndb_mgmd` is invoked with `--initial` but cannot find a global configuration file, the management server cannot start.

In MySQL Cluster NDB 7.0.8 and later, when starting, the management server checks for another management server in the same MySQL Cluster and tries to use its configuration data. In other words, `ndb_mgmd` ignores `--initial` unless it is the only management server running. This behavior has implications when performing a rolling restart of a MySQL Cluster with multiple management nodes. See Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster", for more information.

Formerly, using this option together with the `--config-file` option caused removal of the configuration cache even if the file was not found. Starting with MySQL Cluster NDB 7.0.38 and MySQL Cluster NDB 7.1.27, the cache is cleared in such cases only if the configuration file is actually found. (Bug #1299289)

This option was introduced in MySQL Cluster NDB 6.4.0.

- `--log-name=`*name*

Introduced	5.1.37-ndb-7.0.8	
Command-Line Format	`--log-name=name`	
Permitted Values	**Type**	`string`
	Default	`MgmtSrvr`

Provides a name to be used for this node in the cluster log.

This option was added in MySQL Cluster NDB 7.0.8.

- `--nodaemon`

Introduced	5.1.37-ndb-7.0.8
Command-Line Format	`--nodaemon`
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Instructs `ndb_mgmd` not to start as a daemon process.

As of MySQL Cluster NDB 7.0.8, the default behavior for `ndb_mgmd` on Windows is to run in the foreground, making this option unnecessary on Windows platforms. (Bug #45588)

- `--print-full-config`, `-P`

Command-Line Format	`--print-full-config`
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Shows extended information regarding the configuration of the cluster. With this option on the command line the `ndb_mgmd` process prints information about the cluster setup including an extensive list of the cluster configuration sections as well as parameters and their values. Normally used together with the `--config-file` (`-f`) option.

- `--reload`

Introduced	5.1.30-ndb-6.4.0
Command-Line Format	`--reload`
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Beginning with MySQL Cluster NDB 6.4.0, configuration data is stored internally rather than being read from the cluster global configuration file each time the management server is started (see Section 17.3.3, "MySQL Cluster Configuration Files"). Using this option forces the management server to check its internal data store against the cluster configuration file and to reload the configuration if it finds that the configuration file does not match the cache. Existing configuration cache files are preserved, but not used.

This differs in two ways from the `--initial` option. First, `--initial` causes all cache files to be deleted. Second, `--initial` forces the management server to re-read the global configuration file and construct a new cache.

If the management server cannot find a global configuration file, then the `--reload` option is ignored.

In MySQL Cluster NDB 7.0.8 and later, when starting, the management server checks for another management server in the same MySQL Cluster and tries to use its configuration data. In other words, `ndb_mgmd` ignores `--reload` unless it is the only management server running. This behavior has implications when performing a rolling restart of a MySQL Cluster with multiple management nodes. See Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster", for more information.

This option was introduced in MySQL Cluster NDB 6.4.0.

- `--nowait-nodes`

Introduced	5.1.39-ndb-7.1.0	
Command-Line Format	`--nowait-nodes=list`	
Permitted Values	**Type**	`numeric`
	Default	
	Min Value	`1`
	Max Value	`255`

When starting a MySQL Cluster is configured with two management nodes and running MySQL Cluster NDB 7.0 and later, each management server normally checks to see whether the other `ndb_mgmd` is also operational and whether the other management server's configuration is identical to its own. However, it is sometimes desirable to start the cluster with only one management node (and perhaps to allow the other `ndb_mgmd` to be started later). This option causes the management node to bypass any checks for any other management nodes whose node IDs are passed to this option, permitting the cluster to start as though configured to use only the management node that was started.

For purposes of illustration, consider the following portion of a `config.ini` file (where we have omitted most of the configuration parameters that are not relevant to this example):

```
[ndbd]
NodeId = 1
HostName = 192.168.0.101

[ndbd]
NodeId = 2
HostName = 192.168.0.102

[ndbd]
NodeId = 3
HostName = 192.168.0.103

[ndbd]
NodeId = 4
HostName = 192.168.0.104

[ndb_mgmd]
NodeId = 10
HostName = 192.168.0.150

[ndb_mgmd]
NodeId = 11
HostName = 192.168.0.151

[api]
NodeId = 20
HostName = 192.168.0.200

[api]
NodeId = 21
HostName = 192.168.0.201
```

Assume that you wish to start this cluster using only the management server having node ID `10` and running on the host having the IP address 192.168.0.150. (Suppose, for example, that the host computer on which you intend to the other management server is temporarily unavailable due to a hardware

failure, and you are waiting for it to be repaired.) To start the cluster in this way, use a command line on the machine at 192.168.0.150 to enter the following command:

```
shell> ndb_mgmd --ndb-nodeid=10 --nowait-nodes=11
```

As shown in the preceding example, when using `--nowait-nodes`, you must also use the `--ndb-nodeid` option to specify the node ID of this `ndb_mgmd` process.

You can then start each of the cluster's data nodes in the usual way. If you wish to start and use the second management server in addition to the first management server at a later time without restarting the data nodes, you must start each data node with a connection string that references both management servers, like this:

```
shell> ndbd -c 192.168.0.150,192.168.0.151
```

The same is true with regard to the connection string used with any `mysqld` processes that you wish to start as MySQL Cluster SQL nodes connected to this cluster. See Section 17.3.3.3, "MySQL Cluster Connection Strings", for more information.

When used with `ndb_mgmd`, this option affects the behavior of the management node with regard to other management nodes only. Do not confuse it with the `--nowait-nodes` option used with `ndbd` (or `ndbmtd` in MySQL Cluster NDB 7.0 and later) to permit a cluster to start with fewer than its full complement of data nodes; when used with data nodes, this option affects their behavior only with regard to other data nodes.

Multiple management node IDs may be passed to this option as a comma-separated list. Each node ID must be no less than 1 and no greater than 255. In practice, it is quite rare to use more than two management servers for the same MySQL Cluster (or to have any need for doing so); in most cases you need to pass to this option only the single node ID for the one management server that you do not wish to use when starting the cluster.

> **Note**
>
> When you later start the "missing" management server, its configuration must match that of the management server that is already in use by the cluster. Otherwise, it fails the configuration check performed by the existing management server, and does not start.

This option was introduced in MySQL Cluster NDB 7.0.10 and MySQL Cluster NDB 7.1.0.

It is not strictly necessary to specify a connection string when starting the management server. However, if you are using more than one management server, a connection string should be provided and each node in the cluster should specify its node ID explicitly.

See Section 17.3.3.3, "MySQL Cluster Connection Strings", for information about using connection strings. Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon", describes other options for `ndb_mgmd`.

The following files are created or used by `ndb_mgmd` in its starting directory, and are placed in the `DataDir` as specified in the `config.ini` configuration file. In the list that follows, *node_id* is the unique node identifier.

- `config.ini` is the configuration file for the cluster as a whole. This file is created by the user and read by the management server. Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1", discusses how to set up this file.

- `ndb_`*`node_id`*`_cluster.log` is the cluster events log file. Examples of such events include checkpoint startup and completion, node startup events, node failures, and levels of memory usage. A complete listing of cluster events with descriptions may be found in Section 17.5, "Management of MySQL Cluster".

  By default, when the size of the cluster log reaches one million bytes, the file is renamed to `ndb_`*`node_id`*`_cluster.log.`*`seq_id`*, where *`seq_id`* is the sequence number of the cluster log file. (For example: If files with the sequence numbers 1, 2, and 3 already exist, the next log file is named using the number 4.) You can change the size and number of files, and other characteristics of the cluster log, using the `LogDestination` configuration parameter.

- `ndb_`*`node_id`*`_out.log` is the file used for `stdout` and `stderr` when running the management server as a daemon.

- `ndb_`*`node_id`*`.pid` is the process ID file used when running the management server as a daemon.

- `--install[=`*`name`*`]`

Introduced	5.1.47-ndb-7.1.5
Command-Line Format	`--install[=name]`
Platform Specific	Windows
Permitted Values	**Type** `string`
	Default `ndb_mgmd`

  Causes `ndb_mgmd` to be installed as a Windows service. Optionally, you can specify a name for the service; if not set, the service name defaults to `ndb_mgmd`. Although it is preferable to specify other `ndb_mgmd` program options in a `my.ini` or `my.cnf` configuration file, it is possible to use them together with `--install`. However, in such cases, the `--install` option must be specified first, before any other options are given, for the Windows service installation to succeed.

  It is generally not advisable to use this option together with the `--initial` option, since this causes the configuration cache to be wiped and rebuilt every time the service is stopped and started. Care should also be taken if you intend to use any other `ndb_mgmd` options that affect the starting of the management server, and you should make absolutely certain you fully understand and allow for any possible consequences of doing so.

  The `--install` option has no effect on non-Windows platforms.

  This option became available in MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5.

- `--remove[=`*`name`*`]`

Introduced	5.1.47-ndb-7.1.5
Command-Line Format	`--remove[=name]`
Platform Specific	Windows
Permitted Values	**Type** `string`
	Default `ndb_mgmd`

  Causes an `ndb_mgmd` process that was previously installed as a Windows service to be removed. Optionally, you can specify a name for the service to be uninstalled; if not set, the service name defaults to `ndb_mgmd`.

  The `--remove` option has no effect on non-Windows platforms.

This option became available in MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5.

17.4.5 `ndb_mgm` — The MySQL Cluster Management Client

The `ndb_mgm` management client process is actually not needed to run the cluster. Its value lies in providing a set of commands for checking the cluster's status, starting backups, and performing other administrative functions. The management client accesses the management server using a C API. Advanced users can also employ this API for programming dedicated management processes to perform tasks similar to those performed by `ndb_mgm`.

To start the management client, it is necessary to supply the host name and port number of the management server:

```
shell> ndb_mgm [host_name [port_num]]
```

For example:

```
shell> ndb_mgm ndb_mgmd.mysql.com 1186
```

The default host name and port number are `localhost` and 1186, respectively.

The following table includes options that are specific to the MySQL Cluster management client program `ndb_mgm`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_mgm`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.72 This table describes command-line options for the ndb_mgm program

Format	Description	Added or Removed
`--try-reconnect=#`, `-t`	Set the number of times to retry a connection before giving up; synonym for --connect-retries	All MySQL 5.1 based releases
`--execute=name`, `-e`	Execute command and exit	All MySQL 5.1 based releases

- `--execute=command`, `-e command`

Command-Line Format	`--execute=name`

This option can be used to send a command to the MySQL Cluster management client from the system shell. For example, either of the following is equivalent to executing `SHOW` in the management client:

```
shell> ndb_mgm -e "SHOW"

shell> ndb_mgm --execute="SHOW"
```

This is analogous to how the `--execute` or `-e` option works with the `mysql` command-line client. See Section 4.2.4, "Using Options on the Command Line".

> **Note**
>
> If the management client command to be passed using this option contains any space characters, then the command *must* be enclosed in quotation marks.

> Either single or double quotation marks may be used. If the management client
> command contains no space characters, the quotation marks are optional.

- `--try-reconnect=`*`number`*

Command-Line Format	`--try-reconnect=#`	
Permitted Values	**Type**	`integer`
	Default	`3`
	Min Value	`0`
	Max Value	`4294967295`

If the connection to the management server is broken, the node tries to reconnect to it every 5 seconds
until it succeeds. By using this option, it is possible to limit the number of attempts to *`number`* before
giving up and reporting an error instead.

Additional information about using `ndb_mgm` can be found in Section 17.5.2, "Commands in the MySQL
Cluster Management Client".

17.4.6 `ndb_blob_tool` — Check and Repair BLOB and TEXT columns of MySQL Cluster Tables

This tool, which is available in MySQL Cluster NDB 7.0.4 and later, can be used to check for and remove
orphaned BLOB column parts from `NDB` tables, as well as to generate a file listing any orphaned parts. It is
sometimes useful in diagnosing and repairing corrupted or damaged `NDB` tables containing `BLOB` or `TEXT`
columns.

The basic syntax for `ndb_blob_tool` is shown here:

```
ndb_blob_tool [options] table [column, ...]
```

Unless you use the `--help` option, you must specify an action to be performed by including one or
more of the options `--check-orphans`, `--delete-orphans`, or `--dump-file`. These options cause
`ndb_blob_tool` to check for orphaned BLOB parts, remove any orphaned BLOB parts, and generate a
dump file listing orphaned BLOB parts, respectively, and are described in more detail later in this section.

You must also specify the name of a table when invoking `ndb_blob_tool`. In addition, you can optionally
follow the table name with the (comma-separated) names of one or more `BLOB` or `TEXT` columns from that
table. If no columns are listed, the tool works on all of the table's `BLOB` and `TEXT` columns. If you need to
specify a database, use the `--database` (`-d`) option.

The `--verbose` option provides additional information in the output about the tool's progress.

The following table includes options that are specific to `ndb_blob_tool`. Additional descriptions follow
the table. For options common to most MySQL Cluster programs (including `ndb_blob_tool`), see
Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster
Programs".

Table 17.73 This table describes command-line options for the ndb_blob_tool program

Format	Description	Added or Removed
`--check-orphans`	Check for orphan blob parts	ADDED: NDB 7.0.4
`--database=db_name,`	Database to find the table in.	ADDED: NDB 7.0.4

Format	Description	Added or Removed
`-d`		
`--delete-orphans`	Delete orphan blob parts	ADDED: NDB 7.0.4
`--dump-file=file`	Write orphan keys to specified file	ADDED: NDB 7.0.4
`--verbose`,	Verbose output	ADDED: NDB 7.0.4
`-v`		

- `--check-orphans`

Introduced	5.1.32-ndb-7.0.4	
Command-Line Format	`--check-orphans`	
Permitted Values (>= 5.1.32-ndb-7.0.4)	**Type**	`boolean`
	Default	`FALSE`

Check for orphaned BLOB parts in MySQL Cluster tables.

- `--database=db_name`, `-d`

Introduced	5.1.32-ndb-7.0.4	
Command-Line Format	`--database=db_name`	
Permitted Values (>= 5.1.32-ndb-7.0.4)	**Type**	`string`
	Default	`[none]`

Specify the database to find the table in.

- `--delete-orphans`

Introduced	5.1.32-ndb-7.0.4	
Command-Line Format	`--delete-orphans`	
Permitted Values (>= 5.1.32-ndb-7.0.4)	**Type**	`boolean`
	Default	`FALSE`

Remove orphaned BLOB parts from MySQL Cluster tables.

- `--dump-file=file`

Introduced	5.1.32-ndb-7.0.4	
Command-Line Format	`--dump-file=file`	
Permitted Values (>= 5.1.32-ndb-7.0.4)	**Type**	`file name`
	Default	`[none]`

Writes a list of orphaned BLOB column parts to `file`. The information written to the file includes the table key and BLOB part number for each orphaned BLOB part.

- `--verbose`

Introduced	5.1.32-ndb-7.0.4
Command-Line Format	`--verbose`

Permitted Values (>= 5.1.32-ndb-7.0.4)	Type	`boolean`
	Default	`FALSE`

Provide extra information in the tool's output regarding its progress.

Example

First we create an `NDB` table in the `test` database, using the `CREATE TABLE` statement shown here:

```
USE test;

CREATE TABLE btest (
    c0 BIGINT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    c1 TEXT,
    c2 BLOB
)   ENGINE=NDB;
```

Then we insert a few rows into this table, using a series of statements similar to this one:

```
INSERT INTO btest VALUES (NULL, 'x', REPEAT('x', 1000));
```

When run with `--check-orphans` against this table, `ndb_blob_tool` generates the following output:

```
shell> ndb_blob_tool --check-orphans --verbose -d test btest
connected
processing 2 blobs
processing blob #0 c1 NDB$BLOB_19_1
NDB$BLOB_19_1: nextResult: res=1
total parts: 0
orphan parts: 0
processing blob #1 c2 NDB$BLOB_19_2
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=1
total parts: 10
orphan parts: 0
disconnected

NDBT_ProgramExit: 0 - OK
```

The tool reports that there are no `NDB` BLOB column parts associated with column `c1`, even though `c1` is a `TEXT` column. This is due to the fact that, in an `NDB` table, only the first 256 bytes of a `BLOB` or `TEXT` column value are stored inline, and only the excess, if any, is stored separately; thus, if there are no values using more than 256 bytes in a given column of one of these types, no `BLOB` column parts are created by `NDB` for this column. See Section 11.7, "Data Type Storage Requirements", for more information.

17.4.7 `ndb_config` — Extract MySQL Cluster Configuration Information

This tool extracts current configuration information for data nodes, SQL nodes, and API nodes from one of a number of sources: a MySQL Cluster management node, or its `config.ini` or `my.cnf` file. By default, the management node is the source for the configuration data; to override the default, execute ndb_config with the `--config-file` or `--mycnf` option. Beginning with MySQL Cluster NDB 7.0.27 and MySQL

Cluster NDB 7.1.16, it is also possible to use a data node as the source by specifying its node ID using `--config_from_node=node_id`.

Beginning with MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.6, `ndb_config` can also provide an offline dump of all configuration parameters which can be used, along with their default, maximum, and minimum values and other information. The dump can be produced in either text or XML format; for more information, see the discussion of the `--configinfo` and `--xml` options later in this section).

Beginning with MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, you can filter the results by section (`DB`, `SYSTEM`, or `CONNECTIONS`) using one of the options `--nodes`, `--system`, or `--connections`.

The following table includes options that are specific to `ndb_config`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_config`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.74 This table describes command-line options for the ndb_config program

Format	Description	Added or Removed
`--nodes`	Print node information ([ndbd] or [ndbd default] section of cluster configuration file) only. Cannot be used with --system or --connections.	All MySQL 5.1 based releases
`--connections`	Print connections information ([tcp], [tcp default], [sci], [sci default], [shm], or [shm default] sections of cluster configuration file) only. Cannot be used with --system or --nodes.	All MySQL 5.1 based releases

`--query=string,`
 	
`-q`
	One or more query options (attributes)	All MySQL 5.1 based releases

`--host=name`	Specify host	All MySQL 5.1 based releases
`--type=name`	Specify node type	All MySQL 5.1 based releases

`--nodeid,`
 	
`--id`
	Get configuration of node with this ID	All MySQL 5.1 based releases

`--fields=string,`
 	
`-f`
	Field separator	All MySQL 5.1 based releases

`--rows=string,`
 	
`-r`
	Row separator	All MySQL 5.1 based releases

`--config-file=file_name`	Set the path to config.ini file	All MySQL 5.1 based releases
`--mycnf`	Read configuration data from my.cnf file	All MySQL 5.1 based releases
`-c`	Short form for --ndb-connectstring	ADDED: 5.1.12
`--configinfo`	Dumps information about all NDB configuration parameters in text format with default, maximum,	ADDED: NDB 6.3.25, NDB 7.0.6

Format	Description	Added or Removed
	and minimum values. Use with --xml to obtain XML output.	
`--configinfo --xml`	Use --xml with --configinfo to obtain a dump of all NDB configuration parameters in XML format with default, maximum, and minimum values.	ADDED: NDB 6.3.25, NDB 7.0.6
`--system`	Print SYSTEM section information only (see ndb_config --configinfo output). Cannot be used with --nodes or --connections.	ADDED: NDB 7.0.27, NDB 7.1.16
`--config_from_node=#`	Obtain configuration data from the node having this ID (must be a data node).	ADDED: NDB 7.0.27, NDB 7.1.16

- `--usage`, `--help`, or `-?`

Command-Line Format	`--help`
	`--usage`

Causes `ndb_config` to print a list of available options, and then exit.

- `--config_from_node=#`

Introduced	5.1.56-ndb-7.1.16	
Command-Line Format	`--config_from_node=#`	
Permitted Values	Type	`numeric`
	Default	`none`
	Min Value	`1`
	Max Value	`48`

Obtain the cluster's configuration data from the data node that has this ID.

If the node having this ID is not a data node, `ndb_config` fails with an error. (To obtain configuration data from the management node instead, simply omit this option.)

`--config_from_node` was added in MySQL Cluster NDB 7.0.27 and MySQL NDB 7.1.16.

- `--version`, `-V`

Command-Line Format	`--version`

Causes `ndb_config` to print a version information string, and then exit.

- `--ndb-connectstring=`*`connection_string`*

Command-Line Format	`--ndb-connectstring=connectstring`
	`--connect-string=connectstring`

Permitted Values	Type	string
	Default	localhost:1186

Specifies the connection string to use in connecting to the management server. The format for the connection string is the same as described in Section 17.3.3.3, "MySQL Cluster Connection Strings", and defaults to `localhost:1186`.

The use of `-c` as a short version for this option is supported for `ndb_config` beginning with MySQL 5.1.12.

- `--config-file=path-to-file`

Command-Line Format	--config-file=file_name	
Permitted Values	Type	file name
	Default	

Gives the path to the management server's configuration file (`config.ini`). This may be a relative or absolute path. If the management node resides on a different host from the one on which `ndb_config` is invoked, then an absolute path must be used.

- `--mycnf`

Command-Line Format	--mycnf	
Permitted Values	Type	boolean
	Default	FALSE

Read configuration data from the `my.cnf` file.

- `--query=query-options`, `-q query-options`

Command-Line Format	--query=string	
Permitted Values	Type	string
	Default	

This is a comma-delimited list of *query options*—that is, a list of one or more node attributes to be returned. These include `id` (node ID), type (node type—that is, `ndbd`, `mysqld`, or `ndb_mgmd`), and any configuration parameters whose values are to be obtained.

For example, `--query=id,type,indexmemory,datamemory` returns the node ID, node type, `DataMemory`, and `IndexMemory` for each node.

> **Note**
>
> If a given parameter is not applicable to a certain type of node, than an empty string is returned for the corresponding value. See the examples later in this section for more information.

- `--host=hostname`

Command-Line Format	--host=name	
Permitted Values	Type	string
	Default	

Specifies the host name of the node for which configuration information is to be obtained.

> **Note**
>
> While the hostname `localhost` usually resolves to the IP address `127.0.0.1`, this may not necessarily be true for all operating platforms and configurations. This means that it is possible, when `localhost` is used in `config.ini`, for `ndb_config --host=localhost` to fail if `ndb_config` is run on a different host where `localhost` resolves to a different address (for example, on some versions of SUSE Linux, this is `127.0.0.2`). In general, for best results, you should use numeric IP addresses for all MySQL Cluster configuration values relating to hosts, or verify that all MySQL Cluster hosts handle `localhost` in the same fashion.

- `--id=node_id`

  `--nodeid=node_id`

Command-Line Format	`--ndb-nodeid=#`	
Permitted Values	**Type**	`numeric`
	Default	`0`

Either of these options can be used to specify the node ID of the node for which configuration information is to be obtained. `--nodeid` is the preferred form.

- `--nodes`

Command-Line Format	`--nodes`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Tells `ndb_config` to print information relating only to parameters defined in an `[ndbd]` or `[ndbd default]` section of the cluster configuration file (see Section 17.3.3.6, "Defining MySQL Cluster Data Nodes"). Prior to MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, this option had no affect.

This option is mutually exclusive with `--connections` and `--system`; only one of these 3 options can be used.

- `--connections`

Command-Line Format	`--connections`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Tells `ndb_config` to print `CONNECTIONS` information only—that is, information about parameters found in the `[tcp]`, `[tcp default]`, `[sci]`, `[sci default]`, `[shm]`, or `[shm default]` sections of the cluster configuration file (see Section 17.3.3.9, "MySQL Cluster TCP/IP Connections", Section 17.3.3.12, "SCI Transport Connections in MySQL Cluster", and Section 17.3.3.11, "MySQL Cluster Shared-Memory Connections", for more information). This option existed prior to MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16, but had no affect before then.

This option is mutually exclusive with `--nodes` and `--system`; only one of these 3 options can be used.

- `--system`

Introduced	5.1.56-ndb-7.1.16
Command-Line Format	`--system`
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Tells `ndb_config` to print `SYSTEM` information only. This consists of system variables that cannot be changed at run time; thus, there is no corresponding section of the cluster configuration file for them. They can be seen (prefixed with `****** SYSTEM ******`) in the output of `ndb_config --configinfo`. The `--system` option was introduced in MySQL Cluster NDB 7.0.27 and MySQL Cluster NDB 7.1.16.

This option is mutually exclusive with `--nodes` and `--connections`; only one of these 3 options can be used.

- `--type=node_type`

Command-Line Format	`--type=name`
Permitted Values	**Type**	`enumeration`
	Default	`[none]`
	Valid Values	`ndbd`
		`mysqld`
		`ndb_mgmd`

Filters results so that only configuration values applying to nodes of the specified `node_type` (`ndbd`, `mysqld`, or `ndb_mgmd`) are returned.

- `--fields=delimiter`, `-f delimiter`

Command-Line Format	`--fields=string`
Permitted Values	**Type**	`string`
	Default	

Specifies a `delimiter` string used to separate the fields in the result. The default is "`,`" (the comma character).

> **Note**
>
> If the `delimiter` contains spaces or escapes (such as `\n` for the linefeed character), then it must be quoted.

- `--rows=separator`, `-r separator`

Command-Line Format	`--rows=string`
Permitted Values	**Type**	`string`
	Default	

Specifies a `separator` string used to separate the rows in the result. The default is a space character.

> **Note**
>
> If the `separator` contains spaces or escapes (such as `\n` for the linefeed character), then it must be quoted.

- `--configinfo`

The `--configinfo` option, added in MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.6, causes `ndb_config` to dump a list of each MySQL Cluster configuration parameter supported by the MySQL Cluster distribution of which `ndb_config` is a part, including the following information:

- A brief description of each parameter's purpose, effects, and usage

- The section of the `config.ini` file where the parameter may be used

- The parameter's data type or unit of measurement

- Where applicable, the parameter's default, minimum, and maximum values

- MySQL Cluster release version and build information

By default, this output is in text format. Part of this output is shown here:

```
shell> ndb_config --configinfo

****** SYSTEM ******

Name (String)
Name of system (NDB Cluster)
MANDATORY

PrimaryMGMNode (Non-negative Integer)
Node id of Primary ndb_mgmd(MGM) node
Default: 0 (Min: 0, Max: 4294967039)

ConfigGenerationNumber (Non-negative Integer)
Configuration generation number
Default: 0 (Min: 0, Max: 4294967039)

****** DB ******

MaxNoOfSubscriptions (Non-negative Integer)
Max no of subscriptions (default 0 == MaxNoOfTables)
Default: 0 (Min: 0, Max: 4294967039)

MaxNoOfSubscribers (Non-negative Integer)
Max no of subscribers (default 0 == 2 * MaxNoOfTables)
Default: 0 (Min: 0, Max: 4294967039)

…
```

- `--configinfo --xml`

Introduced	5.1.34-ndb-7.0.6	
Command-Line Format	`--configinfo --xml`	
Permitted Values	**Type**	`boolean`
	Default	`false`

You can obtain the output of `ndb_config --configinfo` as XML by adding the `--xml` option (like the `--configinfo` option, available beginning with MySQL Cluster NDB 6.3.25 and MySQL Cluster NDB 7.0.6). A portion of the resulting output is shown in this example:

```
shell> ndb_config --configinfo --xml

<configvariables protocolversion="1" ndbversionstring="5.1.77-ndb-7.1.37"
                 ndbversion="458758" ndbversionmajor="7" ndbversionminor="0"
                 ndbversionbuild="6">
  <section name="SYSTEM">
    <param name="Name" comment="Name of system (NDB Cluster)" type="string"
           mandatory="true"/>
    <param name="PrimaryMGMNode" comment="Node id of Primary ndb_mgmd(MGM) node"
           type="unsigned" default="0" min="0" max="4294967039"/>
    <param name="ConfigGenerationNumber" comment="Configuration generation number"
           type="unsigned" default="0" min="0" max="4294967039"/>
  </section>
  <section name="NDBD">
    <param name="MaxNoOfSubscriptions"
           comment="Max no of subscriptions (default 0 == MaxNoOfTables)"
           type="unsigned" default="0" min="0" max="4294967039"/>
    <param name="MaxNoOfSubscribers"
           comment="Max no of subscribers (default 0 == 2 * MaxNoOfTables)"
           type="unsigned" default="0" min="0" max="4294967039"/>

    …

  </section>

  …

</configvariables>
```

Note

Normally, the XML output produced by `ndb_config --configinfo --xml` is formatted using one line per element; we have added extra whitespace in the previous example, as well as the next one, for reasons of legibility. This should not make any difference to applications using this output, since most XML processors either ignore nonessential whitespace as a matter of course, or can be instructed to do so.

Beginning with MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, the XML output also indicates when changing a given parameter requires that data nodes be restarted using the `--initial` option. This is shown by the presence of an `initial="true"` attribute in the corresponding `<param>` element. In addition (also beginning with MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10), the restart type (`system` or `node`) is also shown; if a given parameter requires a system restart, this is indicated by the presence of a `restart="system"` attribute in the corresponding `<param>` element. For example, changing the value set for the `Diskless` parameter requires a system initial restart, as shown here (with the `restart` and `initial` attributes highlighted for visibility):

```
<param name="Diskless" comment="Run wo/ disk" type="bool" default="false"
       restart="system" initial="true"/>
```

Currently, no `initial` attribute is included in the XML output for `<param>` elements corresponding to parameters which do not require initial restarts; in other words, `initial="false"` is the default, and the value `false` should be assumed if the attribute is not present. Similarly, the default restart type is `node` (that is, an online or "rolling" restart of the cluster), but the `restart` attribute is included only if

the restart type is `system` (meaning that all cluster nodes must be shut down at the same time, then restarted).

> ⚠️ **Important**
>
> The `--xml` option can be used only with the `--configinfo` option. Using `--xml` without `--configinfo` fails with an error.

Unlike the options used with this program to obtain current configuration data, `--configinfo` and `--xml` use information obtained from the MySQL Cluster sources when `ndb_config` was compiled. For this reason, no connection to a running MySQL Cluster or access to a `config.ini` or `my.cnf` file is required for these two options.

Combining other `ndb_config` options (such as `--query` or `--type`) with `--configinfo` or `--xml` is not supported. Currently, if you attempt to do so, the usual result is that all other options besides `--configinfo` or `--xml` are simply ignored. *However, this behavior is not guaranteed and is subject to change at any time.* In addition, since `ndb_config`, when used with the `--configinfo` option, does not access the MySQL Cluster or read any files, trying to specify additional options such as `--ndb-connectstring` or `--config-file` with `--configinfo` serves no purpose.

Examples

1. To obtain the node ID and type of each node in the cluster:

```
shell> ./ndb_config --query=id,type --fields=':' --rows='\n'
1:ndbd
2:ndbd
3:ndbd
4:ndbd
5:ndb_mgmd
6:mysqld
7:mysqld
8:mysqld
9:mysqld
```

In this example, we used the `--fields` options to separate the ID and type of each node with a colon character (`:`), and the `--rows` options to place the values for each node on a new line in the output.

2. To produce a connection string that can be used by data, SQL, and API nodes to connect to the management server:

```
shell> ./ndb_config --config-file=usr/local/mysql/cluster-data/config.ini \
--query=hostname,portnumber --fields=: --rows=, --type=ndb_mgmd
192.168.0.179:1186
```

3. This invocation of `ndb_config` checks only data nodes (using the `--type` option), and shows the values for each node's ID and host name, as well as the values set for its `DataMemory`, `IndexMemory`, and `DataDir` parameters:

```
shell> ./ndb_config --type=ndbd --query=id,host,datamemory,indexmemory,datadir -f ' : ' -r '\n'
1 : 192.168.0.193 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
2 : 192.168.0.112 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
3 : 192.168.0.176 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
4 : 192.168.0.119 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
```

In this example, we used the short options `-f` and `-r` for setting the field delimiter and row separator, respectively.

4. To exclude results from any host except one in particular, use the `--host` option:

```
shell> ./ndb_config --host=192.168.0.176 -f : -r '\n' -q id,type
3:ndbd
5:ndb_mgmd
```

In this example, we also used the short form `-q` to determine the attributes to be queried.

Similarly, you can limit results to a node with a specific ID using the `--id` or `--nodeid` option.

17.4.8 `ndb_cpcd` — Automate Testing for NDB Development

This utility is found in the `libexec` directory. It is part of an internal automated test framework used in testing and debugging MySQL Cluster. Because it can control processes on remote systems, it is not advisable to use `ndb_cpcd` in a production cluster.

The source files for `ndb_cpcd` may be found in the directory `storage/ndb/src/cw/cpcd`, in the MySQL Cluster source tree.

Deprecated feature.   As of MySQL Cluster NDB 7.0, this program is deprecated and no longer actively maintained. It is subject to removal in a future MySQL Cluster version.

17.4.9 `ndb_delete_all` — Delete All Rows from an NDB Table

`ndb_delete_all` deletes all rows from the given `NDB` table. In some cases, this can be much faster than `DELETE` or even `TRUNCATE TABLE`.

Usage

```
ndb_delete_all -c connection_string tbl_name -d db_name
```

This deletes all rows from the table named `tbl_name` in the database named `db_name`. It is exactly equivalent to executing `TRUNCATE db_name.tbl_name` in MySQL.

The following table includes options that are specific to `ndb_delete_all`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_delete_all`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.75 This table describes command-line options for the ndb_delete_all program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.1 based releases
`--transactional`, `-t`	Perform the delete in a single transaction (may run out of operations)	All MySQL 5.1 based releases
`--tupscan`	Run tup scan	All MySQL 5.1 based releases
`--diskscan`	Run disk scan	All MySQL 5.1 based releases

- `--transactional`, `-t`

  Use of this option causes the delete operation to be performed as a single transaction.

> **Warning**
>
> With very large tables, using this option may cause the number of operations available to the cluster to be exceeded.

17.4.10 ndb_desc — Describe NDB Tables

ndb_desc provides a detailed description of one or more NDB tables.

Usage

```
ndb_desc -c connection_string tbl_name -d db_name [options]
```

(*MySQL Cluster NDB 7.0.36 and later; MySQL Cluster NDB 7.1.25 and later:*)

```
ndb_desc -c connection_string index_name -d db_name -t tbl_name
```

Additional options that can be used with ndb_desc are listed later in this section.

Sample Output

MySQL table creation and population statements:

```
USE test;

CREATE TABLE fish (
    id INT(11) NOT NULL AUTO_INCREMENT,
    name VARCHAR(20) NOT NULL,
    length_mm INT(11) NOT NULL,
    weight_gm INT(11) NOT NULL,

    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
) ENGINE=NDB;

INSERT INTO fish VALUES
    ('','guppy', 35, 2), ('','tuna', 2500, 150000),
    ('','shark', 3000, 110000), ('','manta ray', 1500, 50000),
    ('','grouper', 900, 125000), ('','puffer', 250, 2500);
```

Output from ndb_desc:

```
shell> ./ndb_desc -c localhost fish -d test -p
-- fish --
Version: 2
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 311
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
```

```
-- Attributes --
id Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
length_mm Int NOT NULL AT=FIXED ST=MEMORY
weight_gm Int NOT NULL AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex
uk$unique(name) - UniqueHashIndex
uk(name) - OrderedIndex

-- Per partition info --
Partition  Row count  Commit count   Frag fixed memory ...
0          2          2              32768             ...
1          4          4              32768             ...

... Frag varsized memory  Extent_space  Free extent_space
... 32768                 0             0
... 32768                 0             0

NDBT_ProgramExit: 0 - OK
```

Information about multiple tables can be obtained in a single invocation of ndb_desc by using their names, separated by spaces. All of the tables must be in the same database.

Beginning with MySQL Cluster NDB 7.0.36 and MySQL Cluster NDB 7.1.25, it is possible to obtain additional information about a specific index using the --table (short form: -t) option introduced in these versions and supplying the name of the index as the first argument to ndb_desc, as shown here:

```
shell> ./ndb_desc uk -d test -t fish
-- uk --
Version: 3
Base table: fish
Number of attributes: 1
Logging: 0
Index type: OrderedIndex
Index status: Retrieved
-- Attributes --
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
-- IndexTable 10/uk --
Version: 3
Fragment type: FragUndefined
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: yes
Number of attributes: 2
Number of primary keys: 1
Length of frm data: 0
Row Checksum: 1
Row GCI: 1
SingleUserMode: 2
ForceVarPart: 0
FragmentCount: 4
ExtraRowGciBits: 0
ExtraRowAuthorBits: 0
TableStatus: Retrieved
-- Attributes --
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
NDB$TNODE Unsigned [64] PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY
-- Indexes --
PRIMARY KEY(NDB$TNODE) - UniqueHashIndex

NDBT_ProgramExit: 0 - OK
```

When an index is specified in this way, the `--extra-partition-info` and `--extra-node-info` options have no effect.

The `Version` column in the output contains the table's schema object version. For information about interpreting this value, see NDB Schema Object Versions.

The `Extent_space` and `Free extent_space` columns were added in MySQL Cluster NDB 6.3.27 and MySQL Cluster NDB 7.0.8. They are applicable only to `NDB` tables having columns on disk; for tables having only in-memory columns, these columns always contain the value `0`.

To illustrate their use, we modify the previous example. First, we must create the necessary Disk Data objects, as shown here:

```
CREATE LOGFILE GROUP lg_1
    ADD UNDOFILE 'undo_1.log'
    INITIAL_SIZE 16M
    UNDO_BUFFER_SIZE 2M
    ENGINE NDB;

ALTER LOGFILE GROUP lg_1
    ADD UNDOFILE 'undo_2.log'
    INITIAL_SIZE 12M
    ENGINE NDB;

CREATE TABLESPACE ts_1
    ADD DATAFILE 'data_1.dat'
    USE LOGFILE GROUP lg_1
    INITIAL_SIZE 32M
    ENGINE NDB;

ALTER TABLESPACE ts_1
    ADD DATAFILE 'data_2.dat'
    INITIAL_SIZE 48M
    ENGINE NDB;
```

(For more information on the statements just shown and the objects created by them, see Section 17.5.12.1, "MySQL Cluster Disk Data Objects", as well as Section 13.1.14, "CREATE LOGFILE GROUP Syntax", and Section 13.1.18, "CREATE TABLESPACE Syntax".)

Now we can create and populate a version of the `fish` table that stores 2 of its columns on disk (deleting the previous version of the table first, if it already exists):

```
CREATE TABLE fish (
    id INT(11) NOT NULL AUTO_INCREMENT,
    name VARCHAR(20) NOT NULL,
    length_mm INT(11) NOT NULL,
    weight_gm INT(11) NOT NULL,

    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
) TABLESPACE ts_1 STORAGE DISK
ENGINE=NDB;

INSERT INTO fish VALUES
    ('','guppy', 35, 2), ('','tuna', 2500, 150000),
    ('','shark', 3000, 110000), ('','manta ray', 1500, 50000),
    ('','grouper', 900, 125000), ('','puffer', 250, 2500);
```

When run against this version of the table, `ndb_desc` displays the following output:

```
shell> ./ndb_desc -c localhost fish -d test -p
-- fish --
Version: 3
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 321
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
length_mm Int NOT NULL AT=FIXED ST=DISK
weight_gm Int NOT NULL AT=FIXED ST=DISK

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex
uk$unique(name) - UniqueHashIndex
uk(name) - OrderedIndex
-- Per partition info --
Partition  Row count  Commit count  Frag fixed memory ...
0          2          2             32768             ...
1          4          4             32768             ...

... Frag varsized memory  Extent_space  Free extent_space
... 32768                 0             0
... 32768                 0             0

NDBT_ProgramExit: 0 - OK
```

This means that 1048576 bytes are allocated from the tablespace for this table on each partition, of which 1044440 bytes remain free for additional storage. In other words, 1048576 - 1044440 = 4136 bytes per partition is currently being used to store the data from this table's disk-based columns. The number of bytes shown as `Free extent_space` is available for storing on-disk column data from the `fish` table only; for this reason, it is not visible when selecting from the `INFORMATION_SCHEMA.FILES` table.

The following table includes options that are specific to `ndb_desc`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_desc`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.76 This table describes command-line options for the ndb_desc program

Format	Description	Added or Removed
--blob-info, -b	Include partition information for BLOB tables in output. Requires that the -p option also be used	ADDED: NDB 6.3.32, NDB 7.0.13, NDB 7.1.2
--database=dbname, -d	Name of database containing table	All MySQL 5.1 based releases
--extra-node-info, -n	Include partition-to-data-node mappings in output. Requires that the -p option also be used	ADDED: NDB 6.2.19, NDB 6.3.33, NDB 7.0.14, NDB 7.1.2

Format	Description	Added or Removed
`--extra-partition-info`, `-p`	Display information about partitions	All MySQL 5.1 based releases
`--retries=#`, `-r`	Number of times to retry the connection (once per second)	All MySQL 5.1 based releases
`--table=tbl_name`, `-t`	Specify the table in which to find an index. When this option is used, -p and -n have no effect and are ignored.	ADDED: NDB 7.0.36, NDB 7.1.25
`--unqualified`, `-u`	Use unqualified table names	All MySQL 5.1 based releases

- `--blob-info`, `-b`

  Include information about subordinate `BLOB` and `TEXT` columns.

  Use of this option also requires the use of the `--extra-partition-info` (`-p`) option.

  This option was added in MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2.

- `--database=`*db_name*, `-d`

  Specify the database in which the table should be found.

- `--extra-node-info`, `-n`

  Include information about the mappings between table partitions and the data nodes upon which they reside. This information can be useful for verifying distribution awareness mechanisms and supporting more efficient application access to the data stored in MySQL Cluster.

  Use of this option also requires the use of the `--extra-partition-info` (`-p`) option.

  This option was added in MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.33, MySQL Cluster NDB 7.0.14, and MySQL Cluster NDB 7.1.2.

- `--extra-partition-info`, `-p`

  Print additional information about the table's partitions.

- `--retries=#`, `-r`

  Try to connect this many times before giving up. One connect attempt is made per second.

- `--table=`*tbl_name*, `-t`

  Specify the table in which to look for an index.

  This option was added in MySQL Cluster NDB 7.0.36 and MySQL Cluster NDB 7.1.25.

- `--unqualified`, `-u`

  Use unqualified table names.

17.4.11 `ndb_drop_index` — Drop Index from an NDB Table

`ndb_drop_index` drops the specified index from an `NDB` table. *It is recommended that you use this utility only as an example for writing NDB API applications*—see the Warning later in this section for details.

Usage

```
ndb_drop_index -c connection_string table_name index -d db_name
```

The statement shown above drops the index named *index* from the *table* in the *database*.

The following table includes options that are specific to `ndb_drop_index`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_drop_index`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.77 This table describes command-line options for the ndb_drop_index program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.1 based releases

> **Warning**
>
> *Operations performed on Cluster table indexes using the NDB API are not visible to MySQL and make the table unusable by a MySQL server.* If you use this program to drop an index, then try to access the table from an SQL node, an error results, as shown here:

```
shell> ./ndb_drop_index -c localhost dogs ix -d ctest1
Dropping index dogs/idx...OK

NDBT_ProgramExit: 0 - OK

shell> ./mysql -u jon -p ctest1
Enter password: *******
Reading table information for completion of table and column names
You can turn off this feature to get a quicker startup with -A

Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 7 to server version: 5.1.77-ndb-7.1.37

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SHOW TABLES;
+------------------+
| Tables_in_ctest1 |
+------------------+
| a                |
| bt1              |
| bt2              |
| dogs             |
| employees        |
| fish             |
+------------------+
6 rows in set (0.00 sec)

mysql> SELECT * FROM dogs;
```

```
ERROR 1296 (HY000): Got error 4243 'Index not found' from NDBCLUSTER
```

In such a case, your *only* option for making the table available to MySQL again is to drop the table and re-create it. You can use either the SQL statement `DROP TABLE` or the `ndb_drop_table` utility (see Section 17.4.12, "`ndb_drop_table` — Drop an NDB Table") to drop the table.

17.4.12 `ndb_drop_table` — Drop an NDB Table

`ndb_drop_table` drops the specified `NDB` table. (If you try to use this on a table created with a storage engine other than `NDB`, the attempt fails with the error `723: No such table exists`.) This operation is extremely fast; in some cases, it can be an order of magnitude faster than using a MySQL `DROP TABLE` statement on an `NDB` table.

Usage

```
ndb_drop_table -c connection_string tbl_name -d db_name
```

The following table includes options that are specific to `ndb_drop_table`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_drop_table`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.78 This table describes command-line options for the ndb_drop_table program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.1 based releases

17.4.13 `ndb_error_reporter` — NDB Error-Reporting Utility

`ndb_error_reporter` creates an archive from data node and management node log files that can be used to help diagnose bugs or other problems with a cluster. *It is highly recommended that you make use of this utility when filing reports of bugs in MySQL Cluster.*

The following table includes command options specific to the MySQL Cluster program `ndb_error_reporter`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_error_reporter`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

`ndb_error_reporter` did not support the `--help` option prior to MySQL Cluster NDB 6.3.52, MySQL Cluster NDB 7.0.40, and MySQL Cluster NDB 7.1.29 (Bug #11756666, Bug #48606). The `--connection-timeout --dry-scp`, and `--skip-nodegroup` options were also added in these releases (Bug #16602002).

Table 17.79 This table describes command-line options for the ndb_error_reporter program

Format	Description	Added or Removed
`--connection-timeout=timeout`	Number of seconds to wait when connecting to nodes before timing out.	ADDED: NDB 6.3.52, NDB 7.0.40, NDB 7.1.29
`--dry-scp`	Disable scp with remote hosts; used only for testing.	ADDED: NDB 6.3.52, NDB 7.0.40, NDB 7.1.29

Format	Description	Added or Removed
`--fs`	Include file system data in error report; can use a large amount of disk space	All MySQL 5.1 based releases
`--skip-nodegroup=nodegroup_id`	Skip all nodes in the node group having this ID.	ADDED: NDB 6.3.52, NDB 7.0.40, NDB 7.1.29

Usage

```
ndb_error_reporter path/to/config-file [username] [options]
```

This utility is intended for use on a management node host, and requires the path to the management host configuration file (usually named `config.ini`). Optionally, you can supply the name of a user that is able to access the cluster's data nodes using SSH, to copy the data node log files. `ndb_error_reporter` then includes all of these files in archive that is created in the same directory in which it is run. The archive is named `ndb_error_report_YYYYMMDDHHMMSS.tar.bz2`, where `YYYYMMDDHHMMSS` is a datetime string.

`ndb_error_reporter` also accepts the options listed here:

- `--connection-timeout=timeout`

Introduced	5.1.72-ndb-7.1.29	
Command-Line Format	`--connection-timeout=timeout`	
Permitted Values	**Type**	`integer`
	Default	0

Wait this many seconds when trying to connect to nodes before timing out.

- `--dry-scp`

Introduced	5.1.72-ndb-7.1.29	
Command-Line Format	`--dry-scp`	
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

Run `ndb_error_reporter` without using scp from remote hosts. Used for testing only.

- `--fs`

Command-Line Format	`--fs`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Copy the data node file systems to the management host and include them in the archive.

Because data node file systems can be extremely large, even after being compressed, we ask that you please do *not* send archives created using this option to Oracle unless you are specifically requested to do so.

- `--skip-nodegroup=nodegroup_id`

Introduced	5.1.72-ndb-7.1.29	
Command-Line Format	`--connection-timeout=timeout`	
Permitted Values	**Type**	`integer`
	Default	`0`

Skip all nodes belong to the node group having the supplied node group ID.

17.4.14 `ndb_index_stat` — NDB Index Statistics Utility

`ndb_index_stat` provides per-fragment statistical information about indexes on `NDB` tables. This includes cache version and age, number of index entries per partition, and memory consumption by indexes.

Usage

To obtain basic index statistics about a given `NDB` table, invoke `ndb_index_stat` as shown here, with the name of the table as the first argument and the name of the database containing this table specified immediately following it, using the `--database` (`-d`) option:

```
ndb_index_stat table -d database
```

In this example, we use `ndb_index_stat` to obtain such information about an `NDB` table named `mytable` in the `test` database:

```
shell> ndb_index_stat -d test mytable
table:City index:PRIMARY fragCount:2
sampleVersion:3 loadTime:1399585986 sampleCount:1994 keyBytes:7976
query cache: valid:1 sampleCount:1994 totalBytes:27916
times in ms: save: 7.133 sort: 1.974 sort per sample: 0.000

NDBT_ProgramExit: 0 - OK
```

`sampleVersion` is the version number of the cache from which the statistics data is taken. Running `ndb_index_stat` with the `--update` option causes sampleVersion to be incremented.

`loadTime` shows when the cache was last updated. This is expressed as seconds since the Unix Epoch.

`sampleCount` is the number of index entries found per partition. You can estimate the total number of entries by multiplying this by the number of fragments (shown as `fragCount`).

`sampleCount` can be compared with the cardinality of `SHOW INDEX` or `INFORMATION_SCHEMA.STATISTICS`, although the latter two provide a view of the table as a whole, while `ndb_index_stat` provides a per-fragment average.

`keyBytes` is the number of bytes used by the index. In this example, the primary key is an integer, which requires four bytes for each index, so `keyBytes` can be calculated in this case as shown here:

```
    keyBytes = sampleCount * (4 bytes per index) = 1994 * 4 = 7976
```

This information can also be obtained using the corresponding column definitions from `INFORMATION_SCHEMA.COLUMNS` (this requires a MySQL Server and a MySQL client application).

`totalBytes` is the total memory consumed by all indexes on the table, in bytes.

Timings shown in the preceding examples are specific to each invocation of `ndb_index_stat`.

The `--verbose` option provides some additional output, as shown here:

```
shell> ndb_index_stat -d test mytable --verbose
random seed 1337010518
connected
loop 1 of 1
table:mytable index:PRIMARY fragCount:4
sampleVersion:2 loadTime:1336751773 sampleCount:0 keyBytes:0
read stats
query cache created
query cache: valid:1 sampleCount:0 totalBytes:0
times in ms: save: 20.766 sort: 0.001
disconnected

NDBT_ProgramExit: 0 - OK

shell>
```

Options

The following table includes options that are specific to the MySQL Cluster `ndb_index_stat` utility.
Additional descriptions are listed following the table. For options common to most MySQL Cluster
programs (including `ndb_index_stat`), see Section 17.4.26, "Options Common to MySQL Cluster
Programs — Options Common to MySQL Cluster Programs".

Table 17.80 This table describes command-line options for the ndb_index_stat program

Format	Description	Added or Removed
`--database=name`, `-d`	Name of the database containing the table.	All MySQL 5.1 based releases
`--delete`	Delete index statistics for the given table, stopping any auto-update previously configured.	All MySQL 5.1 based releases
`--update`	Update index statistics for the given table, restarting any auto-update previously configured.	All MySQL 5.1 based releases
`--dump`	Print the query cache.	All MySQL 5.1 based releases
`--query=#`	Perform a number of random range queries on first key attr (must be int unsigned).	All MySQL 5.1 based releases
`--sys-drop`	Drop any statistics tables and events in NDB kernel (all statistics are lost)	All MySQL 5.1 based releases
`--sys-create`	Create all statistics tables and events in NDB kernel, if none of them already exist	All MySQL 5.1 based releases
`--sys-create-if-not-exist`	Create any statistics tables and events in NDB kernel that do not already exist.	All MySQL 5.1 based releases
`--sys-create-if-not-valid`	Create any statistics tables or events that do not already exist in the NDB kernel. after dropping any that are invalid.	All MySQL 5.1 based releases

Format	Description	Added or Removed
`--sys-check`	Verify that NDB system index statistics and event tables exist.	All MySQL 5.1 based releases
`--sys-skip-tables`	Do not apply sys-* options to tables.	All MySQL 5.1 based releases
`--sys-skip-events`	Do not apply sys-* options to events.	All MySQL 5.1 based releases
`--verbose`, `-v`	Turn on verbose output	All MySQL 5.1 based releases
`--loops=#`	Set the number of times to perform a given command. Default is 0.	All MySQL 5.1 based releases

ndb_index_stat statistics options.   The following options are used to generate index statistics. They work with a given table and database. They cannot be mixed with system options (see ndb_index_stat system options).

- `--database=`*name*`, -d `*name*

Command-Line Format	`--database=name`	
Permitted Values	**Type**	`string`
	Default	`[none]`
	Min Value	
	Max Value	

The name of the database that contains the table being queried.

- `--delete`

Command-Line Format	`--delete`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	
	Max Value	

Delete the index statistics for the given table, stopping any auto-update that was previously configured.

- `--update`

Command-Line Format	`--update`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	

	Max Value	

Update the index statistics for the given table, and restart any auto-update that was previously configured.

- `--dump`

Command-Line Format	`--dump`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	
	Max Value	

Dump the contents of the query cache.

- `--query=#`

Command-Line Format	`--query=#`	
Permitted Values	**Type**	`numeric`
	Default	`0`
	Min Value	`0`
	Max Value	`MAX_INT`

Perform random range queries on first key attribute (must be int unsigned).

ndb_index_stat system options. The following options are used to generate and update the statistics tables in the NDB kernel. None of these options can be mixed with statistics options (see ndb_index_stat statistics options).

- `--sys-drop`

Command-Line Format	`--sys-drop`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	
	Max Value	

Drop all statistics tables and events in the NDB kernel. *This causes all statistics to be lost.*

- `--sys-create`

Command-Line Format	`--sys-create`	
Permitted Values	**Type**	`boolean`

Default	`false`
Min Value	
Max Value	

Create all statistics tables and events in the NDB kernel. This works only if none of them exist previously.

- `sys-create-if-not-exist`

Command-Line Format	`--sys-create-if-not-exist`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	
	Max Value	

Create any NDB system statistics tables or events (or both) that do not already exist when the program is invoked.

- `--sys-create-if-not-valid`

Command-Line Format	`--sys-create-if-not-valid`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	
	Max Value	

Create any NDB system statistics tables or events that do not already exist, after dropping any that are invalid.

- `--sys-check`

Command-Line Format	`--sys-check`	
Permitted Values	**Type**	`boolean`
	Default	`false`
	Min Value	
	Max Value	

Verify that all required system statistics tables and events exist in the NDB kernel.

- `--sys-skip-tables`

Command-Line Format	`--sys-skip-tables`

Permitted Values	Type	boolean
	Default	false
	Min Value	
	Max Value	

Do not apply any `--sys-*` options to any statistics tables.

- `--sys-skip-events`

Command-Line Format	`--sys-skip-events`	
Permitted Values	Type	boolean
	Default	false
	Min Value	
	Max Value	

Do not apply any `--sys-*` options to any events.

- `--verbose`

Command-Line Format	`--verbose`	
Permitted Values	Type	boolean
	Default	false
	Min Value	
	Max Value	

Turn on verbose output.

- `--loops=#`

Command-Line Format	`--loops=#`	
Permitted Values	Type	numeric
	Default	0
	Min Value	0
	Max Value	MAX_INT

Repeat commands this number of times (for use in testing).

17.4.15 `ndb_print_backup_file` — Print NDB Backup File Contents

`ndb_print_backup_file` obtains diagnostic information from a cluster backup file.

Usage

```
ndb_print_backup_file file_name
```

file_name is the name of a cluster backup file. This can be any of the files (`.Data`, `.ctl`, or `.log` file) found in a cluster backup directory. These files are found in the data node's backup directory under the subdirectory `BACKUP-#`, where `#` is the sequence number for the backup. For more information about cluster backup files and their contents, see Section 17.5.3.1, "MySQL Cluster Backup Concepts".

Like `ndb_print_schema_file` and `ndb_print_sys_file` (and unlike most of the other `NDB` utilities that are intended to be run on a management server host or to connect to a management server) `ndb_print_backup_file` must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

None.

17.4.16 `ndb_print_file` — Print NDB Disk Data File Contents

`ndb_print_file` obtains information from a MySQL Cluster Disk Data file.

Usage

```
ndb_print_file [-v] [-q] file_name+
```

file_name is the name of a MySQL Cluster Disk Data file. Multiple filenames are accepted, separated by spaces.

Like `ndb_print_schema_file` and `ndb_print_sys_file` (and unlike most of the other `NDB` utilities that are intended to be run on a management server host or to connect to a management server) `ndb_print_file` must be run on a MySQL Cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

`ndb_print_file` supports the following options:

- `-v`: Make output verbose.

- `-q`: Suppress output (quiet mode).

- `--help`, `-h`, `-?`: Print help message.

  This option did not work correctly prior to MySQL Cluster NDB 7.1.33. (Bug #17069285)

For more information, see Section 17.5.12, "MySQL Cluster Disk Data Tables".

17.4.17 `ndb_print_schema_file` — Print NDB Schema File Contents

`ndb_print_schema_file` obtains diagnostic information from a cluster schema file.

Usage

```
ndb_print_schema_file file_name
```

file_name is the name of a cluster schema file. For more information about cluster schema files, see MySQL Cluster Data Node File System Directory Files.

Like `ndb_print_backup_file` and `ndb_print_sys_file` (and unlike most of the other `NDB` utilities that are intended to be run on a management server host or to connect to a management server) `ndb_print_schema_file` must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

None.

17.4.18 `ndb_print_sys_file` — Print NDB System File Contents

`ndb_print_sys_file` obtains diagnostic information from a MySQL Cluster system file.

Usage

```
ndb_print_sys_file file_name
```

file_name is the name of a cluster system file (sysfile). Cluster system files are located in a data node's data directory (`DataDir`); the path under this directory to system files matches the pattern `ndb_#_fs/D#/DBDIH/P#.sysfile`. In each case, the `#` represents a number (not necessarily the same number). For more information, see MySQL Cluster Data Node File System Directory Files.

Like `ndb_print_backup_file` and `ndb_print_schema_file` (and unlike most of the other `NDB` utilities that are intended to be run on a management server host or to connect to a management server) `ndb_print_backup_file` must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

None.

17.4.19 `ndbd_redo_log_reader` — Check and Print Content of Cluster Redo Log

Reads a redo log file, checking it for errors, printing its contents in a human-readable format, or both. `ndbd_redo_log_reader` is intended for use primarily by MySQL Cluster developers and Support personnel in debugging and diagnosing problems.

This utility was made available as part of default builds beginning with MySQL Cluster NDB 6.1.3. It remains under development, and its syntax and behavior are subject to change in future releases. For this reason, it should be considered experimental at this time.

The C++ source files for `ndbd_redo_log_reader` can be found in the directory `/storage/ndb/src/kernel/blocks/dblqh/redoLogReader`.

The following table includes options that are specific to the MySQL Cluster program `ndbd_redo_log_reader`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndbd_redo_log_reader`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.81 This table describes command-line options for the ndbd_redo_log_reader program

Format	Description	Added or Removed
`-noprint`	Do not print records	All MySQL 5.1 based releases
`-nocheck`	Do not check records for errors	All MySQL 5.1 based releases
`--help`	Print usage information	ADDED: NDB 6.3.53, NDB 7.0.41, NDB 7.1.30

Usage

```
ndbd_redo_log_reader file_name [options]
```

`file_name` is the name of a cluster redo log file. redo log files are located in the numbered directories under the data node's data directory (`DataDir`); the path under this directory to the redo log files matches the pattern `ndb_#_fs/D#/LCP/#/T#F#.Data`. In each case, the `#` represents a number (not necessarily the same number). For more information, see MySQL Cluster Data Node File System Directory Files.

The name of the file to be read may be followed by one or more of the options listed here:

Command-Line Format	`-noprint`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

  `-noprint`: Do not print the contents of the log file.

Command-Line Format	`-nocheck`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

  `-nocheck`: Do not check the log file for errors.

Introduced	5.1.73-ndb-7.1.30
Command-Line Format	`--help`

  `--help`: Print usage information.

  Added in MySQL Cluster NDB 6.3.53, MySQL Cluster NDB 7.0.41, and MySQL Cluster NDB 7.1.30. (Bug #11749591, Bug #36805)

Like `ndb_print_backup_file` and `ndb_print_schema_file` (and unlike most of the `NDB` utilities that are intended to be run on a management server host or to connect to a management server) `ndbd_redo_log_reader` must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

17.4.20 `ndb_restore` — Restore a MySQL Cluster Backup

The cluster restoration program is implemented as a separate command-line utility `ndb_restore`, which can normally be found in the MySQL `bin` directory. This program reads the files created as a result of the backup and inserts the stored information into the database.

`ndb_restore` must be executed once for each of the backup files that were created by the `START BACKUP` command used to create the backup (see Section 17.5.3.2, "Using The MySQL Cluster

Management Client to Create a Backup"). This is equal to the number of data nodes in the cluster at the time that the backup was created.

> **Note**
>
> Before using `ndb_restore`, it is recommended that the cluster be running in single user mode, unless you are restoring multiple data nodes in parallel. See Section 17.5.8, "MySQL Cluster Single User Mode", for more information.

The following table includes options that are specific to the MySQL Cluster native backup restoration program `ndb_restore`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_restore`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.82 This table describes command-line options for the ndb_restore program

Format	Description	Added or Removed
`--connect`, `-c`	Alias for --connectstring.	All MySQL 5.1 based releases
`--nodeid=#`, `-n`	Restore backup files to node with this ID	All MySQL 5.1 based releases
`--backupid=#`, `-b`	Restore from the backup with the given ID	All MySQL 5.1 based releases
`--restore_data`, `-r`	Restore table data and logs into NDB Cluster using the NDB API	All MySQL 5.1 based releases
`--restore_meta`, `-m`	Restore metadata to NDB Cluster using the NDB API	All MySQL 5.1 based releases
`--no-upgrade`, `-u`	Do not upgrade array type for varsize attributes which do not already resize VAR data, and do not change column attributes	ADDED: 5.1.19
`--promote-attributes`, `-A`	Allow attributes to be promoted when restoring data from backup	ADDED: NDB 6.3.8
`--preserve-trailing-spaces`, `-P`	Allow preservation of trailing spaces (including padding) when promoting fixed-width string types to variable-width types	ADDED: NDB 6.3.8
`--no-restore-disk-objects`, `-d`	Do not restore objects relating to Disk Data	ADDED: 5.1.6
`--restore_epoch`, `-e`	Restore epoch info into the status table. Convenient on a MySQL Cluster replication slave for starting replication. The row in mysql.ndb_apply_status with id 0 will be updated/inserted.	All MySQL 5.1 based releases

Format	Description	Added or Removed
`--skip-table-check`, `-s`	Skip table structure check during restoring of data	ADDED: 5.1.17
`--parallelism=#`, `-p`	Number of parallel transactions to use while restoring data	All MySQL 5.1 based releases
`--print`	Print metadata, data and log to stdout (equivalent to --print_meta --print_data --print_log)	All MySQL 5.1 based releases
`--print_meta`	Print metadata to stdout	All MySQL 5.1 based releases
`--print_data`	Print data to stdout	All MySQL 5.1 based releases
`--print_log`	Print to stdout	All MySQL 5.1 based releases
`--backup_path=dir_name`	Path to backup files directory	ADDED: 5.1.17, NDB 6.1.5
`--dont_ignore_systab_0`, `-f`	Do not ignore system table during restore. Experimental only; not for production use	All MySQL 5.1 based releases
`--ndb-nodegroup-map=map`, `-z`	Nodegroup map for NDBCLUSTER storage engine. Syntax: list of (source_nodegroup, destination_nodegroup)	All MySQL 5.1 based releases
`--fields-enclosed-by=char`	Fields are enclosed with the indicated character	ADDED: 5.1.18
`--fields-terminated-by=char`	Fields are terminated by the indicated character	ADDED: 5.1.18
`--fields-optionally-enclosed-by`	Fields are optionally enclosed with the indicated character	ADDED: 5.1.18
`--lines-terminated-by=char`	Lines are terminated by the indicated character	ADDED: 5.1.18
`--hex`	Print binary types in hexadecimal format	ADDED: 5.1.18
`--tab=dir_name`, `-T dir_name`	Creates a tab-separated .txt file for each table in the given path	ADDED: 5.1.18
`--append`	Append data to a tab-delimited file	ADDED: 5.1.18
`--progress-frequency=#`	Print status of restoration each given number of seconds	All MySQL 5.1 based releases
`--no-binlog`	If a mysqld is connected and using binary logging, do not log the restored data	ADDED: NDB 6.2.16, NDB 6.3.16
`--verbose=#`	Level of verbosity in output	All MySQL 5.1 based releases
`--include-databases=db-list`	List of one or more databases to restore (excludes those not named)	ADDED: NDB 6.3.22, NDB 6.4.3
`--exclude-databases=db-list`	List of one or more databases to exclude (includes those not named)	ADDED: NDB 6.3.22, NDB 6.4.3

Format	Description	Added or Removed
`--include-tables=table-list`	List of one or more tables to restore (excludes those in same database that are not named); each table reference must include the database name	ADDED: NDB 6.3.22, NDB 6.4.3
`--exclude-tables=table-list`	List of one or more tables to exclude (includes those in the same database that are not named); each table reference must include the database name	ADDED: NDB 6.3.22, NDB 6.4.3
`--exclude-missing-columns`	Causes columns from the backup version of a table that are missing from the version of the table in the database to be ignored.	ADDED: NDB 6.3.26, NDB 7.0.7
`--exclude-missing-tables`	Causes tables from the backup that are missing from the database to be ignored.	ADDED: NDB 7.1.33
`--disable-indexes`	Causes indexes from a backup to be ignored; may decrease time needed to restore data.	ADDED: NDB 6.3.31, NDB 7.0.11, NDB 7.1.2
`--rebuild-indexes`	Causes multi-threaded rebuilding of ordered indexes found in the backup. Number of threads used is determined by setting BuildIndexThreads parameter.	ADDED: NDB 6.3.31, NDB 7.0.11, NDB 7.1.2
`--skip-broken-objects`	Causes missing blob tables in the backup file to be ignored.	ADDED: NDB 6.3.40, NDB 7.0.21, NDB 7.1.10
`--skip-unknown-objects`	Causes schema objects not recognized by ndb_restore to be ignored when restoring a backup made from a newer MySQL Cluster version to an older version.	ADDED: NDB 6.3.34, NDB 7.0.15, NDB 7.1.4
`--rewrite-database=olddb,newdb`	Restores to a database with a different name than the original	ADDED: NDB 6.3.41, NDB 7.0.22, NDB 7.1.11
`--lossy-conversions`, `-L`	Allow lossy conversions of column values (type demotions or changes in sign) when restoring data from backup	ADDED: NDB 7.1.11
`--restore-privilege-tables`	Restore MySQL privilege tables that were previously moved to NDB.	ADDED: NDB 7.2.0
`--exclude-intermediate-sql-tables[=TRUE|FALSE]`	If TRUE (the default), do not restore any intermediate tables (having names prefixed with '#sql-') that were left over from copying ALTER TABLE operations.	ADDED: NDB 7.1.31

Typical options for this utility are shown here:

```
ndb_restore [-c connection_string] -n node_id -b backup_id \
      [-m] -r --backup_path=/path/to/backup/files
```

Normally, when restoring from a MySQL Cluster backup, `ndb_restore` requires at a minimum the `--nodeid` (short form: `-n`), `--backupid` (short form: `-b`), and `--backup_path` options.

The `-c` option is used to specify a connection string which tells `ndb_restore` where to locate the cluster management server. (See Section 17.3.3.3, "MySQL Cluster Connection Strings", for information on connection strings.) If this option is not used, then `ndb_restore` attempts to connect to a management server on `localhost:1186`. This utility acts as a cluster API node, and so requires a free connection "slot" to connect to the cluster management server. This means that there must be at least one `[api]` or `[mysqld]` section that can be used by it in the cluster `config.ini` file. It is a good idea to keep at least one empty `[api]` or `[mysqld]` section in `config.ini` that is not being used for a MySQL server or other application for this reason (see Section 17.3.3.7, "Defining SQL and Other API Nodes in a MySQL Cluster").

You can verify that `ndb_restore` is connected to the cluster by using the `SHOW` command in the `ndb_mgm` management client. You can also accomplish this from a system shell, as shown here:

```
shell> ndb_mgm -e "SHOW"
```

The `--nodeid` or `-n` is used to specify the node ID of the data node on which the backup should be restored.

The first time you run the `ndb_restore` restoration program, you also need to restore the metadata. In other words, you must re-create the database tables—this can be done by running it with the `--restore_meta` (`-m`) option. Restoring the metdata need be done only on a single data node; this is sufficient to restore it to the entire cluster. Note that the cluster should have an empty database when starting to restore a backup. (In other words, you should start `ndbd` with `--initial` prior to performing the restore.)

It is possible to restore data without restoring table metadata. Prior to MySQL 5.1.17, `ndb_restore` did not perform any checks of table schemas; if a table was altered between the time the backup was taken and when `ndb_restore` was run, `ndb_restore` would still attempt to restore the data to the altered table.

Beginning with MySQL 5.1.17, the default behavior is for `ndb_restore` to fail with an error if table data do not match the table schema; this can be overridden using the `--skip-table-check` or `-s` option. Prior to MySQL 5.1.21, if this option is used, then `ndb_restore` attempts to fit data into the existing table schema, but the result of restoring a backup to a table schema that does not match the original is unspecified.

Beginning with MySQL Cluster NDB 6.3.35, MySQL Cluster NDB 7.0.16, and MySQL Cluster NDB 7.1.5, some of the restrictions on mismatches in column definitions when restoring data using `ndb_restore` are relaxed; when one of these types of mismatches is encountered, `ndb_restore` does not stop with an error as it did previously, but rather accepts the data and inserts it into the target table while issuing a warning to the user that this is being done. This behavior occurs whether or not either of the options `--skip-table-check` or `--promote-attributes` is in use. These differences in column definitions are of the following types:

- Different `COLUMN_FORMAT` settings (`FIXED`, `DYNAMIC`, `DEFAULT`)

- Different `STORAGE` settings (`MEMORY`, `DISK`)

- Different default values

- Different distribution key settings

Beginning with MySQL Cluster NDB 6.3.8, `ndb_restore` supports limited *attribute promotion* in much the same way that it is supported by MySQL replication; that is, data backed up from a column of a given type can generally be restored to a column using a "larger, similar" type. For example, data from a `CHAR(20)` column can be restored to a column declared as `VARCHAR(20)`, `VARCHAR(30)`, or `CHAR(30)`; data from a `MEDIUMINT` column can be restored to a column of type `INT` or `BIGINT`. See Replication of Columns Having Different Data Types, for a table of type conversions currently supported by attribute promotion.

Attribute promotion by `ndb_restore` must be enabled explicitly, as follows:

1. Prepare the table to which the backup is to be restored. `ndb_restore` cannot be used to re-create the table with a different definition from the original; this means that you must either create the table manually, or alter the columns which you wish to promote using `ALTER TABLE` after restoring the table metadata but before restoring the data.

2. Invoke `ndb_restore` with the `--promote-attributes` option (short form `-A`) when restoring the table data. Attribute promotion does not occur if this option is not used; instead, the restore operation fails with an error.

Prior to MySQL Cluster NDB 7.0.40 and MySQL Cluster NDB 7.1.29, conversions between character data types and `TEXT` or `BLOB` were not handled correctly (Bug #17325051).

Prior to MySQL Cluster NDB 7.1.32, demotion of `TEXT` to `TINYTEXT` was not handled correctly (Bug #18875137).

When converting between character data types and `TEXT` or `BLOB`, only conversions between character types (`CHAR` and `VARCHAR`) and binary types (`BINARY` and `VARBINARY`) can be performed at the same time. For example, you cannot promote an `INT` column to `BIGINT` while promoting a `VARCHAR` column to `TEXT` in the same invocation of `ndb_restore`.

Converting between `TEXT` columns using different character sets is not supported. Beginning with MySQL Cluster NDB 7.1.32, it is expressly disallowed (Bug #18875137).

When performing conversions of character or binary types to `TEXT` or `BLOB` with `ndb_restore`, you may notice that it creates and uses one or more staging tables named `table_name$ST`*node_id*. These tables are not needed afterwards, and are normally deleted by `ndb_restore` following a successful restoration.

`--lossy-conversions`, `-L`

Introduced	5.1.51-ndb-7.1.11	
Command-Line Format	`--lossy-conversions`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This option is intended to complement the `--promote-attributes` option. Using `--lossy-conversions` allows lossy conversions of column values (type demotions or changes in sign) when restoring data from backup. With some exceptions, the rules governing demotion are the same as for MySQL replication; see Replication of Columns Having Different Data Types, for information about specific type conversions currently supported by attribute demotion.

`ndb_restore` reports any truncation of data that it performs during lossy conversions once per attribute and column.

This option was added in MySQL Cluster NDB 7.1.11.

The `--preserve-trailing-spaces` option is also available beginning with MySQL Cluster NDB 6.3.8. This option (short form `-R`) causes trailing spaces to be preserved when promoting a fixed-width character data type to its variable-width equivalent—that is, when promoting a `CHAR` column value to `VARCHAR` or a `BINARY` column value to `VARBINARY`. Otherwise, any trailing spaces are dropped from such column values when they are inserted into the new columns.

> **Note**
>
> Although you can promote `CHAR` columns to `VARCHAR` and `BINARY` columns to `VARBINARY`, you cannot promote `VARCHAR` columns to `CHAR` or `VARBINARY` columns to `BINARY`.

The `-b` option is used to specify the ID or sequence number of the backup, and is the same number shown by the management client in the `Backup backup_id completed` message displayed upon completion of a backup. (See Section 17.5.3.2, "Using The MySQL Cluster Management Client to Create a Backup".)

> **Important**
>
> When restoring cluster backups, you must be sure to restore all data nodes from backups having the same backup ID. Using files from different backups will at best result in restoring the cluster to an inconsistent state, and may fail altogether.

`--restore_epoch` (short form: `-e`) adds (or restores) epoch information to the cluster replication status table. This is useful for starting replication on a MySQL Cluster replication slave. When this option is used, the row in the `mysql.ndb_apply_status` having `0` in the `id` column is updated if it already exists; such a row is inserted if it does not already exist. (See Section 17.6.9, "MySQL Cluster Backups With MySQL Cluster Replication".)

`--restore_data`

This option causes `ndb_restore` to output `NDB` table data and logs.

`--restore_meta`

This option causes `ndb_restore` to print `NDB` table metadata. Generally, you need only use this option when restoring the first data node of a cluster; additional data nodes can obtain the metadata from the first one.

`--restore-privilege-tables`

`ndb_restore` does not by default restore distributed MySQL privilege tables (MySQL Cluster NDB 7.2.0 and later). This option causes `ndb_restore` to restore the privilege tables.

This works only if the privilege tables were converted to `NDB` before the backup was taken. For more information, see Section 17.5.14, "Distributed MySQL Privileges for MySQL Cluster".

`--backup_path`

The path to the backup directory is required; this is supplied to `ndb_restore` using the `--backup_path` option, and must include the subdirectory corresponding to the ID backup of the backup to be restored. For example, if the data node's `DataDir` is `/var/lib/mysql-cluster`, then the backup directory is `/var/lib/mysql-cluster/BACKUP`, and the backup files for the backup with the ID 3 can be found in `/var/lib/mysql-cluster/BACKUP/BACKUP-3`. The path may be absolute or relative to the directory in which the `ndb_restore` executable is located, and may be optionally prefixed with `backup_path=`.

> **Note**
>
> Previous to MySQL 5.1.17 and MySQL Cluster NDB 6.1.5, the path to the backup directory was specified as shown here, with `backup_path=` being optional:
>
> ```
> [backup_path=]/path/to/backup/files
> ```
>
> Beginning with MySQL 5.1.17 and MySQL Cluster NDB 6.1.5, this syntax changed to `--backup_path=/path/to/backup/files`, to conform more closely with options used by other MySQL programs; `--backupid` is required, and there is no short form for this option.

It is possible to restore a backup to a database with a different configuration than it was created from. For example, suppose that a backup with backup ID `12`, created in a cluster with two database nodes having the node IDs `2` and `3`, is to be restored to a cluster with four nodes. Then `ndb_restore` must be run twice—once for each database node in the cluster where the backup was taken. However, `ndb_restore` cannot always restore backups made from a cluster running one version of MySQL to a cluster running a different MySQL version. See Section 17.2.7, "Upgrading and Downgrading MySQL Cluster", for more information.

> **Important**
>
> It is not possible to restore a backup made from a newer version of MySQL Cluster using an older version of `ndb_restore`. You can restore a backup made from a newer version of MySQL to an older cluster, but you must use a copy of `ndb_restore` from the newer MySQL Cluster version to do so.
>
> For example, to restore a cluster backup taken from a cluster running MySQL Cluster NDB 7.1.8 to a cluster running MySQL Cluster NDB 7.0.16, you must use the `ndb_restore` that comes with the MySQL Cluster NDB 7.1.8 distribution.

For more rapid restoration, the data may be restored in parallel, provided that there is a sufficient number of cluster connections available. That is, when restoring to multiple nodes in parallel, you must have an `[api]` or `[mysqld]` section in the cluster `config.ini` file available for each concurrent `ndb_restore` process. However, the data files must always be applied before the logs.

  `--no-upgrade`

Formerly, when using `ndb_restore` to restore a backup made from a MySQL 5.0 cluster to a 5.1 cluster, `VARCHAR` columns were not resized and were recreated using the 5.0 fixed format. Beginning with MySQL 5.1.19, `ndb_restore` recreates such `VARCHAR` columns using MySQL Cluster 5.1's variable-width format. Also beginning with MySQL 5.1.19, this behavior can be overridden using the `--no-upgrade` option (short form: `-u`) when running `ndb_restore`.

  `--print_data`

The `--print_data` option causes `ndb_restore` to direct its output to `stdout`.

`TEXT` and `BLOB` column values are always truncated to the first 256 bytes in the output; this cannot currently be overridden when using `--print_data`.

Beginning with MySQL 5.1.18, several additional options are available for use with the `--print_data` option in generating data dumps, either to `stdout`, or to a file. These are similar to some of the options used with `mysqldump`, and are shown in the following list:

- `--tab`, `-T`

Introduced	5.1.18	
Command-Line Format	`--tab=dir_name`	
Permitted Values	**Type**	`directory name`

This option causes `--print_data` to create dump files, one per table, each named `tbl_name.txt`. It requires as its argument the path to the directory where the files should be saved; use `.` for the current directory.

- `--fields-enclosed-by=string`

Introduced	5.1.18	
Command-Line Format	`--fields-enclosed-by=char`	
Permitted Values	**Type**	`string`
	Default	

Each column values are enclosed by the string passed to this option (regardless of data type; see next item).

- `--fields-optionally-enclosed-by=string`

Introduced	5.1.18	
Command-Line Format	`--fields-optionally-enclosed-by`	
Permitted Values	**Type**	`string`
	Default	

The string passed to this option is used to enclose column values containing character data (such as `CHAR`, `VARCHAR`, `BINARY`, `TEXT`, or `ENUM`).

- `--fields-terminated-by=string`

Introduced	5.1.18	
Command-Line Format	`--fields-terminated-by=char`	
Permitted Values	**Type**	`string`
	Default	`\t (tab)`

The string passed to this option is used to separate column values. The default value is a tab character (`\t`).

- `--hex`

Introduced	5.1.18
Command-Line Format	`--hex`

If this option is used, all binary values are output in hexadecimal format.

- `--fields-terminated-by=string`

Introduced	5.1.18
Command-Line Format	`--fields-terminated-by=char`

Permitted Values	Type	`string`
	Default	`\t (tab)`

This option specifies the string used to end each line of output. The default is a linefeed character (`\n`).

- `--append`

Introduced	5.1.18
Command-Line Format	`--append`

When used with the `--tab` and `--print_data` options, this causes the data to be appended to any existing files having the same names.

> **Note**
>
> If a table has no explicit primary key, then the output generated when using the `--print_data` option includes the table's hidden primary key.

`--print_meta`

This option causes `ndb_restore` to print all metadata to `stdout`.

`--print_log`

The `--print_log` option causes `ndb_restore` to output its log to `stdout`.

`--print`

Causes `ndb_restore` to print all data, metadata, and logs to `stdout`. Equivalent to using the `--print_data`, `--print_meta`, and `--print_log` options together.

> **Note**
>
> Use of `--print` or any of the `--print_*` options is in effect performing a dry run. Including one or more of these options causes any output to be redirected to `stdout`; in such cases, `ndb_restore` makes no attempt to restore data or metadata to a MySQL Cluster.

`--dont_ignore_systab_0`

Normally, when restoring table data and metadata, `ndb_restore` ignores the copy of the `NDB` system table that is present in the backup. `--dont_ignore_systab_0` causes the system table to be restored. *This option is intended for experimental and development use only, and is not recommended in a production environment.*

`--ndb-nodegroup-map`, `-z`

This option can be used to restore a backup taken from one node group to a different node group. Its argument is a list of the form *source_node_group, target_node_group*.

`--no-binlog`

This option prevents any connected SQL nodes from writing data restored by `ndb_restore` to their binary logs. Available beginning with MySQL Cluster NDB 6.2.16 and MySQL Cluster NDB 6.3.16.

`--no-restore-disk-objects`, `-d`

This option stops `ndb_restore` from restoring any MySQL Cluster Disk Data objects, such as tablespaces and log file groups; see Section 17.5.12, "MySQL Cluster Disk Data Tables", for more information about these. Added in MySQL 5.1.6.

`--parallelism=#`, `-p`

`ndb_restore` uses single-row transactions to apply many rows concurrently. This parameter determines the number of parallel transactions (concurrent rows) that an instance of `ndb_restore` tries to use. By default, this is 128; the minimum is 1, and the maximum is 1024.

The work of performing the inserts is parallelized across the threads in the data nodes involved. This mechanism is employed for restoring bulk data from the `.Data` file—that is, the fuzzy snapshot of the data; it is not used for building or rebuilding indexes. The change log is applied serially; index drops and builds are DDL operations and handled separately. There is no thread-level parallelism on the client side of the restore.

`--progress-frequency=N`

Print a status report each *N* seconds while the backup is in progress. 0 (the default) causes no status reports to be printed. The maximum is 65535.

`--verbose=#`

Sets the level for the verbosity of the output. The minimum is 0; the maximum is 255. The default value is 1.

Beginning with MySQL 5.1.18, it is possible to restore only selected databases, or selected tables from a single database, using the syntax shown here:

```
ndb_restore other_options db_name,[db_name[,...] | tbl_name[,tbl_name][,...]]
```

In other words, you can specify either of the following to be restored:

* All tables from one or more databases

* One or more tables from a single database

`--include-databases=db_name[,db_name][,...]`

Introduced	5.1.32-ndb-6.4.3	
Command-Line Format	`--include-databases=db-list`	
Permitted Values	**Type**	`string`
	Default	

`--include-tables=db_name.tbl_name[,db_name.tbl_name][,...]`

Introduced	5.1.32-ndb-6.4.3	
Command-Line Format	`--include-tables=table-list`	
Permitted Values	**Type**	`string`
	Default	

Beginning with MySQL Cluster NDB 6.3.22 and MySQL Cluster NDB 6.4.3, you can (and should) use instead the `--include-databases` option or the `--include-tables` option for restoring only specific databases or tables, respectively. `--include-databases` takes a comma-delimited list of databases to be restored. `--include-tables` takes a comma-delimited list of tables (in `database.table` format) to be restored.

When `--include-databases` or `--include-tables` is used, only those databases or tables named by the option are restored; all other databases and tables are excluded by `ndb_restore`, and are not restored.

The following table shows several invocations of `ndb_restore` using `--include-*` options (other options possibly required have been omitted for clarity), and the effects these have on restoring from a MySQL Cluster backup:

Option Used	Result
`--include-databases=db1`	Only tables in database `db1` are restored; all tables in all other databases are ignored
`--include-databases=db1,db2` (or `--include-databases=db1 --include-databases=db2`)	Only tables in databases `db1` and `db2` are restored; all tables in all other databases are ignored
`--include-tables=db1.t1`	Only table `t1` in database `db1` is restored; no other tables in `db1` or in any other database are restored
`--include-tables=db1.t2,db2.t1` (or `--include-tables=db1.t2 --include-tables=db2.t1`)	Only the table `t2` in database `db1` and the table `t1` in database `db2` are restored; no other tables in `db1`, `db2`, or any other database are restored

Beginning with MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, you can use these two options together. For example, the following causes all tables in databases `db1` and `db2`, together with the tables `t1` and `t2` in database `db3`, to be restored (and no other databases or tables):

```
shell> ndb_restore [...] --include-databases=db1,db2 --include-tables=db3.t1,db3.t2
```

(Again we have omitted other, possibly required, options in the example just shown.)

> **Note**
>
> Prior to MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, multiple `--include-*` options were not handled correctly, and the result of the options shown in the previous example was that only the tables `db3.t1` and `db3.t2` were actually restored. (Bug #48907)

`--exclude-databases=`*db_name*`[,`*db_name*`][,...]`

Introduced	5.1.32-ndb-6.4.3	
Command-Line Format	`--exclude-databases=db-list`	
Permitted Values	**Type**	`string`
	Default	

`--exclude-tables=`*db_name.tbl_name*`[,`*db_name.tbl_name*`][,...]`

Introduced	5.1.32-ndb-6.4.3	
Command-Line Format	`--exclude-tables=table-list`	
Permitted Values	**Type**	`string`
	Default	

Beginning with MySQL Cluster NDB 6.3.22 and MySQL Cluster NDB 6.4.3, it is possible to prevent one or more databases or tables from being restored using the `ndb_restore` options `--exclude-databases` and `--exclude-tables`. `--exclude-databases` takes a comma-delimited list of one or

more databases which should not be restored. `--exclude-tables` takes a comma-delimited list of one or more tables (using `database.table` format) which should not be restored.

When `--exclude-databases` or `--exclude-tables` is used, only those databases or tables named by the option are excluded; all other databases and tables are restored by `ndb_restore`.

This table shows several invocations of `ndb_restore` usng `--exclude-*` options (other options possibly required have been omitted for clarity), and the effects these options have on restoring from a MySQL Cluster backup:

Option Used	Result
`--exclude-databases=db1`	All tables in all databases except `db1` are restored; no tables in `db1` are restored
`--exclude-databases=db1,db2` (or `--exclude-databases=db1 --exclude-databases=db2`)	All tables in all databases except `db1` and `db2` are restored; no tables in `db1` or `db2` are restored
`--exclude-tables=db1.t1`	All tables except `t1` in database `db1` are restored; all other tables in `db1` are restored; all tables in all other databases are restored
`--exclude-tables=db1.t2,db2.t1` (or `--exclude-tables=db1.t2 --exclude-tables=db2.t1`)	All tables in database `db1` except for `t2` and all tables in database `db2` except for table `t1` are restored; no other tables in `db1` or `db2` are restored; all tables in all other databases are restored

Beginning with MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, you can use these two options together. For example, the following causes all tables in all databases *except for* databases `db1` and `db2`, and tables `t1` and `t2` in database `db3`, to be restored:

```
shell> ndb_restore [...] --exclude-databases=db1,db2 --exclude-tables=db3.t1,db3.t2
```

(Again, we have omitted other possibly necessary options in the interest of clarity and brevity from the example just shown.)

Note

Prior to MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, multiple `--exclude-*` options were not handled correctly, with the result that the options shown in the previous example caused ndb_restore to exclude only the tables `db3.t1` and `db3.t2`. (Bug #48907)

Beginning with MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, you can use `--include-*` and `--exclude-*` options together, subject to the following rules:

- The actions of all `--include-*` and `--exclude-*` options are cumulative.

- All `--include-*` and `--exclude-*` options are evaluated in the order passed to ndb_restore, from right to left.

- In the event of conflicting options, the first (rightmost) option takes precedence. In other words, the first option (going from right to left) that matches against a given database or table "wins".

For example, the following set of options causes `ndb_restore` to restore all tables from database `db1` except `db1.t1`, while restoring no other tables from any other databases:

```
--include-databases=db1 --exclude-tables=db1.t1
```

However, reversing the order of the options just given simply causes all tables from database `db1` to be restored (including `db1.t1`, but no tables from any other database), because the `--include-databases` option, being farthest to the right, is the first match against database `db1` and thus takes precedence over any other option that matches `db1` or any tables in `db1`:

```
--exclude-tables=db1.t1 --include-databases=db1
```

> **Note**
>
> Prior to MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10, it was not possible to use `--include-databases` or `--include-tables` together with `--exclude-databases` or `--exclude-tables`, as these combinations were evaluated inconsistently. (Bug #48907)

`--exclude-missing-columns`

Introduced	5.1.35-ndb-7.0.7
Command-Line Format	`--exclude-missing-columns`

Beginning with MySQL Cluster NDB 6.3.26 and MySQL Cluster NDB 7.0.7, it is also possible to restore only selected table columns using the `--exclude-missing-columns` option. When this option is used, `ndb_restore` ignores any columns missing from tables being restored as compared to the versions of those tables found in the backup. This option applies to all tables being restored. If you wish to apply this option only to selected tables or databases, you can use it in combination with one or more of the options described in the previous paragraph to do so, then restore data to the remaining tables using a complementary set of these options.

`--exclude-missing-tables`

Introduced	5.1.73-ndb-7.1.33
Command-Line Format	`--exclude-missing-tables`

Beginning with MySQL Cluster NDB 7.1.33, it is also possible to restore only selected tables columns using this option, which causes `ndb_restore` to ignore any tables from the backup that are not found in the target database.

`--disable-indexes`

Introduced	5.1.41-ndb-7.1.2
Command-Line Format	`--disable-indexes`

Beginning with MySQL Cluster NDB 6.3.31, MySQL Cluster NDB 7.0.11, and MySQL Cluster NDB 7.1.2, you can use this option with `ndb_restore` to disable restoration of indexes during restoration of the data from a native NDB backup. Afterwards, you can restore indexes for all tables at once with multi-threaded building of indexes using `--rebuild-indexes`, which should be faster than rebuilding indexes concurrently for very large tables.

`--rebuild-indexes`

Introduced	5.1.41-ndb-7.1.2
Command-Line Format	`--rebuild-indexes`

Beginning with MySQL Cluster NDB 6.3.31, MySQL Cluster NDB 7.0.11, and MySQL Cluster NDB 7.1.2, you can use this option with `ndb_restore` to cause multi-threaded rebuilding of the ordered indexes while

restoring a native `NDB` backup. The number of threads used for building ordered indexes by `ndb_restore` with this option is controlled by the `BuildIndexThreads` data node configuration parameter.

It is necessary to use this option only for the first run of `ndb_restore`; this causes all ordered indexes to be rebuilt without using `--rebuild-indexes` again when restoring subsequent nodes. You should use this option prior to inserting new rows into the database; otherwise, it is possible for a row to be inserted that later causes a unique constraint violation when trying to rebuild the indexes.

Building of ordered indices is parallelized with the number of LDMs by default. Offline index builds performed during node and system restarts can be made faster using the `BuildIndexThreads` data node configuration parameter; this parameter has no effect on dropping and rebuilding of indexes by `ndb_restore`, which is performed online.

Rebuilding of unique indexes uses disk write bandwidth for redo logging and local checkpointing. An insufficient amount of this bandwith can lead to redo buffer overload or log overload errors. In such cases you can run `ndb_restore --rebuild-indexes` again; the process resumes at the point where the error occurred. You can also do this when you have encountered temporary errors. You can repeat execution of `ndb_restore --rebuild-indexes` indefinitely; you may be able to stop such errors by reducing the value of `DiskCheckpointSpeed` to provide additional disk bandwidth to redo logging, or reducing the `--parallelism`. If the problem is insufficient space, you can increase the size of the redo log (`FragmentLogFileSize` node configuration parameter), or you can increase the speed at which LCPs are performed (`DiskCheckpointSpeed`), in order to free space more quickly.

`--skip-broken-objects`

Introduced	5.1.51-ndb-7.1.10
Command-Line Format	`--skip-broken-objects`

This option causes `ndb_restore` to ignore corrupt tables while reading a native `NDB` backup, and to continue restoring any remaining tables (that are not also corrupted). Currently, the `--skip-broken-objects` option works only in the case of missing blob parts tables.

This option was added in MySQL Cluster NDB 6.3.40, MySQL Cluster NDB 7.0.21, and MySQL Cluster NDB 7.1.10.

`--skip-unknown-objects`

Introduced	5.1.44-ndb-7.1.4
Command-Line Format	`--skip-unknown-objects`

This option causes `ndb_restore` to ignore any schema objects it does not recognize while reading a native `NDB` backup. This can be used for restoring a backup made from a cluster running MySQL Cluster NDB 7.0 to a cluster running MySQL Cluster NDB 6.3.

This option was added in MySQL Cluster NDB 6.3.34, MySQL Cluster NDB 7.0.15, and MySQL Cluster NDB 7.1.4.

`--rewrite-database=old_dbname,new_dbname`

Introduced	5.1.51-ndb-7.1.11	
Command-Line Format	`--rewrite-database=olddb,newdb`	
Permitted Values	**Type**	`string`
	Default	`none`

This option makes it possible to restore to a database having a different name from that used in the backup. For example, if a backup is made of a database named `products`, you can restore the data it

contains to a database named `inventory`, use this option as shown here (omitting any other options that might be required):

```
shell> ndb_restore --rewrite-database=product,inventory
```

The option can be employed multiple times in a single invocation of `ndb_restore`. Thus it is possible to restore simultaneously from a database named `db1` to a database named `db2` and from a database named `db3` to one named `db4` using `--rewrite-database=db1,db2 --rewrite-database=db3,db4`. Other `ndb_restore` options may be used between multiple occurrences of `--rewrite-database`.

In the event of conflicts between multiple `--rewrite-database` options, the last `--rewrite-database` option used, reading from left to right, is the one that takes effect. For example, if `--rewrite-database=db1,db2 --rewrite-database=db1,db3` is used, only `--rewrite-database=db1,db3` is honored, and `--rewrite-database=db1,db2` is ignored. It is also possible to restore from multiple databases to a single database, so that `--rewrite-database=db1,db3 --rewrite-database=db2,db3` restores all tables and data from databases `db1` and `db2` into database `db3`.

> **Important**
>
> When restoring from multiple backup databases into a single target database using `--rewrite-database`, no check is made for collisions between table or other object names, and the order in which rows are restored is not guaranteed. This means that it is possible in such cases for rows to be overwritten and updates to be lost.

This option was added in MySQL Cluster NDB 6.3.41, MySQL Cluster NDB 7.0.22, and MySQL Cluster NDB 7.1.11.

• `--exclude-intermediate-sql-tables[=TRUE|FALSE]`

Introduced	5.1.73-ndb-7.1.31
Command-Line Format	`--exclude-intermediate-sql-tables[=TRUE|FALSE]`
Permitted Values	**Type** `boolean`
	Default `TRUE`

When performing copying `ALTER TABLE` operations, `mysqld` creates intermediate tables (whose names are prefixed with `#sql-`). When `TRUE`, the `--exclude-intermediate-sql-tables` option keeps `ndb_restore` from restoring such tables that may have been left over from such operations. This option is `TRUE` by default.

The `--exclude-intermediate-sql-tables` option was introduced in MySQL Cluster NDB 7.1.31. (Bug #17882305)

Error reporting.
`ndb_restore` reports both temporary and permanent errors. In the case of temporary errors, it may able to recover from them. Beginning with MySQL 5.1.12, it reports `Restore successful, but encountered temporary error, please look at configuration` in such cases.

> **Important**
>
> After using `ndb_restore` to initialize a MySQL Cluster for use in circular replication, binary logs on the SQL node acting as the replication slave are not automatically created, and you must cause them to be created manually. To cause

the binary logs to be created, issue a `SHOW TABLES` statement on that SQL node
before running `START SLAVE`. This is a known issue in MySQL Cluster.

17.4.21 `ndb_select_all` — Print Rows from an NDB Table

`ndb_select_all` prints all rows from an `NDB` table to `stdout`.

Usage

```
ndb_select_all -c connection_string tbl_name -d db_name [> file_name]
```

The following table includes options that are specific to the MySQL Cluster native backup restoration
program `ndb_select_all`. Additional descriptions follow the table. For options common to most MySQL
Cluster programs (including `ndb_select_all`), see Section 17.4.26, "Options Common to MySQL
Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.83 This table describes command-line options for the ndb_select_all program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.1 based releases
`--parallelism=#`, `-p`	Degree of parallelism	All MySQL 5.1 based releases
`--lock=#`, `-l`	Lock type	All MySQL 5.1 based releases
`--order=index`, `-o`	Sort resultset according to index whose name is supplied	All MySQL 5.1 based releases
`--descending`, `-z`	Sort resultset in descending order (requires order flag)	All MySQL 5.1 based releases
`--header`, `-h`	Print header (set to 0|FALSE to disable headers in output)	All MySQL 5.1 based releases
`--useHexFormat`, `-x`	Output numbers in hexadecimal format	All MySQL 5.1 based releases
`--delimiter=char`, `-D`	Set a column delimiter	All MySQL 5.1 based releases
`--disk`	Print disk references (useful only for Disk Data tables having nonindexed columns)	All MySQL 5.1 based releases
`--rowid`	Print rowid	All MySQL 5.1 based releases
`--gci`	Include GCI in output	All MySQL 5.1 based releases
`--gci64`	Include GCI and row epoch in output	All MySQL 5.1 based releases
`--tupscan`,	Scan in tup order	All MySQL 5.1 based releases

Format	Description	Added or Removed

`-t`
 	
`--nodata`
	Do not print table column data	All MySQL 5.1 based releases

- `--database=`*dbname*, `-d` *dbname*

  Name of the database in which the table is found. The default value is `TEST_DB`.

- `parallelism=#`, `-p #`

  Specifies the degree of parallelism.

- `--lock=`*lock_type*, `-l` *lock_type*

  Employs a lock when reading the table. Possible values for *lock_type* are:

  - `0`: Read lock

  - `1`: Read lock with hold

  - `2`: Exclusive read lock

  There is no default value for this option.

- `--order=`*index_name*, `-o` *index_name*

  Orders the output according to the index named *index_name*.

  > **Note**
  >
  > This is the name of an index, not of a column; the index must have been explicitly named when created.

- `--descending`, `-z`

  Sorts the output in descending order. This option can be used only in conjunction with the `-o` (`--order`) option.

- `--header=FALSE`

  Excludes column headers from the output.

- `--useHexFormat -x`

  Causes all numeric values to be displayed in hexadecimal format. This does not affect the output of numerals contained in strings or datetime values.

- `--delimiter=`*character*, `-D` *character*

  Causes the *character* to be used as a column delimiter. Only table data columns are separated by this delimiter.

  The default delimiter is the tab character.

- `--disk`

  Adds a disk reference column to the output. The column is nonempty only for Disk Data tables having nonindexed columns.

- `--rowid`

  Adds a `ROWID` column providing information about the fragments in which rows are stored.

- `--gci`

  Adds a `GCI` column to the output showing the global checkpoint at which each row was last updated. See Section 17.1, "MySQL Cluster Overview", and Section 17.5.6.2, "MySQL Cluster Log Events", for more information about checkpoints.

- `--gci64`

  Adds a `ROW$GCI64` column to the output showing the global checkpoint at which each row was last updated, as well as the number of the epoch in which this update occurred.

- `--tupscan`, `-t`

  Scan the table in the order of the tuples.

- `--nodata`

  Causes any table data to be omitted.

Sample Output

Output from a MySQL `SELECT` statement:

```
mysql> SELECT * FROM ctest1.fish;
+----+-----------+
| id | name      |
+----+-----------+
|  3 | shark     |
|  6 | puffer    |
|  2 | tuna      |
|  4 | manta ray |
|  5 | grouper   |
|  1 | guppy     |
+----+-----------+
6 rows in set (0.04 sec)
```

Output from the equivalent invocation of `ndb_select_all`:

```
shell> ./ndb_select_all -c localhost fish -d ctest1
id      name
3       [shark]
6       [puffer]
2       [tuna]
4       [manta ray]
5       [grouper]
1       [guppy]
6 rows returned

NDBT_ProgramExit: 0 - OK
```

All string values are enclosed by square brackets ("[...]") in the output of `ndb_select_all`. For another example, consider the table created and populated as shown here:

```
CREATE TABLE dogs (
    id INT(11) NOT NULL AUTO_INCREMENT,
```

```
    name VARCHAR(25) NOT NULL,
    breed VARCHAR(50) NOT NULL,
    PRIMARY KEY pk (id),
    KEY ix (name)
)
TABLESPACE ts STORAGE DISK
ENGINE=NDBCLUSTER;

INSERT INTO dogs VALUES
    ('', 'Lassie', 'collie'),
    ('', 'Scooby-Doo', 'Great Dane'),
    ('', 'Rin-Tin-Tin', 'Alsatian'),
    ('', 'Rosscoe', 'Mutt');
```

This demonstrates the use of several additional ndb_select_all options:

```
shell> ./ndb_select_all -d ctest1 dogs -o ix -z --gci --disk
GCI     id name            breed         DISK_REF
834461  2  [Scooby-Doo]    [Great Dane]  [ m_file_no: 0 m_page: 98 m_page_idx: 0 ]
834878  4  [Rosscoe]       [Mutt]        [ m_file_no: 0 m_page: 98 m_page_idx: 16 ]
834463  3  [Rin-Tin-Tin]   [Alsatian]    [ m_file_no: 0 m_page: 34 m_page_idx: 0 ]
835657  1  [Lassie]        [Collie]      [ m_file_no: 0 m_page: 66 m_page_idx: 0 ]
4 rows returned

NDBT_ProgramExit: 0 - OK
```

> **Note**
>
> In earlier MySQL Cluster NDB 7.0 and 7.1 releases, ndb_select_all did not print
> any output for NULL values as it did in MySQL Cluster NDB 6.3 and earlier release
> series. This issue was fixed in MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB
> 7.1.11. (Bug #60045)

17.4.22 ndb_select_count — Print Row Counts for NDB Tables

ndb_select_count prints the number of rows in one or more NDB tables. With a single table, the result is
equivalent to that obtained by using the MySQL statement SELECT COUNT(*) FROM tbl_name.

Usage

```
ndb_select_count [-c connection_string] -ddb_name tbl_name[, tbl_name2[, ...]]
```

The following table includes options that are specific to the MySQL Cluster native backup restoration
program ndb_select_count. Additional descriptions follow the table. For options common to most
MySQL Cluster programs (including ndb_select_count), see Section 17.4.26, "Options Common to
MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.84 This table describes command-line options for the ndb_select_count program

Format	Description	Added or Removed
--database=dbname, -d	Name of the database in which the table is found	All MySQL 5.1 based releases
--parallelism=#, -p	Degree of parallelism	All MySQL 5.1 based releases
--lock=#,	Lock type	All MySQL 5.1 based releases

Format	Description	Added or Removed
`-l`		

You can obtain row counts from multiple tables in the same database by listing the table names separated by spaces when invoking this command, as shown under **Sample Output**.

Sample Output

```
shell> ./ndb_select_count -c localhost -d ctest1 fish dogs
6 records in table fish
4 records in table dogs

NDBT_ProgramExit: 0 - OK
```

17.4.23 `ndb_show_tables` — Display List of NDB Tables

`ndb_show_tables` displays a list of all `NDB` database objects in the cluster. By default, this includes not only both user-created tables and `NDB` system tables, but `NDB`-specific indexes, internal triggers, and MySQL Cluster Disk Data objects as well.

The following table includes options that are specific to the MySQL Cluster native backup restoration program `ndb_show_tables`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_show_tables`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.85 This table describes command-line options for the ndb_show_tables program

Format	Description	Added or Removed
`--database=string`, `-d`	Specifies the database in which the table is found	All MySQL 5.1 based releases
`--loops=#`, `-l`	Number of times to repeat output	All MySQL 5.1 based releases
`--type=#`, `-t`	Limit output to objects of this type	All MySQL 5.1 based releases
`--unqualified`, `-u`	Do not qualify table names	All MySQL 5.1 based releases
`--parsable`, `-p`	Return output suitable for MySQL LOAD DATA INFILE statement	All MySQL 5.1 based releases
`--show-temp-status`	Show table temporary flag	All MySQL 5.1 based releases

Usage

```
ndb_show_tables [-c connection_string]
```

- `--database`, `-d`

  Specifies the name of the database in which the tables are found.

- `--loops`, `-l`

Specifies the number of times the utility should execute. This is 1 when this option is not specified, but if you do use the option, you must supply an integer argument for it.

- `--parsable`, `-p`

Using this option causes the output to be in a format suitable for use with `LOAD DATA INFILE`.

- `--show-temp-status`

If specified, this causes temporary tables to be displayed.

- `--type`, `-t`

Can be used to restrict the output to one type of object, specified by an integer type code as shown here:

- `1`: System table
- `2`: User-created table
- `3`: Unique hash index

Any other value causes all `NDB` database objects to be listed (the default).

- `--unqualified`, `-u`

If specified, this causes unqualified object names to be displayed.

> **Note**
>
> Only user-created MySQL Cluster tables may be accessed from MySQL; system tables such as `SYSTAB_0` are not visible to `mysqld`. However, you can examine the contents of system tables using `NDB` API applications such as `ndb_select_all` (see Section 17.4.21, "`ndb_select_all` — Print Rows from an NDB Table").

17.4.24 `ndb_size.pl` — NDBCLUSTER Size Requirement Estimator

This is a Perl script that can be used to estimate the amount of space that would be required by a MySQL database if it were converted to use the `NDBCLUSTER` storage engine. Unlike the other utilities discussed in this section, it does not require access to a MySQL Cluster (in fact, there is no reason for it to do so). However, it does need to access the MySQL server on which the database to be tested resides.

Requirements

- A running MySQL server. The server instance does not have to provide support for MySQL Cluster.

- A working installation of Perl.

- The `DBI` module, which can be obtained from CPAN if it is not already part of your Perl installation. (Many Linux and other operating system distributions provide their own packages for this library.)

- Previous to MySQL 5.1.18, `ndb_size.pl` also required the `HTML::Template` module and an associated template file `share/mysql/ndb_size.tmpl`. Beginning with MySQL 5.1.18, `ndb_size.tmpl` is no longer needed (or included).

- A MySQL user account having the necessary privileges. If you do not wish to use an existing account, then creating one using `GRANT USAGE ON db_name.*`—where `db_name` is the name of the database to be examined—is sufficient for this purpose.

`ndb_size.pl` can also be found in the MySQL sources in `storage/ndb/tools`.

The following table includes options that are specific to the MySQL Cluster program `ndb_size.pl`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_size.pl`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.86 This table describes command-line options for the ndb_size.pl program

Format	Description	Added or Removed
`--database=dbname`	The database or databases to examine; accepts a comma-delimited list; the default is ALL (use all databases found on the server)	All MySQL 5.1 based releases
`--hostname[:port]`	Specify host and optional port as host[:port]	All MySQL 5.1 based releases
`--socket=file_name`	Specify a socket to connect to	ADDED: NDB 6.2.5
`--user=string`	Specify a MySQL user name	All MySQL 5.1 based releases
`--password=string`	Specify a MySQL user password	All MySQL 5.1 based releases
`--format=string`	Set output format (text or HTML)	All MySQL 5.1 based releases
`--excludetables=tbl_list`	Skip any tables in a comma-separated list of tables	All MySQL 5.1 based releases
`--excludedbs=db_list`	Skip any databases in a comma-separated list of databases	All MySQL 5.1 based releases
`--savequeries=file`	Saves all queries to the database into the file specified	All MySQL 5.1 based releases
`--loadqueries=file`	Loads all queries from the file specified; does not connect to a database	All MySQL 5.1 based releases
`--real_table_name=table`	Designates a table to handle unique index size calculations	ADDED: NDB 6.2.5

Usage

```
perl ndb_size.pl [--database={db_name|ALL}] [--hostname=host[:port]] [--socket=socket] \
       [--user=user] [--password=password]  \
       [--help|-h] [--format={html|text}] \
       [--loadqueries=file_name] [--savequeries=file_name]
```

By default, this utility attempts to analyze all databases on the server. You can specify a single database using the `--database` option; the default behavior can be made explicit by using `ALL` for the name of the database. You can also exclude one or more databases by using the `--excludedbs` option with a comma-separated list of the names of the databases to be skipped. Similarly, you can cause specific tables to be skipped by listing their names, separated by commas, following the optional `--excludetables` option. A host name (and possibly a port as well) can be specified using `--hostname`; the default is `localhost`. Beginning with MySQL Cluster NDB 6.3.49, MySQL Cluster NDB 7.0.32, and MySQL Cluster NDB 7.1.21, you can specify a port in addition to the host using *host*:*port* format for the value of `--hostname`. The default port number is 3306. If necessary, you can also specify a socket; the default is `/var/lib/mysql.sock`. A MySQL user name and password can be specified the corresponding options shown. It also possible to control the format of the output using the `--format`

option; this can take either of the values `html` or `text`, with `text` being the default. An example of the text output is shown here:

```
shell> ndb_size.pl --database=test --socket=/tmp/mysql.sock
ndb_size.pl report for database: 'test' (1 tables)
--------------------------------------------------
Connected to: DBI:mysql:host=localhost;mysql_socket=/tmp/mysql.sock

Including information for versions: 4.1, 5.0, 5.1

test.t1
-------

DataMemory for Columns (* means varsized DataMemory):
          Column Name            Type  Varsized  Key  4.1  5.0   5.1
      HIDDEN_NDB_PKEY            bigint            PRI   8    8     8
                   c2     varchar(50)       Y          52   52    4*
                   c1         int(11)                   4    4     4
                                                       --   --    --
Fixed Size Columns DM/Row                             64   64    12
   Varsize Columns DM/Row                              0    0     4

DataMemory for Indexes:
   Index Name                    Type       4.1       5.0        5.1
      PRIMARY                   BTREE        16        16         16
                                            --        --         --
         Total Index DM/Row                 16        16         16

IndexMemory for Indexes:
            Index Name       4.1       5.0       5.1
               PRIMARY        33        16        16
                              --        --        --
         Indexes IM/Row       33        16        16

Summary (for THIS table):
                              4.1       5.0       5.1
      Fixed Overhead DM/Row    12        12        16
            NULL Bytes/Row      4         4         4
            DataMemory/Row     96        96        48
                  (Includes overhead, bitmap and indexes)

  Varsize Overhead DM/Row        0         0         8
  Varsize NULL Bytes/Row         0         0         4
     Avg Varside DM/Row          0         0        16

              No. Rows           0         0         0

       Rows/32kb DM Page       340       340       680
Fixedsize DataMemory (KB)        0         0         0

Rows/32kb Varsize DM Page        0         0      2040
  Varsize DataMemory (KB)        0         0         0

       Rows/8kb IM Page        248       512       512
         IndexMemory (KB)        0         0         0

Parameter Minimum Requirements
------------------------------
* indicates greater than default

            Parameter     Default        4.1          5.0          5.1
       DataMemory (KB)      81920          0            0            0
     NoOfOrderedIndexes       128          1            1            1
            NoOfTables        128          1            1            1
        IndexMemory (KB)    18432          0            0            0
   NoOfUniqueHashIndexes       64          0            0            0
```

NoOfAttributes	1000	3	3	3
NoOfTriggers	768	5	5	5

For debugging purposes, the Perl arrays containing the queries run by this script can be read from the file specified using can be saved to a file using `--savequeries`; a file containing such arrays to be read in during script execution can be specified using `--loadqueries`. Neither of these options has a default value.

To produce output in HTML format, use the `--format` option and redirect the output to a file, as shown here:

```
shell> ndb_size.pl --database=test --socket=/tmp/mysql.sock --format=html > ndb_size.html
```

(Without the redirection, the output is sent to `stdout`.)

The output from this script includes the following information:

- Minimum values for the `DataMemory`, `IndexMemory`, `MaxNoOfTables`, `MaxNoOfAttributes`, `MaxNoOfOrderedIndexes`, `MaxNoOfUniqueHashIndexes`, and `MaxNoOfTriggers` configuration parameters required to accommodate the tables analyzed.

- Memory requirements for all of the tables, attributes, ordered indexes, and unique hash indexes defined in the database.

- The `IndexMemory` and `DataMemory` required per table and table row.

> **Note**
>
> Prior to MySQL 5.1.23, MySQL Cluster NDB 6.2.5, and MySQL Cluster NDB 6.3.7, `ndb_size.pl` was invoked as shown here:
>
> ```
> perl ndb_size.pl db_name hostname username password > file_name.html
> ```
>
> For more information about this change, see Bug #28683 and Bug #28253.

17.4.25 `ndb_waiter` — Wait for MySQL Cluster to Reach a Given Status

`ndb_waiter` repeatedly (each 100 milliseconds) prints out the status of all cluster data nodes until either the cluster reaches a given status or the `--timeout` limit is exceeded, then exits. By default, it waits for the cluster to achieve `STARTED` status, in which all nodes have started and connected to the cluster. This can be overridden using the `--no-contact` and `--not-started` options.

The node states reported by this utility are as follows:

- `NO_CONTACT`: The node cannot be contacted.

- `UNKNOWN`: The node can be contacted, but its status is not yet known. Usually, this means that the node has received a `START` or `RESTART` command from the management server, but has not yet acted on it.

- `NOT_STARTED`: The node has stopped, but remains in contact with the cluster. This is seen when restarting the node using the management client's `RESTART` command.

- `STARTING`: The node's `ndbd` process has started, but the node has not yet joined the cluster.

- `STARTED`: The node is operational, and has joined the cluster.

- `SHUTTING_DOWN`: The node is shutting down.

- `SINGLE USER MODE`: This is shown for all cluster data nodes when the cluster is in single user mode.

The following table includes options that are specific to the MySQL Cluster native backup restoration program `ndb_waiter`. Additional descriptions follow the table. For options common to most MySQL Cluster programs (including `ndb_waiter`), see Section 17.4.26, "Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs".

Table 17.87 This table describes command-line options for the ndb_waiter program

Format	Description	Added or Removed
`--no-contact`, `-n`	Wait for cluster to reach NO CONTACT state	All MySQL 5.1 based releases
`--not-started`	Wait for cluster to reach NOT STARTED state	All MySQL 5.1 based releases
`--single-user`	Wait for cluster to enter single user mode	All MySQL 5.1 based releases
`--timeout=#`, `-t`	Wait this many seconds, then exit whether or not cluster has reached desired state; default is 2 minutes (120 seconds)	All MySQL 5.1 based releases
`--nowait-nodes=list`	List of nodes not to be waited for.	ADDED: NDB 6.2.1
`--wait-nodes=list`, `-w`	List of nodes to be waited for.	ADDED: NDB 6.3.34, NDB 7.0.15, NDB 7.1.4

Usage

```
ndb_waiter [-c connection_string]
```

Additional Options

- `--no-contact`, `-n`

  Instead of waiting for the `STARTED` state, `ndb_waiter` continues running until the cluster reaches `NO_CONTACT` status before exiting.

- `--not-started`

  Instead of waiting for the `STARTED` state, `ndb_waiter` continues running until the cluster reaches `NOT_STARTED` status before exiting.

- `--timeout=seconds`, `-t seconds`

  Time to wait. The program exits if the desired state is not achieved within this number of seconds. The default is 120 seconds (1200 reporting cycles).

- `--single-user`

  The program waits for the cluster to enter single user mode.

- `--nowait-nodes=list`

  When this option is used, ndb_waiter does not wait for the nodes whose IDs are listed. The list is comma-delimited; ranges can be indicated by dashes, as shown here:

```
shell> ndb_waiter --nowait-nodes=1,3,7-9
```

> **⚠ Important**
>
> Do *not* use this option together with the `--wait-nodes` option.

This option was added in MySQL Cluster NDB 6.2.1.

- `--wait-nodes=`*list*`, -w` *list*

When this option is used, `ndb_waiter` waits only for the nodes whose IDs are listed. The list is comma-delimited; ranges can be indicated by dashes, as shown here:

```
shell> ndb_waiter --wait-nodes=2,4-6,10
```

> **⚠ Important**
>
> Do *not* use this option together with the `--nowait-nodes` option.

This option was added in MySQL Cluster NDB 6.3.34, 7.0.15, and 7.1.4.

Sample Output.   Shown here is the output from `ndb_waiter` when run against a 4-node cluster in which two nodes have been shut down and then started again manually. Duplicate reports (indicated by "`...`") are omitted.

```
shell> ./ndb_waiter -c localhost

Connecting to mgmsrv at (localhost)
State node 1 STARTED
State node 2 NO_CONTACT
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED


...

State node 1 STARTED
State node 2 UNKNOWN
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED


...

State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED


...

State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 UNKNOWN
Waiting for cluster enter state STARTED


...
```

```
State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 STARTING
Waiting for cluster enter state STARTED


...

State node 1 STARTED
State node 2 STARTED
State node 3 STARTED
State node 4 STARTING
Waiting for cluster enter state STARTED


...

State node 1 STARTED
State node 2 STARTED
State node 3 STARTED
State node 4 STARTED
Waiting for cluster enter state STARTED

NDBT_ProgramExit: 0 - OK
```

> **Note**
>
> If no connection string is specified, then `ndb_waiter` tries to connect to a
> management on `localhost`, and reports `Connecting to mgmsrv at (null)`.

17.4.26 Options Common to MySQL Cluster Programs — Options Common to MySQL Cluster Programs

All MySQL Cluster programs accept the options described in this section, with the following exceptions:

- `mysqld`

- `ndb_print_backup_file`

- `ndb_print_schema_file`

- `ndb_print_sys_file`

Users of earlier MySQL Cluster versions should note that some of these options have been changed to make them consistent with one another as well as with `mysqld`. You can use the `--help` option with any MySQL Cluster program—with the exception of `ndb_print_backup_file`, `ndb_print_schema_file`, and `ndb_print_sys_file`—to view a list of the options which the program supports.

The options in the following table are common to all MySQL Cluster executables (except those noted previously in this section).

Table 17.88 This table describes command-line options common to all MySQL Cluster programs

Format	Description	Added or Removed
`--help`, `--usage`, `-?`	Display help message and exit	All MySQL 5.1 based releases

Format	Description	Added or Removed
`--character-sets-dir=dir_name`	Directory where character sets are installed	All MySQL 5.1 based releases
`--core-file`	Write core on errors (defaults to TRUE in debug builds)	All MySQL 5.1 based releases
`--debug=options`	Enable output from debug calls. Can be used only for versions compiled with debugging enabled	All MySQL 5.1 based releases

`--ndb-connectstring=connectstring`
 	
`--connect-string=connectstring`,
 	
`-c`
	Set connection string for connecting to ndb_mgmd. Syntax: [nodeid=<id>;] [host=]<hostname>[:<port>]. Overrides entries specified in NDB_CONNECTSTRING or my.cnf.	All MySQL 5.1 based releases

`--ndb-mgmd-host=host[:port]`	Set the host (and port, if desired) for connecting to management server	All MySQL 5.1 based releases
`--ndb-nodeid=#`	Set node id for this node	All MySQL 5.1 based releases
`--ndb-optimized-node-selection`	Select nodes for transactions in a more optimal way	All MySQL 5.1 based releases
`--ndb-shm`	Allow for optimization using shared memory connections where available (was EXPERIMENTAL, later REMOVED)	REMOVED: NDB 7.0.16, NDB 7.1.5
`--version`, `-V`	Output version information and exit	All MySQL 5.1 based releases

For options specific to individual MySQL Cluster programs, see Section 17.4, "MySQL Cluster Programs".

See MySQL Server Options for MySQL Cluster, for `mysqld` options relating to MySQL Cluster.

- `--help`, `--usage`, `-?`

Command-Line Format	`--help`
	`--usage`

Prints a short list with descriptions of the available command options.

- `--character-sets-dir=`*name*

Command-Line Format	`--character-sets-dir=dir_name`	
Permitted Values	**Type**	`directory name`
	Default	

Tells the program where to find character set information.

- `--ndb-connectstring=`*connection_string*, `--connect-string=`*connection_string*, `-c` *connection_string*

Command-Line Format	`--ndb-connectstring=connectstring`	
	`--connect-string=connectstring`	
Permitted Values	Type	`string`
	Default	`localhost:1186`

This option takes a MySQL Cluster connection string that specifies the management server for the application to connect to, as shown here:

```
shell> ndbd --ndb-connectstring="nodeid=2;host=ndb_mgmd.mysql.com:1186"
```

For more information, see Section 17.3.3.3, "MySQL Cluster Connection Strings".

- `--core-file`

Command-Line Format	`--core-file`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

Write a core file if the program dies. The name and location of the core file are system-dependent. (For MySQL Cluster programs nodes running on Linux, the default location is the program's working directory—for a data node, this is the node's `DataDir`.) For some systems, there may be restrictions or limitations; for example, it might be necessary to execute `ulimit -c unlimited` before starting the server. Consult your system documentation for detailed information.

If MySQL Cluster was built using the `--debug` option for `configure`, then `--core-file` is enabled by default. For regular builds, `--core-file` is disabled by default.

- `--debug[=options]`

Command-Line Format	`--debug=options`	
Permitted Values	Type	`string`
	Default	`d:t:O,/tmp/ndb_restore.trace`

This option can be used only for versions compiled with debugging enabled. It is used to enable output from debug calls in the same manner as for the `mysqld` process.

- `--ndb-mgmd-host=host[:port]`

Command-Line Format	`--ndb-mgmd-host=host[:port]`	
Permitted Values	Type	`string`
	Default	`localhost:1186`

Can be used to set the host and port number of a single management server for the program to connect to. If the program requires node IDs or references to multiple management servers (or both) in its connection information, use the `--ndb-connectstring` option instead.

- `--ndb-nodeid=#`

Command-Line Format	`--ndb-nodeid=#`	
Permitted Values	Type	`numeric`

	Default	0

Sets this node's MySQL Cluster node ID. *The range of permitted values depends on the node's type (data, management, or API) and the MySQL Cluster software version.* See Section 17.1.6.2, "Limits and Differences of MySQL Cluster from Standard MySQL Limits", for more information.

- `--ndb-optimized-node-selection`

Command-Line Format	`--ndb-optimized-node-selection`	
Permitted Values	**Type**	`boolean`
	Default	`TRUE`

Optimize selection of nodes for transactions. Enabled by default.

- `--version`, `-V`

Command-Line Format	`--version`

Prints the MySQL Cluster version number of the executable. The version number is relevant because not all versions can be used together, and the MySQL Cluster startup process verifies that the versions of the binaries being used can co-exist in the same cluster. This is also important when performing an online (rolling) software upgrade or downgrade of MySQL Cluster.

See Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster"), for more information.

- `--ndb-shm`

Removed	5.1.47-ndb-7.1.5	
Command-Line Format	`--ndb-shm`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

In older versions of MySQL Cluster, this experimental option allowed the application to use shared memory for optimization when available. `--ndb-shm` was removed from all MySQL Cluster programs beginning with MySQL Cluster NDB 7.0.16 and MySQL Cluster 7.1.5.

17.5 Management of MySQL Cluster

Managing a MySQL Cluster involves a number of tasks, the first of which is to configure and start MySQL Cluster. This is covered in Section 17.3, "Configuration of MySQL Cluster NDB 6.1-7.1", and Section 17.4, "MySQL Cluster Programs".

The next few sections cover the management of a running MySQL Cluster.

For information about security issues relating to management and deployment of a MySQL Cluster, see Section 17.5.11, "MySQL Cluster Security Issues".

There are essentially two methods of actively managing a running MySQL Cluster. The first of these is through the use of commands entered into the management client whereby cluster status can be checked, log levels changed, backups started and stopped, and nodes stopped and started. The second method involves studying the contents of the cluster log `ndb_node_id_cluster.log`; this is usually found in the management server's `DataDir` directory, but this location can be overridden using the `LogDestination` option. (Recall that `node_id` represents the unique identifier of the node whose activity is being logged.)

The cluster log contains event reports generated by `ndbd`. It is also possible to send cluster log entries to a Unix system log.

Some aspects of the cluster's operation can be also be monitored from an SQL node using the `SHOW ENGINE NDB STATUS` statement.

In MySQL Cluster NDB 7.1.1 and later, detailed information about cluster operations is available in real time through an SQL interface using the `ndbinfo` database. For more information, see Section 17.5.10, "The ndbinfo MySQL Cluster Information Database".

Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, NDB statistics counters provide improved monitoring using the `mysql` client. These counters, implemented in the NDB kernel, relate to operations performed by or affecting `Ndb` objects, such as starting, closing, and aborting transactions; primary key and unique key operations; table, range, and pruned scans; blocked threads waiting for various operations to complete; and data and events sent and received by MySQL Cluster. The counters are incremented by the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes.

`mysqld` exposes the NDB API statistics counters as system status variables, which can be identified from the prefix common to all of their names (`Ndb_api_`). The values of these variables can be read in the `mysql` client from the output of a `SHOW STATUS` statement, or by querying either the `SESSION_STATUS` table or the `GLOBAL_STATUS` table (in the `INFORMATION_SCHEMA` database). By comparing the values of the status variables before and after the execution of an SQL statement that acts on `NDB` tables, you can observe the actions taken on the NDB API level that correspond to this statement, which can be beneficial for monitoring and performance tuning of MySQL Cluster.

MySQL Cluster Manager provides an advanced command-line interface that simplifies many otherwise complex MySQL Cluster management tasks, such as starting, stopping, or restarting a MySQL Cluster with a large number of nodes. The MySQL Cluster Manager client also supports commands for getting and setting the values of most node configuration parameters as well as `mysqld` server options and variables relating to MySQL Cluster. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

17.5.1 Summary of MySQL Cluster Start Phases

This section provides a simplified outline of the steps involved when MySQL Cluster data nodes are started. More complete information can be found in MySQL Cluster Start Phases, in the *NDB Internals Guide.*

These phases are the same as those reported in the output from the *node_id* `STATUS` command in the management client (see Section 17.5.2, "Commands in the MySQL Cluster Management Client"). In MySQL Cluster NDB 7.1.1 and later, these start phases are also reported in the `start_phase` column of the `ndbinfo.nodes` table.

Start types.   There are several different startup types and modes, as shown in the following list:

- **Initial start.**   The cluster starts with a clean file system on all data nodes. This occurs either when the cluster started for the very first time, or when all data nodes are restarted using the `--initial` option.

  > **Note**
  >
  > Disk Data files are not removed when restarting a node using `--initial`.

- **System restart.**   The cluster starts and reads data stored in the data nodes. This occurs when the cluster has been shut down after having been in use, when it is desired for the cluster to resume operations from the point where it left off.

- **Node restart.**   This is the online restart of a cluster node while the cluster itself is running.

- **Initial node restart.**   This is the same as a node restart, except that the node is reinitialized and started with a clean file system.

Setup and initialization (phase -1).   Prior to startup, each data node (`ndbd` process) must be initialized. Initialization consists of the following steps:

1. Obtain a node ID

2. Fetch configuration data

3. Allocate ports to be used for inter-node communications

4. Allocate memory according to settings obtained from the configuration file

When a data node or SQL node first connects to the management node, it reserves a cluster node ID. To make sure that no other node allocates the same node ID, this ID is retained until the node has managed to connect to the cluster and at least one `ndbd` reports that this node is connected. This retention of the node ID is guarded by the connection between the node in question and `ndb_mgmd`.

Freeing unused node IDs.   Normally, in the event of a problem with the node, the node disconnects from the management server, the socket used for the connection is closed, and the reserved node ID is freed. However, if a node is disconnected abruptly—for example, due to a hardware failure in one of the cluster hosts, or because of network issues—the normal closing of the socket by the operating system may not take place. In this case, the node ID continues to be reserved and not released until a TCP timeout occurs 10 or so minutes later.

To take care of this problem, you can use `PURGE STALE SESSIONS`. Running this statement forces all reserved node IDs to be checked; any that are not being used by nodes actually connected to the cluster are then freed.

Beginning with MySQL 5.1.11, timeout handling of node ID assignments is implemented. This performs the ID usage checks automatically after approximately 20 seconds, so that `PURGE STALE SESSIONS` should no longer be necessary in a normal Cluster start.

After each data node has been initialized, the cluster startup process can proceed. The stages which the cluster goes through during this process are listed here:

- **Phase 0.**   The `NDBFS` and `NDBCNTR` blocks start (see NDB Kernel Blocks). Data node file systems are cleared on those data nodes that were started with `--initial` option.

- **Phase 1.**   In this stage, all remaining `NDB` kernel blocks are started. MySQL Cluster connections are set up, inter-block communications are established, and heartbeats are started. In the case of a node restart, API node connections are also checked.

  > **Note**
  >
  > When one or more nodes hang in Phase 1 while the remaining node or nodes hang in Phase 2, this often indicates network problems. One possible cause of such issues is one or more cluster hosts having multiple network interfaces. Another common source of problems causing this condition is the blocking of TCP/IP ports needed for communications between cluster nodes. In the latter case, this is often due to a misconfigured firewall.

- **Phase 2.**   The `NDBCNTR` kernel block checks the states of all existing nodes. The master node is chosen, and the cluster schema file is initialized.

- **Phase 3.**   The `DBLQH` and `DBTC` kernel blocks set up communications between them. The startup type is determined; if this is a restart, the `DBDIH` block obtains permission to perform the restart.

- **Phase 4.** For an initial start or initial node restart, the redo log files are created. The number of these files is equal to `NoOfFragmentLogFiles`.

  For a system restart:

  - Read schema or schemas.

  - Read data from the local checkpoint.

  - Apply all redo information until the latest restorable global checkpoint has been reached.

  For a node restart, find the tail of the redo log.

- **Phase 5.** Most of the database-related portion of a data node start is performed during this phase. For an initial start or system restart, a local checkpoint is executed, followed by a global checkpoint. Periodic checks of memory usage begin during this phase, and any required node takeovers are performed.

- **Phase 6.** In this phase, node groups are defined and set up.

- **Phase 7.** The arbitrator node is selected and begins to function. The next backup ID is set, as is the backup disk write speed. Nodes reaching this start phase are marked as `Started`. It is now possible for API nodes (including SQL nodes) to connect to the cluster.

- **Phase 8.** If this is a system restart, all indexes are rebuilt (by `DBDIH`).

- **Phase 9.** The node internal startup variables are reset.

- **Phase 100 (OBSOLETE).** Formerly, it was at this point during a node restart or initial node restart that API nodes could connect to the node and begin to receive events. Currently, this phase is empty.

- **Phase 101.** At this point in a node restart or initial node restart, event delivery is handed over to the node joining the cluster. The newly-joined node takes over responsibility for delivering its primary data to subscribers. This phase is also referred to as *SUMA* *handover phase*.

After this process is completed for an initial start or system restart, transaction handling is enabled. For a node restart or initial node restart, completion of the startup process means that the node may now act as a transaction coordinator.

17.5.2 Commands in the MySQL Cluster Management Client

In addition to the central configuration file, a cluster may also be controlled through a command-line interface available through the management client `ndb_mgm`. This is the primary administrative interface to a running cluster.

Commands for the event logs are given in Section 17.5.6, "Event Reports Generated in MySQL Cluster"; commands for creating backups and restoring from them are provided in Section 17.5.3, "Online Backup of MySQL Cluster".

Using ndb_mgm with MySQL Cluster Manager. MySQL Cluster Manager handles starting and stopping processes and tracks their states internally, so it is not necessary to use `ndb_mgm` for these tasks for a MySQL Cluster that is under MySQL Cluster Manager control. it is recommended *not* to use the `ndb_mgm` command-line client that comes with the MySQL Cluster distribution to perform operations that involve starting or stopping nodes. These include but are not limited to the `START`, `STOP`, `RESTART`, and `SHUTDOWN` commands. For more information, see MySQL Cluster Manager Process Commands.

The management client has the following basic commands. In the listing that follows, *node_id* denotes either a database node ID or the keyword `ALL`, which indicates that the command should be applied to all of the cluster's data nodes.

- `HELP`

  Displays information on all available commands.

- `CONNECT` *`connection-string`*

  Connects to the management server indicated by the connection string. If the client is already connected to this server, the client reconnects.

- `SHOW`

  Displays information on the cluster's status. Possible node status values include `UNKNOWN`, `NO_CONTACT`, `NOT_STARTED`, `STARTING`, `STARTED`, `SHUTTING_DOWN`, and `RESTARTING`.

  Beginning with MySQL Cluster NDB 6.2.8 and MySQL Cluster NDB 6.3.6, the output from this command indicates when the cluster is in single user mode (status `SINGLE USER MODE`).

  Prior to MySQL Cluster NDB 7.0.26 and MySQL Cluster NDB 7.1.5, in a cluster having multiple management nodes, this command displayed information only for data nodes that were actually connected to the current management server; in addition, management servers could not find each other until all nodes had been started. Beginning with these versions, such issues are fixed (see Bug #12352191), and management nodes can be additionally be reported with status `RESUME` or `CONNECTED`.

- *`node_id`* `START`

  Brings online the data node identified by *`node_id`* (or all data nodes).

  `ALL START` works on all data nodes only, and does not affect management nodes.

  > **Important**
  >
  > To use this command to bring a data node online, the data node must have been started using `--nostart` or `-n`.

- *`node_id`* `STOP [-a] [-f]`

  Stops the data or management node identified by *`node_id`*.

  > **Note**
  >
  > `ALL STOP` works to stop all data nodes only, and does not affect management nodes.

  A node affected by this command disconnects from the cluster, and its associated `ndbd` or `ndb_mgmd` process terminates.

  The `-a` option causes the node to be stopped immediately, without waiting for the completion of any pending transactions.

  Normally, `STOP` fails if the result would cause an incomplete cluster. The `-f` option, added in MySQL Cluster NDB 7.0.19 and MySQL Cluster NDB 7.1.8, forces the node to shut down without checking for this. If this option is used and the result is an incomplete cluster, the cluster immediately shuts down.

  > **Warning**
  >
  > Use of the `-a` option also disables the safety check otherwise performed when `STOP` is invoked to insure that stopping the node does not cause an incomplete

> cluster. In other words, you should exercise extreme care when using the `-a` option with the `STOP` command, due to the fact that this option makes it possible for the cluster to undergo a forced shutdown because it no longer has a complete copy of all data stored in `NDB`.

- `node_id RESTART [-n] [-i] [-a] [-f]`

  Restarts the data node identified by `node_id` (or all data nodes).

  Using the `-i` option with `RESTART` causes the data node to perform an initial restart; that is, the node's file system is deleted and recreated. The effect is the same as that obtained from stopping the data node process and then starting it again using `ndbd --initial` from the system shell.

  > **Note**
  >
  > Backup files and Disk Data files are not removed when this option is used.

  Using the `-n` option causes the data node process to be restarted, but the data node is not actually brought online until the appropriate `START` command is issued. The effect of this option is the same as that obtained from stopping the data node and then starting it again using `ndbd --nostart` or `ndbd -n` from the system shell.

  Using the `-a` causes all current transactions relying on this node to be aborted. No GCP check is done when the node rejoins the cluster.

  Normally, `RESTART` fails if taking the node offline would result in an incomplete cluster. The `-f` option, added in MySQL Cluster NDB 7.0.19 and MySQL Cluster NDB 7.1.8, forces the node to restart without checking for this. If this option is used and the result is an incomplete cluster, the entire cluster is restarted.

- `node_id STATUS`

  Displays status information for the data node identified by `node_id` (or for all data nodes).

  Beginning with MySQL Cluster NDB 6.2.8 and MySQL Cluster NDB 6.3.6, the output from this command indicates when the cluster is in single user mode.

- `node_id REPORT report-type`

  Displays a report of type `report-type` for the data node identified by `node_id`, or for all data nodes using `ALL`.

  Currently, there are three accepted values for `report-type`:

  - `BackupStatus` provides a status report on a cluster backup in progress

  - `MemoryUsage` displays how much data memory and index memory is being used by each data node as shown in this example:

    ```
    ndb_mgm> ALL REPORT MEMORY

    Node 1: Data usage is 5%(177 32K pages of total 3200)
    Node 1: Index usage is 0%(108 8K pages of total 12832)
    Node 2: Data usage is 5%(177 32K pages of total 3200)
    Node 2: Index usage is 0%(108 8K pages of total 12832)
    ```

In MySQL Cluster NDB 7.1.1 and later, this information is also available from the `ndbinfo.memoryusage` table.

- `EventLog` reports events from the event log buffers of one or more data nodes.

`report-type` is case-insensitive and "fuzzy"; for `MemoryUsage`, you can use `MEMORY` (as shown in the prior example), `memory`, or even simply `MEM` (or `mem`). You can abbreviate `BackupStatus` in a similar fashion.

Prior to MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26, `ALL REPORT BackupStatus` did not work correctly with multi-threaded data nodes. (Bug #15908907)

The `REPORT` command was introduced in MySQL Cluster NDB 6.2.3 and MySQL Cluster NDB 6.3.0.

- `ENTER SINGLE USER MODE node_id`

Enters single user mode, whereby only the MySQL server identified by the node ID `node_id` is permitted to access the database.

Currently, it is not possible for data nodes to join a MySQL Cluster while it is running in single user mode. (Bug #20395)

- `EXIT SINGLE USER MODE`

Exits single user mode, enabling all SQL nodes (that is, all running `mysqld` processes) to access the database.

> **Note**
>
> It is possible to use `EXIT SINGLE USER MODE` even when not in single user mode, although the command has no effect in this case.

- `QUIT`, `EXIT`

Terminates the management client.

This command does not affect any nodes connected to the cluster.

- `SHUTDOWN`

Shuts down all cluster data nodes and management nodes. To exit the management client after this has been done, use `EXIT` or `QUIT`.

This command does *not* shut down any SQL nodes or API nodes that are connected to the cluster.

- `CREATE NODEGROUP nodeid[, nodeid, ...]`

Creates a new MySQL Cluster node group and causes data nodes to join it.

This command is used after adding new data nodes online to a MySQL Cluster, and causes them to join a new node group and thus to begin participating fully in the cluster. The command takes as its sole parameter a comma-separated list of node IDs—these are the IDs of the nodes just added and started that are to join the new node group. The number of nodes must be the same as the number of nodes in each node group that is already part of the cluster (each MySQL Cluster node group must have the same number of nodes). In other words, if the MySQL Cluster has 2 node groups of 2 data nodes each, then the new node group must also have 2 data nodes.

The node group ID of the new node group created by this command is determined automatically, and always the next highest unused node group ID in the cluster; it is not possible to set it manually.

This command was introduced in MySQL Cluster NDB 6.4.0. For more information, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

- `DROP NODEGROUP` *`nodegroup_id`*

Drops the MySQL Cluster node group with the given *`nodegroup_id`*.

This command can be used to drop a node group from a MySQL Cluster. `DROP NODEGROUP` takes as its sole argument the node group ID of the node group to be dropped.

`DROP NODEGROUP` acts only to remove the data nodes in the effected node group from that node group. It does not stop data nodes, assign them to a different node group, or remove them from the cluster's configuration. A data node that does not belong to a node group is indicated in the output of the management client `SHOW` command with `no nodegroup` in place of the node group ID, like this (indicated using bold text):

```
id=3    @10.100.2.67  (5.1.77-ndb-7.1.37, no nodegroup)
```

Prior to MySQL Cluster NDB 7.0.4, the `SHOW` output was not updated correctly following `DROP NODEGROUP`. (Bug #43413)

`DROP NODEGROUP` works only when all data nodes in the node group to be dropped are completely empty of any table data and table definitions. Since there is currently no way using `ndb_mgm` or the `mysql` client to remove all data from a specific data node or node group, this means that the command succeeds only in the two following cases:

1. After issuing `CREATE NODEGROUP` in the `ndb_mgm` client, but before issuing any `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements in the `mysql` client.

2. After dropping all `NDBCLUSTER` tables using `DROP TABLE`.

   `TRUNCATE TABLE` does not work for this purpose because this removes only the table data; the data nodes continue to store an `NDBCLUSTER` table's definition until a `DROP TABLE` statement is issued that causes the table metadata to be dropped.

`DROP NODEGROUP` was introduced in MySQL Cluster NDB 6.4.0. For more information, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

Additional commands.   A number of other commands available in the `ndb_mgm` client are described elsewhere, as shown in the following list:

- `START BACKUP` is used to perform an online backup in the `ndb_mgm` client; the `ABORT BACKUP` command is used to cancel a backup already in progress. For more information, see Section 17.5.3, "Online Backup of MySQL Cluster".

- The `CLUSTERLOG` command is used to perform various logging functions. See Section 17.5.6, "Event Reports Generated in MySQL Cluster", for more information and examples.

- For testing and diagnostics work, the client also supports a `DUMP` command which can be used to execute internal commands on the cluster. It should never be used in a production setting unless directed to do so by MySQL Support. For more information, see MySQL Cluster Internals.

- In older versions of MySQL Cluster (prior to MySQL 5.1.11), it could sometimes be necessary to force the management server to check connections to the data nodes to ensure that dropped connections were not missed. This could be done using the `PURGE STALE SESSIONS` command. Newer versions now perform this check automatically, so that the command is no longer needed. See Section 17.5.1, "Summary of MySQL Cluster Start Phases", for more information.

17.5.3 Online Backup of MySQL Cluster

The next few sections describe how to prepare for and then to create a MySQL Cluster backup using the functionality for this purpose found in the `ndb_mgm` management client. To distinguish this type of backup from a backup made using `mysqldump`, we sometimes refer to it as a "native" MySQL Cluster backup. (For information about the creation of backups with `mysqldump`, see Section 4.5.4, "`mysqldump` — A Database Backup Program".) Restoration of MySQL Cluster backups is done using the `ndb_restore` utility provided with the MySQL Cluster distribution; for information about `ndb_restore` and its use in restoring MySQL Cluster backups, see Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup".

17.5.3.1 MySQL Cluster Backup Concepts

A backup is a snapshot of the database at a given time. The backup consists of three main parts:

- **Metadata.** The names and definitions of all database tables

- **Table records.** The data actually stored in the database tables at the time that the backup was made

- **Transaction log.** A sequential record telling how and when data was stored in the database

Each of these parts is saved on all nodes participating in the backup. During backup, each node saves these three parts into three files on disk:

- `BACKUP-backup_id.node_id.ctl`

  A control file containing control information and metadata. Each node saves the same table definitions (for all tables in the cluster) to its own version of this file.

- `BACKUP-backup_id-0.node_id.data`

  A data file containing the table records, which are saved on a per-fragment basis. That is, different nodes save different fragments during the backup. The file saved by each node starts with a header that states the tables to which the records belong. Following the list of records there is a footer containing a checksum for all records.

- `BACKUP-backup_id.node_id.log`

  A log file containing records of committed transactions. Only transactions on tables stored in the backup are stored in the log. Nodes involved in the backup save different records because different nodes host different database fragments.

In the listing above, `backup_id` stands for the backup identifier and `node_id` is the unique identifier for the node creating the file.

17.5.3.2 Using The MySQL Cluster Management Client to Create a Backup

Before starting a backup, make sure that the cluster is properly configured for performing one. (See Section 17.5.3.3, "Configuration for MySQL Cluster Backups".)

The `START BACKUP` command is used to create a backup:

```
START BACKUP [backup_id] [wait_option] [snapshot_option]

wait_option:
WAIT {STARTED | COMPLETED} | NOWAIT

snapshot_option:
SNAPSHOTSTART | SNAPSHOTEND
```

Successive backups are automatically identified sequentially, so the `backup_id`, an integer greater than or equal to 1, is optional; if it is omitted, the next available value is used. If an existing `backup_id` value is used, the backup fails with the error `Backup failed: file already exists`. If used, the `backup_id` must follow `START BACKUP` immediately, before any other options are used.

Prior to MySQL Cluster NDB 6.2.17, 6.3.23, and 6.4.3, backup IDs greater than 2147483648 (2^{31}) were not supported correctly. (Bug #43042) Beginning with these versions, the maximum possible backup ID is 4294967296 (2^{32}).

> **Note**
>
> Prior to MySQL Cluster NDB 7.0.5, when starting a backup using `ndb_mgm -e "START BACKUP"`, the `backup_id` was required. (Bug #31754)

The `wait_option` can be used to determine when control is returned to the management client after a `START BACKUP` command is issued, as shown in the following list:

* If `NOWAIT` is specified, the management client displays a prompt immediately, as seen here:

```
ndb_mgm> START BACKUP NOWAIT
ndb_mgm>
```

In this case, the management client can be used even while it prints progress information from the backup process.

* With `WAIT STARTED` the management client waits until the backup has started before returning control to the user, as shown here:

```
ndb_mgm> START BACKUP WAIT STARTED
Waiting for started, this may take several minutes
Node 2: Backup 3 started from node 1
ndb_mgm>
```

* `WAIT COMPLETED` causes the management client to wait until the backup process is complete before returning control to the user.

`WAIT COMPLETED` is the default.

Beginning with MySQL Cluster NDB 6.4.0, a `snapshot_option` can be used to determine whether the backup matches the state of the cluster when `START BACKUP` was issued, or when it was completed. `SNAPSHOTSTART` causes the backup to match the state of the cluster when the backup began; `SNAPSHOTEND` causes the backup to reflect the state of the cluster when the backup was finished. `SNAPSHOTEND` is the default, and matches the behavior found in previous MySQL Cluster releases.

> **Note**
>
> If you use the `SNAPSHOTSTART` option with `START BACKUP`, and the `CompressedBackup` parameter is enabled, only the data and control files are compressed—the log file is not compressed.

If both a *wait_option* and a *snapshot_option* are used, they may be specified in either order. For example, all of the following commands are valid, assuming that there is no existing backup having 4 as its ID:

```
START BACKUP WAIT STARTED SNAPSHOTSTART
START BACKUP SNAPSHOTSTART WAIT STARTED
START BACKUP 4 WAIT COMPLETED SNAPSHOTSTART
START BACKUP SNAPSHOTEND WAIT COMPLETED
START BACKUP 4 NOWAIT SNAPSHOTSTART
```

The procedure for creating a backup consists of the following steps:

1. Start the management client (ndb_mgm), if it not running already.

2. Execute the **START BACKUP** command. This produces several lines of output indicating the progress of the backup, as shown here:

```
ndb_mgm> START BACKUP
Waiting for completed, this may take several minutes
Node 2: Backup 1 started from node 1
Node 2: Backup 1 started from node 1 completed
 StartGCP: 177 StopGCP: 180
 #Records: 7362 #LogRecords: 0
 Data: 453648 bytes Log: 0 bytes
ndb_mgm>
```

3. When the backup has started the management client displays this message:

```
Backup backup_id started from node node_id
```

backup_id is the unique identifier for this particular backup. This identifier is saved in the cluster log, if it has not been configured otherwise. *node_id* is the identifier of the management server that is coordinating the backup with the data nodes. At this point in the backup process the cluster has received and processed the backup request. It does not mean that the backup has finished. An example of this statement is shown here:

```
Node 2: Backup 1 started from node 1
```

4. The management client indicates with a message like this one that the backup has started:

```
Backup backup_id started from node node_id completed
```

As is the case for the notification that the backup has started, *backup_id* is the unique identifier for this particular backup, and *node_id* is the node ID of the management server that is coordinating the backup with the data nodes. This output is accompanied by additional information including relevant global checkpoints, the number of records backed up, and the size of the data, as shown here:

```
Node 2: Backup 1 started from node 1 completed
 StartGCP: 177 StopGCP: 180
 #Records: 7362 #LogRecords: 0
 Data: 453648 bytes Log: 0 bytes
```

It is also possible to perform a backup from the system shell by invoking ndb_mgm with the -e or --execute option, as shown in this example:

```
shell> ndb_mgm -e "START BACKUP 6 WAIT COMPLETED SNAPSHOTSTART"
```

When using `START BACKUP` in this way, you must specify the backup ID.

Cluster backups are created by default in the `BACKUP` subdirectory of the `DataDir` on each data node. This can be overridden for one or more data nodes individually, or for all cluster data nodes in the `config.ini` file using the `BackupDataDir` configuration parameter. The backup files created for a backup with a given *backup_id* are stored in a subdirectory named `BACKUP-`*backup_id* in the backup directory.

Cancelling backups.   To cancel or abort a backup that is already in progress, perform the following steps:

1. Start the management client.

2. Execute this command:

   ```
   ndb_mgm> ABORT BACKUP backup_id
   ```

   The number *backup_id* is the identifier of the backup that was included in the response of the management client when the backup was started (in the message `Backup `*backup_id*` started from node `*management_node_id*).

3. The management client acknowledges the abort request with `Abort of backup `*backup_id*` ordered`.

   > **Note**
   >
   > At this point, the management client has not yet received a response from the cluster data nodes to this request, and the backup has not yet actually been aborted.

4. After the backup has been aborted, the management client will report this fact in a manner similar to what is shown here:

   ```
   Node 1: Backup 3 started from 5 has been aborted.
     Error: 1321 - Backup aborted by user request: Permanent error: User defined error
   Node 3: Backup 3 started from 5 has been aborted.
     Error: 1323 - 1323: Permanent error: Internal error
   Node 2: Backup 3 started from 5 has been aborted.
     Error: 1323 - 1323: Permanent error: Internal error
   Node 4: Backup 3 started from 5 has been aborted.
     Error: 1323 - 1323: Permanent error: Internal error
   ```

   In this example, we have shown sample output for a cluster with 4 data nodes, where the sequence number of the backup to be aborted is 3, and the management node to which the cluster management client is connected has the node ID 5. The first node to complete its part in aborting the backup reports that the reason for the abort was due to a request by the user. (The remaining nodes report that the backup was aborted due to an unspecified internal error.)

   > **Note**
   >
   > There is no guarantee that the cluster nodes respond to an `ABORT BACKUP` command in any particular order.

   The `Backup `*backup_id*` started from node `*management_node_id*` has been aborted` messages mean that the backup has been terminated and that all files relating to this backup have been removed from the cluster file system.

It is also possible to abort a backup in progress from a system shell using this command:

```
shell> ndb_mgm -e "ABORT BACKUP backup_id"
```

> **Note**
>
> If there is no backup having the ID `backup_id` running when an `ABORT BACKUP` is issued, the management client makes no response, nor is it indicated in the cluster log that an invalid abort command was sent.

17.5.3.3 Configuration for MySQL Cluster Backups

Five configuration parameters are essential for backup:

- `BackupDataBufferSize`

  The amount of memory used to buffer data before it is written to disk.

- `BackupLogBufferSize`

  The amount of memory used to buffer log records before these are written to disk.

- `BackupMemory`

  The total memory allocated in a data node for backups. This should be the sum of the memory allocated for the backup data buffer and the backup log buffer.

- `BackupWriteSize`

  The default size of blocks written to disk. This applies for both the backup data buffer and the backup log buffer.

- `BackupMaxWriteSize`

  The maximum size of blocks written to disk. This applies for both the backup data buffer and the backup log buffer.

More detailed information about these parameters can be found in Backup Parameters.

17.5.3.4 MySQL Cluster Backup Troubleshooting

If an error code is returned when issuing a backup request, the most likely cause is insufficient memory or disk space. You should check that there is enough memory allocated for the backup.

> **Important**
>
> If you have set `BackupDataBufferSize` and `BackupLogBufferSize` and their sum is greater than 4MB, then you must also set `BackupMemory` as well.

You should also make sure that there is sufficient space on the hard drive partition of the backup target.

`NDB` does not support repeatable reads, which can cause problems with the restoration process. Although the backup process is "hot", restoring a MySQL Cluster from backup is not a 100% "hot" process. This is due to the fact that, for the duration of the restore process, running transactions get nonrepeatable reads from the restored data. This means that the state of the data is inconsistent while the restore is in progress.

17.5.4 MySQL Server Usage for MySQL Cluster

`mysqld` is the traditional MySQL server process. To be used with MySQL Cluster, `mysqld` needs to be built with support for the `NDBCLUSTER` storage engine, as it is in the precompiled binaries available from

http://dev.mysql.com/downloads/. If you build MySQL from source, you must invoke `configure` with one of the options to enable `NDBCLUSTER` storage engine support:

- `--with-plugins=ndbcluster`

- `--with-plugins=max`

- `--with-plugins=max-no-innodb`

(`--with-ndbcluster` also works to enable `NDBCLUSTER` support, but is deprecated and so produces a `configure` warning as of MySQL 5.1.9.)

For information about other MySQL server options and variables relevant to MySQL Cluster in addition to those discussed in this section, see Section 17.3.3.8, "MySQL Server Options and Variables for MySQL Cluster".

If the `mysqld` binary has been built with Cluster support, the `NDBCLUSTER` storage engine is still disabled by default. You can use either of two possible options to enable this engine:

- Use `--ndbcluster` as a startup option on the command line when starting `mysqld`.

- Insert a line containing `ndbcluster` in the `[mysqld]` section of your `my.cnf` file.

An easy way to verify that your server is running with the `NDBCLUSTER` storage engine enabled is to issue the `SHOW ENGINES` statement in the MySQL Monitor (`mysql`). You should see the value `YES` as the `Support` value in the row for `NDBCLUSTER`. If you see `NO` in this row or if there is no such row displayed in the output, you are not running an `NDB`-enabled version of MySQL. If you see `DISABLED` in this row, you need to enable it in either one of the two ways just described.

To read cluster configuration data, the MySQL server requires at a minimum three pieces of information:

- The MySQL server's own cluster node ID

- The host name or IP address for the management server (MGM node)

- The number of the TCP/IP port on which it can connect to the management server

Node IDs can be allocated dynamically, so it is not strictly necessary to specify them explicitly.

The `mysqld` parameter `ndb-connectstring` is used to specify the connection string either on the command line when starting `mysqld` or in `my.cnf`. The connection string contains the host name or IP address where the management server can be found, as well as the TCP/IP port it uses.

In the following example, `ndb_mgmd.mysql.com` is the host where the management server resides, and the management server listens for cluster messages on port 1186:

```
shell> mysqld --ndbcluster --ndb-connectstring=ndb_mgmd.mysql.com:1186
```

See Section 17.3.3.3, "MySQL Cluster Connection Strings", for more information on connection strings.

Given this information, the MySQL server will be a full participant in the cluster. (We often refer to a `mysqld` process running in this manner as an SQL node.) It will be fully aware of all cluster data nodes as well as their status, and will establish connections to all data nodes. In this case, it is able to use any data node as a transaction coordinator and to read and update node data.

You can see in the `mysql` client whether a MySQL server is connected to the cluster using `SHOW PROCESSLIST`. If the MySQL server is connected to the cluster, and you have the `PROCESS` privilege, then the first row of the output is as shown here:

```
mysql> SHOW PROCESSLIST \G
*************************** 1. row ***************************
     Id: 1
   User: system user
   Host:
     db:
Command: Daemon
   Time: 1
  State: Waiting for event from ndbcluster
   Info: NULL
```

> **Important**
>
> To participate in a MySQL Cluster, the `mysqld` process must be started with *both* the options `--ndbcluster` and `--ndb-connectstring` (or their equivalents in `my.cnf`). If `mysqld` is started with only the `--ndbcluster` option, or if it is unable to contact the cluster, it is not possible to work with `NDB` tables, *nor is it possible to create any new tables regardless of storage engine*. The latter restriction is a safety measure intended to prevent the creation of tables having the same names as `NDB` tables while the SQL node is not connected to the cluster. If you wish to create tables using a different storage engine while the `mysqld` process is not participating in a MySQL Cluster, you must restart the server *without* the `--ndbcluster` option.

17.5.5 Performing a Rolling Restart of a MySQL Cluster

This section discusses how to perform a *rolling restart* of a MySQL Cluster installation, so called because it involves stopping and starting (or restarting) each node in turn, so that the cluster itself remains operational. This is often done as part of a *rolling upgrade* or *rolling downgrade*, where high availability of the cluster is mandatory and no downtime of the cluster as a whole is permissible. Where we refer to upgrades, the information provided here also generally applies to downgrades as well.

There are a number of reasons why a rolling restart might be desirable. These are described in the next few paragraphs.

Configuration change.
To make a change in the cluster's configuration, such as adding an SQL node to the cluster, or setting a configuration parameter to a new value.

MySQL Cluster software upgrade or downgrade. To upgrade the cluster to a newer version of the MySQL Cluster software (or to downgrade it to an older version). This is usually referred to as a "rolling upgrade" (or "rolling downgrade", when reverting to an older version of MySQL Cluster).

Change on node host. To make changes in the hardware or operating system on which one or more MySQL Cluster node processes are running.

System reset (cluster reset).
To reset the cluster because it has reached an undesirable state. In such cases it is often desirable to reload the data and metadata of one or more data nodes. This can be done in any of three ways:

- Start each data node process (`ndbd`, or possibly `ndbmtd` in MySQL Cluster NDB 7.0 and later) with the `--initial` option, which forces the data node to clear its file system and to reload all MySQL Cluster data and metadata from the other data nodes.

- Create a backup using the `ndb_mgm` client `BACKUP` command prior to performing the restart. Following the upgrade, restore the node or nodes using `ndb_restore`.

  See Section 17.5.3, "Online Backup of MySQL Cluster", and Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup", for more information.

- Use `mysqldump` to create a backup prior to the upgrade; afterward, restore the dump using `LOAD DATA INFILE`.

Resource Recovery.
To free memory previously allocated to a table by successive `INSERT` and `DELETE` operations, for re-use by other MySQL Cluster tables.

The process for performing a rolling restart may be generalized as follows:

1. Stop all cluster management nodes (`ndb_mgmd` processes), reconfigure them, then restart them.

   (If there are multiple management servers and you are using MySQL Cluster NDB 7.0.8 or later, see Rolling restarts with multiple management servers (MySQL Cluster NDB 7.0.8 and later).)

2. Stop, reconfigure, then restart each cluster data node (`ndbd` process) in turn.

3. Stop, reconfigure, then restart each cluster SQL node (`mysqld` process) in turn.

The specifics for implementing a given rolling upgrade depend upon the changes being made. A more detailed view of the process is presented here:

Figure 17.8 MySQL Cluster Rolling Restarts By Type

In the previous diagram, the **Stop** and **Start** steps indicate that the process must be stopped completely using a shell command (such as `kill` on most Unix systems) or the management client `STOP` command, then started again from a system shell by invoking the `ndbd` or `ndb_mgmd` executable as appropriate. On Windows (MySQL Cluster NDB 7.1.3 and later), you can also use the system `NET START` and `NET STOP` commands or the Windows Service Manager to start and stop nodes which have been installed as Windows services (see Section 17.2.2.4, "Installing MySQL Cluster Processes as Windows Services").

Restart indicates that the process may be restarted using the `ndb_mgm` management client `RESTART` command (see Section 17.5.2, "Commands in the MySQL Cluster Management Client").

Prior to MySQL Cluster NDB 6.3.29 and MySQL Cluster NDB 7.0.10. When performing an upgrade or downgrade of the cluster software, you must upgrade or downgrade the management nodes first, then the data nodes, and finally the SQL nodes. Doing so in any other order may leave the cluster in an unusable state.

MySQL Cluster NDB 6.3.29 and later; MySQL Cluster NDB 7.0.10 and later. MySQL Cluster supports a more flexible order for upgrading the cluster nodes. When upgrading a cluster running MySQL Cluster NDB 6.3.29 or later, or a cluster that is running MySQL Cluster NDB 7.0.10 or later, you may upgrade API nodes (including SQL nodes) before upgrading the management nodes, data nodes, or both. In other words, you are permitted to upgrade the API and SQL nodes in any order. This is subject to the following provisions:

- This functionality is intended for use as part of an online upgrade only. A mix of node binaries from different MySQL Cluster releases is neither intended nor supported for constant, long-term use in a production setting.

- All management nodes must be upgraded before any data nodes are upgraded. This remains true regardless of the order in which you upgrade the cluster's API and SQL nodes.

- For MySQL Cluster NDB 6.3, the ability to upgrade API nodes in any order relative to upgrading management nodes and data nodes is supported only for MySQL Cluster NDB 6.3.29 and later; for MySQL Cluster NDB 7.0, it supported only for MySQL Cluster NDB 7.0.10 and later. This means that, if you are upgrading from a MySQL Cluster NDB 6.3 release to a MySQL Cluster NDB 7.0 release, the "old" `NDB` engine version must be 6.3.29 or later, and the "new" `NDB` engine version must be 7.0.10 or later.

- When upgrading the cluster from a MySQL Cluster NDB 6.3 release to a MySQL Cluster NDB 7.0 release: Once you have started upgrading the API nodes, you should not perform DDL operations until all management nodes and data nodes have been upgraded. DML operations should be unaffected, and can continue while the upgrade is in progress.

  However, it is possible to perform DDL from an "old" (NDB 6.3 version) API node as long as the master data node is also running the "old" version of MySQL Cluster. You should keep in mind that a data node restart could result in the master node running a "new" (NDB 7.0 version) binary while one or more data nodes are still using the "old" (NDB 6.3) version; in this situation, no DDL can be performed from *any* API node, because the master data node is no longer using an NDB 6.3 binary, but the cluster still contains nodes which are not yet using NDB 7.0. For this reason, we recommend that you avoid performing DDL at any time while the upgrade is in progress.

- Features specific to the "new" version must not be used until all management nodes and data nodes have been upgraded.

  This also applies to any MySQL Server version change that may apply, in addition to the NDB engine version change, so do not forget to take this into account when planning the upgrade. (This is true for online upgrades of MySQL Cluster in general.)

See also Bug #48528 and Bug #49163.

Rolling restarts with multiple management servers (MySQL Cluster NDB 7.0.8 and later). A change in MySQL Cluster NDB 7.0.8 in the way in which management nodes obtain configuration data makes it necessary to alter the procedure previously outlined, when performing a rolling restart of a MySQL Cluster with multiple management nodes. (Previously, a management node checked only its own configuration cache, but in MySQL Cluster NDB 7.0.8 and later, `ndb_mgmd` also checks to see if any other

management node is running, and, if so, tries to use that node's configuration data.) To keep this from occurring, and to force `ndb_mgmd` to reread its configuration file, perform the following steps:

1. Stop all MySQL Cluster `ndb_mgmd` processes.

2. Update all `config.ini` files.

3. Start a single `ndb_mgmd` with `--reload`, `--initial`, or both options as desired.

4. If you started the first `ndb_mgmd` with the `--initial` option, you must also start any remaining `ndb_mgmd` processes using `--initial`.

   Regardless of any other options used when starting the first `ndb_mgmd`, you should not start any remaining `ndb_mgmd` processes after the first one using `--reload`.

5. Complete the rolling restarts of the data nodes and API nodes as normal.

See also Bug #45495 and Bug #46488.

MySQL Cluster NDB 7.0.24 and later; MySQL Cluster NDB 7.1.13 and later. When performing a rolling restart to update the cluster's configuration, you can use the `config_generation` column of the `ndbinfo.nodes` table to keep track of which data nodes have been successfully restarted with the new configuration. See Section 17.5.10.13, "The ndbinfo nodes Table".

17.5.6 Event Reports Generated in MySQL Cluster

In this section, we discuss the types of event logs provided by MySQL Cluster, and the types of events that are logged.

MySQL Cluster provides two types of event log:

- The *cluster log*, which includes events generated by all cluster nodes. The cluster log is the log recommended for most uses because it provides logging information for an entire cluster in a single location.

  By default, the cluster log is saved to a file named `ndb_node_id_cluster.log`, (where `node_id` is the node ID of the management server) in the management server's `DataDir`.

  Cluster logging information can also be sent to `stdout` or a `syslog` facility in addition to or instead of being saved to a file, as determined by the values set for the `DataDir` and `LogDestination` configuration parameters. See Section 17.3.3.5, "Defining a MySQL Cluster Management Server", for more information about these parameters.

- *Node logs* are local to each node.

  Output generated by node event logging is written to the file `ndb_node_id_out.log` (where `node_id` is the node's node ID) in the node's `DataDir`. Node event logs are generated for both management nodes and data nodes.

  Node logs are intended to be used only during application development, or for debugging application code.

Both types of event logs can be set to log different subsets of events.

Each reportable event can be distinguished according to three different criteria:

- *Category*: This can be any one of the following values: `STARTUP`, `SHUTDOWN`, `STATISTICS`, `CHECKPOINT`, `NODERESTART`, `CONNECTION`, `ERROR`, or `INFO`.

- *Priority*: This is represented by one of the numbers from 0 to 15 inclusive, where 0 indicates "most important" and 15 "least important."

- *Severity Level*: This can be any one of the following values: `ALERT`, `CRITICAL`, `ERROR`, `WARNING`, `INFO`, or `DEBUG`.

Both the cluster log and the node log can be filtered on these properties.

The format used in the cluster log is as shown here:

```
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 1: Data usage is 2%(60 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 1: Index usage is 1%(24 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 1: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 2: Data usage is 2%(76 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 2: Index usage is 1%(24 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 2: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 3: Data usage is 2%(58 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 3: Index usage is 1%(25 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 3: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 4: Data usage is 2%(74 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 4: Index usage is 1%(25 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 4: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 4: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 1: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 1: Node 9: API 5.1.77-ndb-7.1.37
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 2: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 2: Node 9: API 5.1.77-ndb-7.1.37
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 3: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 3: Node 9: API 5.1.77-ndb-7.1.37
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 4: Node 9: API 5.1.77-ndb-7.1.37
2007-01-26 19:59:22 [MgmSrvr] ALERT    -- Node 2: Node 7 Disconnected
2007-01-26 19:59:22 [MgmSrvr] ALERT    -- Node 2: Node 7 Disconnected
```

Each line in the cluster log contains the following information:

- A timestamp in `YYYY-MM-DD HH:MM:SS` format.

- The type of node which is performing the logging. In the cluster log, this is always `[MgmSrvr]`.

- The severity of the event.

- The ID of the node reporting the event.

- A description of the event. The most common types of events to appear in the log are connections and disconnections between different nodes in the cluster, and when checkpoints occur. In some cases, the description may contain status information.

17.5.6.1 MySQL Cluster Logging Management Commands

`ndb_mgm` supports a number of management commands related to the cluster log. In the listing that follows, `node_id` denotes either a database node ID or the keyword `ALL`, which indicates that the command should be applied to all of the cluster's data nodes.

- `CLUSTERLOG ON`

  Turns the cluster log on.

- `CLUSTERLOG OFF`

  Turns the cluster log off.

- `CLUSTERLOG INFO`

Provides information about cluster log settings.

- `node_id` `CLUSTERLOG` `category=threshold`

  Logs `category` events with priority less than or equal to `threshold` in the cluster log.

- `CLUSTERLOG FILTER` `severity_level`

  Toggles cluster logging of events of the specified `severity_level`.

The following table describes the default setting (for all data nodes) of the cluster log category threshold. If an event has a priority with a value lower than or equal to the priority threshold, it is reported in the cluster log.

Note that events are reported per data node, and that the threshold can be set to different values on different nodes.

Category	Default threshold (All data nodes)
`STARTUP`	**7**
`SHUTDOWN`	**7**
`STATISTICS`	**7**
`CHECKPOINT`	**7**
`NODERESTART`	**7**
`CONNECTION`	**7**
`ERROR`	**15**
`INFO`	**7**

The `STATISTICS` category can provide a great deal of useful data. See Section 17.5.6.3, "Using CLUSTERLOG STATISTICS in the MySQL Cluster Management Client", for more information.

Thresholds are used to filter events within each category. For example, a `STARTUP` event with a priority of 3 is not logged unless the threshold for `STARTUP` is set to 3 or higher. Only events with priority 3 or lower are sent if the threshold is 3.

The following table shows the event severity levels.

Note

These correspond to Unix `syslog` levels, except for `LOG_EMERG` and `LOG_NOTICE`, which are not used or mapped.

Severity Level Value	Severity	Description
1	`ALERT`	A condition that should be corrected immediately, such as a corrupted system database
2	`CRITICAL`	Critical conditions, such as device errors or insufficient resources
3	`ERROR`	Conditions that should be corrected, such as configuration errors
4	`WARNING`	Conditions that are not errors, but that might require special handling

Severity Level Value	Severity	Description
5	`INFO`	Informational messages
6	`DEBUG`	Debugging messages used for `NDBCLUSTER` development

Event severity levels can be turned on or off (using `CLUSTERLOG FILTER`—see above). If a severity level is turned on, then all events with a priority less than or equal to the category thresholds are logged. If the severity level is turned off then no events belonging to that severity level are logged.

> ⚠️ **Important**
>
> Cluster log levels are set on a per `ndb_mgmd`, per subscriber basis. This means that, in a MySQL Cluster with multiple management servers, using a `CLUSTERLOG` command in an instance of `ndb_mgm` connected to one management server affects only logs generated by that management server but not by any of the others. This also means that, should one of the management servers be restarted, only logs generated by that management server are affected by the resetting of log levels caused by the restart.

17.5.6.2 MySQL Cluster Log Events

An event report reported in the event logs has the following format:

```
datetime [string] severity -- message
```

For example:

```
09:19:30 2005-07-24 [NDB] INFO -- Node 4 Start phase 4 completed
```

This section discusses all reportable events, ordered by category and severity level within each category.

In the event descriptions, GCP and LCP mean "Global Checkpoint" and "Local Checkpoint", respectively.

CONNECTION Events

These events are associated with connections between Cluster nodes.

Event	Priority	Severity Level	Description
`Connected`	8	`INFO`	Data nodes connected
`Disconnected`	8	`ALERT`	Data nodes disconnected
`CommunicationClosed`	8	`INFO`	SQL node or data node connection closed
`CommunicationOpened`	8	`INFO`	SQL node or data node connection open
`ConnectedApiVersion`	8	`INFO`	Connection using API version

CHECKPOINT Events

The logging messages shown here are associated with checkpoints.

Event	Priority	Severity Level	Description
`GlobalCheckpointStarted`	9	`INFO`	Start of GCP: REDO log is written to disk
`GlobalCheckpointCompleted`	10	`INFO`	GCP finished

Event	Priority	Severity Level	Description
LocalCheckpointStarted	7	INFO	Start of LCP: data written to disk
LocalCheckpointCompleted	7	INFO	LCP completed normally
LCPStoppedInCalcKeepGci	0	ALERT	LCP stopped
LCPFragmentCompleted	11	INFO	LCP on a fragment has been completed
UndoLogBlocked	7	INFO	UNDO logging blocked; buffer near overflow
RedoStatus	7	INFO	Redo status

STARTUP Events

The following events are generated in response to the startup of a node or of the cluster and of its success or failure. They also provide information relating to the progress of the startup process, including information concerning logging activities.

Event	Priority	Severity Level	Description
NDBStartStarted	1	INFO	Data node start phases initiated (all nodes starting)
NDBStartCompleted	1	INFO	Start phases completed, all data nodes
STTORRYRecieved	15	INFO	Blocks received after completion of restart
StartPhaseCompleted	4	INFO	Data node start phase X completed
CM_REGCONF	3	INFO	Node has been successfully included into the cluster; shows the node, managing node, and dynamic ID
CM_REGREF	8	INFO	Node has been refused for inclusion in the cluster; cannot be included in cluster due to misconfiguration, inability to establish communication, or other problem
FIND_NEIGHBOURS	8	INFO	Shows neighboring data nodes
NDBStopStarted	1	INFO	Data node shutdown initiated
NDBStopCompleted	1	INFO	Data node shutdown complete
NDBStopForced	1	ALERT	Forced shutdown of data node
NDBStopAborted	1	INFO	Unable to shut down data node normally
StartREDOLog	4	INFO	New redo log started; GCI keep X, newest restorable GCI Y
StartLog	10	INFO	New log started; log part X, start MB Y, stop MB Z
UNDORecordsExecuted	15	INFO	Undo records executed
StartReport	4	INFO	Report started
LogFileInitStatus	7	INFO	Log file initialization status
LogFileInitCompStatus	7	INFO	Log file completion status
StartReadLCP	10	INFO	Start read for local checkpoint
ReadLCPComplete	10	INFO	Read for local checkpoint completed

Event	Priority	Severity Level	Description
RunRedo	8	INFO	Running the redo log
RebuildIndex	10	INFO	Rebuilding indexes

NODERESTART Events

The following events are generated when restarting a node and relate to the success or failure of the node restart process.

Event	Priority	Severity Level	Description
NR_CopyDict	7	INFO	Completed copying of dictionary information
NR_CopyDistr	7	INFO	Completed copying distribution information
NR_CopyFragsStarted	7	INFO	Starting to copy fragments
NR_CopyFragDone	10	INFO	Completed copying a fragment
NR_CopyFragsCompleted	7	INFO	Completed copying all fragments
NodeFailCompleted	8	ALERT	Node failure phase completed
NODE_FAILREP	8	ALERT	Reports that a node has failed
ArbitState	6	INFO	Report whether an arbitrator is found or not; there are seven different possible outcomes when seeking an arbitrator, listed here: • Management server restarts arbitration thread [state=X] • Prepare arbitrator node X [ticket=Y] • Receive arbitrator node X [ticket=Y] • Started arbitrator node X [ticket=Y] • Lost arbitrator node X - process failure [state=Y] • Lost arbitrator node X - process exit [state=Y] • Lost arbitrator node X <error msg> [state=Y]
ArbitResult	2	ALERT	Report arbitrator results; there are eight different possible results for arbitration attempts, listed here: • Arbitration check failed: less than 1/2 nodes left • Arbitration check succeeded: node group majority • Arbitration check failed: missing node group • Network partitioning: arbitration required

Event	Priority	Severity Level	Description
			• Arbitration succeeded: affirmative response from node X • Arbitration failed: negative response from node X • Network partitioning: no arbitrator available • Network partitioning: no arbitrator configured
GCP_TakeoverStarted	7	INFO	GCP takeover started
GCP_TakeoverCompleted	7	INFO	GCP takeover complete
LCP_TakeoverStarted	7	INFO	LCP takeover started
LCP_TakeoverCompleted	7	INFO	LCP takeover complete (state = X)
ConnectCheckStarted	6	INFO	Connection check started
ConnectCheckCompleted	6	INFO	Connection check completed
NodeFailRejected	6	ALERT	Node failure phase failed

STATISTICS Events

The following events are of a statistical nature. They provide information such as numbers of transactions and other operations, amount of data sent or received by individual nodes, and memory usage.

Event	Priority	Severity Level	Description
TransReportCounters	8	INFO	Report transaction statistics, including numbers of transactions, commits, reads, simple reads, writes, concurrent operations, attribute information, and aborts
OperationReportCounters	8	INFO	Number of operations
TableCreated	7	INFO	Report number of tables created
JobStatistic	9	INFO	Mean internal job scheduling statistics
ThreadConfigLoop	9	INFO	Number of thread configuration loops
SendBytesStatistic	9	INFO	Mean number of bytes sent to node X
ReceiveBytesStatistic	9	INFO	Mean number of bytes received from node X
MemoryUsage	5	INFO	Data and index memory usage (80%, 90%, and 100%)
MTSignalStatistics	9	INFO	Multi-threaded signals

SCHEMA Events

These events relate to MySQL Cluster schema operations.

Event	Priority	Severity	Description
CreateSchemaObject	8	INFO	Schema objected created
AlterSchemaObject	8	INFO	Schema object updated

Event	Priority	Severity	Description
`DropSchemaObject`	8	`INFO`	Schema object dropped

ERROR Events

These events relate to Cluster errors and warnings. The presence of one or more of these generally indicates that a major malfunction or failure has occurred.

Event	Priority	Severity	Description
`TransporterError`	2	`ERROR`	Transporter error
`TransporterWarning`	8	`WARNING`	Transporter warning
`MissedHeartbeat`	8	`WARNING`	Node X missed heartbeat number Y
`DeadDueToHeartbeat`	8	`ALERT`	Node X declared "dead" due to missed heartbeat
`WarningEvent`	2	`WARNING`	General warning event
`SubscriptionStatus`	4	`WARNING`	Change in subscription status

INFO Events

These events provide general information about the state of the cluster and activities associated with Cluster maintenance, such as logging and heartbeat transmission.

Event	Priority	Severity	Description
`SentHeartbeat`	12	`INFO`	Sent heartbeat
`CreateLogBytes`	11	`INFO`	Create log: Log part, log file, size in MB
`InfoEvent`	2	`INFO`	General informational event
`EventBufferStatus`	7	`INFO`	Event buffer status

> **Note**
>
> `SentHeartbeat` events are available only if MySQL Cluster was compiled with `VM_TRACE` enabled.

SINGLEUSER Events

These events are associated with entering and exiting single user mode.

Event	Priority	Severity	Description
`SingleUser`	7	`INFO`	Entering or exiting single user mode

BACKUP Events

These events provide information about backups being created or restored.

Event	Priority	Severity	Description
`BackupStarted`	7	`INFO`	Backup started
`BackupStatus`	7	`INFO`	Backup status
`BackupCompleted`	7	`INFO`	Backup completed
`BackupFailedToStart`	7	`ALERT`	Backup failed to start
`BackupAborted`	7	`ALERT`	Backup aborted by user

Event	Priority	Severity	Description
`RestoreStarted`	7	`INFO`	Started restoring from backup
`RestoreMetaData`	7	`INFO`	Restoring metadata
`RestoreData`	7	`INFO`	Restoring data
`RestoreLog`	7	`INFO`	Restoring log files
`RestoreCompleted`	7	`INFO`	Completed restoring from backup
`SavedEvent`	7	`INFO`	Event saved

17.5.6.3 Using CLUSTERLOG STATISTICS in the MySQL Cluster Management Client

The `NDB` management client's `CLUSTERLOG STATISTICS` command can provide a number of useful statistics in its output. Counters providing information about the state of the cluster are updated at 5-second reporting intervals by the transaction coordinator (TC) and the local query handler (LQH), and written to the cluster log.

Transaction coordinator statistics.   Each transaction has one transaction coordinator, which is chosen by one of the following methods:

- In a round-robin fashion

- By communication proximity

- (*Beginning with MySQL Cluster NDB 6.3.4*:) By supplying a data placement hint when the transaction is started

> **Note**
>
> You can determine which TC selection method is used for transactions started from a given SQL node using the `ndb_optimized_node_selection` system variable.

All operations within the same transaction use the same transaction coordinator, which reports the following statistics:

- **Trans count.**   This is the number transactions started in the last interval using this TC as the transaction coordinator. Any of these transactions may have committed, have been aborted, or remain uncommitted at the end of the reporting interval.

> **Note**
>
> Transactions do not migrate between TCs.

- **Commit count.**   This is the number of transactions using this TC as the transaction coordinator that were committed in the last reporting interval. Because some transactions committed in this reporting interval may have started in a previous reporting interval, it is possible for `Commit count` to be greater than `Trans count`.

- **Read count.**   This is the number of primary key read operations using this TC as the transaction coordinator that were started in the last reporting interval, including simple reads. This count also includes reads performed as part of unique index operations. A unique index read operation generates 2 primary key read operations—1 for the hidden unique index table, and 1 for the table on which the read takes place.

- **Simple read count.**   This is the number of simple read operations using this TC as the transaction coordinator that were started in the last reporting interval. This is a subset of `Read count`. Prior to

MySQL CLuster NDB 7.0, the value of `Simple read count` was incremented at a different point in time from `Read count`, which could cause it to lag behind `Read count` slightly, so that it was possible that `Simple read count` was not equal to `Read count` for some reporting interval, even if all reads made during that time were in fact simple reads. In MySQL Cluster NDB 7.0 and later, `NDB` uses a single signal (`TCKEYREQ`) containing all information necessary to forward the request, so these counts should no longer appear to be misaligned in such cases.

- **Write count.**   This is the number of primary key write operations using this TC as the transaction coordinator that were started in the last reporting interval. This includes all inserts, updates, writes and deletes, as well as writes performed as part of unique index operations.

> **Note**
>
> A unique index update operation can generate multiple PK read and write operations on the index table and on the base table.

- **AttrInfoCount.**   This is the number of 32-bit data words received in the last reporting interval for primary key operations using this TC as the transaction coordinator. For reads, this is proportional to the number of columns requested. For inserts and updates, this is proportional to the number of columns written, and the size of their data. For delete operations, this is usually zero.

  Unique index operations generate multiple PK operations and so increase this count. However, data words sent to describe the PK operation itself, and the key information sent, are *not* counted here. Attribute information sent to describe columns to read for scans, or to describe ScanFilters, is also not counted in `AttrInfoCount`.

- **Concurrent Operations.**   This is the number of primary key or scan operations using this TC as the transaction coordinator that were started during the last reporting interval but that were not completed. Operations increment this counter when they are started and decrement it when they are completed; this occurs after the transaction commits. Dirty reads and writes—as well as failed operations—decrement this counter.

  The maximum value that `Concurrent Operations` can have is the maximum number of operations that a TC block can support; currently, this is `(2 * MaxNoOfConcurrentOperations) + 16 + MaxNoOfConcurrentTransactions`. (For more information about these configuration parameters, see the *Transaction Parameters* section of Section 17.3.3.6, "Defining MySQL Cluster Data Nodes".)

- **Abort count.**   This is the number of transactions using this TC as the transaction coordinator that were aborted during the last reporting interval. Because some transactions that were aborted in the last reporting interval may have started in a previous reporting interval, `Abort count` can sometimes be greater than `Trans count`.

- **Scans.**   This is the number of table scans using this TC as the transaction coordinator that were started during the last reporting interval. This does not include range scans (that is, ordered index scans).

- **Range scans.**   This is the number of ordered index scans using this TC as the transaction coordinator that were started in the last reporting interval.

Local query handler statistics (Operations).   There is 1 cluster event per local query handler block (that is, 1 per data node process). Operations are recorded in the LQH where the data they are operating on resides.

> **Note**
>
> A single transaction may operate on data stored in multiple LQH blocks.

The `Operations` statistic provides the number of local operations performed by this LQH block in the last reporting interval, and includes all types of read and write operations (insert, update, write, and delete operations). This also includes operations used to replicate writes. For example, in a 2-replica cluster, the write to the primary replica is recorded in the primary LQH, and the write to the backup will be recorded in the backup LQH. Unique key operations may result in multiple local operations; however, this does *not* include local operations generated as a result of a table scan or ordered index scan, which are not counted.

Process scheduler statistics.   In addition to the statistics reported by the transaction coordinator and local query handler, each `ndbd` process has a scheduler which also provides useful metrics relating to the performance of a MySQL Cluster. This scheduler runs in an infinite loop; during each loop the scheduler performs the following tasks:

1. Read any incoming messages from sockets into a job buffer.

2. Check whether there are any timed messages to be executed; if so, put these into the job buffer as well.

3. Execute (in a loop) any messages in the job buffer.

4. Send any distributed messages that were generated by executing the messages in the job buffer.

5. Wait for any new incoming messages.

Process scheduler statistics include the following:

- **Mean Loop Counter.**   This is the number of loops executed in the third step from the preceding list. This statistic increases in size as the utilization of the TCP/IP buffer improves. You can use this to monitor changes in performance as you add new data node processes.

- **Mean send size and Mean receive size.**   These statistics enable you to gauge the efficiency of, respectively writes and reads between nodes. The values are given in bytes. Higher values mean a lower cost per byte sent or received; the maximum value is 64K.

To cause all cluster log statistics to be logged, you can use the following command in the `NDB` management client:

```
ndb_mgm> ALL CLUSTERLOG STATISTICS=15
```

> **Note**
>
> Setting the threshold for `STATISTICS` to 15 causes the cluster log to become very verbose, and to grow quite rapidly in size, in direct proportion to the number of cluster nodes and the amount of activity in the MySQL Cluster.

For more information about MySQL Cluster management client commands relating to logging and reporting, see Section 17.5.6.1, "MySQL Cluster Logging Management Commands".

17.5.7 MySQL Cluster Log Messages

This section contains information about the messages written to the cluster log in response to different cluster log events. It provides additional, more specific information on `NDB` transporter errors.

17.5.7.1 MySQL Cluster: Messages in the Cluster Log

The following table lists the most common `NDB` cluster log messages. For information about the cluster log, log events, and event types, see Section 17.5.6, "Event Reports Generated in MySQL Cluster". These

log messages also correspond to log event types in the MGM API; see The Ndb_logevent_type Type, for related information of interest to Cluster API developers.

Log Message	Description	Event Name	Event Type	Priority	Severity
Node `mgm_node_id`: Node `data_node_id` Connected	The data node having node ID `node_id` has connected to the management server (node `mgm_node_id`).	`Connected`	`Connection`	8	`INFO`
Node `mgm_node_id`: Node `data_node_id` Disconnected	The data node having node ID `data_node_id` has disconnected from the management server (node `mgm_node_id`).	`Disconnected`	`Connection`	8	`ALERT`
Node `data_node_id`: Communication to Node `api_node_id` closed	The API node or SQL node having node ID `api_node_id` is no longer communicating with data node `data_node_id`.	`CommunicationClosed`	`Connection`	8	`INFO`
Node `data_node_id`: Communication to Node `api_node_id` opened	The API node or SQL node having node ID `api_node_id` is now communicating with data node `data_node_id`.	`CommunicationOpened`	`Connection`	8	`INFO`
Node `mgm_node_id`: Node `api_node_id`: API `version`	The API node having node ID `api_node_id` has connected to management node `mgm_node_id` using `NDB` API version `version` (generally the same as the MySQL version number).	`ConnectedApiVersion`	`Connection`	8	`INFO`
Node `node_id`: Global checkpoint `gci` started	A global checkpoint with the ID `gci` has been started; node `node_id` is the master responsible	`GlobalCheckpointStarted`	`Checkpoint`	9	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
	for this global checkpoint.				
Node *node_id*: Global checkpoint *gci* completed	The global checkpoint having the ID *gci* has been completed; node *node_id* was the master responsible for this global checkpoint.	GlobalCheckpointCompleted	Checkpoint	10	INFO
Node *node_id*: Local checkpoint *lcp* started. Keep GCI = *current_gci* oldest restorable GCI = *old_gci*	The local checkpoint having sequence ID *lcp* has been started on node *node_id*. The most recent GCI that can be used has the index *current_gci*, and the oldest GCI from which the cluster can be restored has the index *old_gci*.	LocalCheckpointStarted	Checkpoint	7	INFO
Node *node_id*: Local checkpoint *lcp* completed	The local checkpoint having sequence ID *lcp* on node *node_id* has been completed.	LocalCheckpointCompleted	Checkpoint	8	INFO
Node *node_id*: Local Checkpoint stopped in CALCULATED_KEEP_GCI	The node was unable to determine the most recent usable GCI.	LCPStoppedInCalcKeepGci	Checkpoint	0	ALERT
Node *node_id*: Table ID = *table_id*, fragment ID = *fragment_id* has completed LCP on Node *node_id* maxGciStarted: *started_gci* maxGciCompleted: *completed_gci*	A table fragment has been checkpointed to disk on node *node_id*. The GCI in progress has the index *started_gci*, and the most recent GCI to have been completed has the index *completed_gci*.	LCPFragmentCompleted	Checkpoint	11	INFO
Node *node_id*: ACC Blocked *num_1* and TUP	Undo logging is blocked because the log	UndoLogBlocked	Checkpoint	7	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
`Blocked num_2 times last second`	buffer is close to overflowing.				
`Node node_id: Start initiated version`	Data node `node_id`, running `NDB` version `version`, is beginning its startup process.	`NDBStartStarted`	`StartUp`	1	`INFO`
`Node node_id: Started version`	Data node `node_id`, running `NDB` version `version`, has started successfully.	`NDBStartCompleted`	`StartUp`	1	`INFO`
`Node node_id: STTORRY received after restart finished`	The node has received a signal indicating that a cluster restart has completed.	`STTORRYRecieved`	`StartUp`	15	`INFO`
`Node node_id: Start phase phase completed (type)`	The node has completed start phase `phase` of a `type` start. For a listing of start phases, see Section 17.5.1, "Summary of MySQL Cluster Start Phases". (`type` is one of `initial`, `system`, `node`, `initial node`, or `<Unknown>`.)	`StartPhaseCompleted`	`StartUp`	4	`INFO`
`Node node_id: CM_REGCONF president = president_id, own Node = own_id, our dynamic id = dynamic_id`	Node `president_id` has been selected as "president". `own_id` and `dynamic_id` should always be the same as the ID (`node_id`) of the reporting node.	`CM_REGCONF`	`StartUp`	3	`INFO`
`Node node_id: CM_REGREF from Node president_id to our Node`	The reporting node (ID `node_id`) was unable to accept node `president_id` as president. The	`CM_REGREF`	`StartUp`	8	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
node_id. Cause = *cause*	*cause* of the problem is given as one of `Busy`, `Election with wait = false`, `Not president`, `Election without selecting new candidate`, or `No such cause`.				
Node *node_id*: We are Node *own_id* with dynamic ID *dynamic_id*, our left neighbor is Node *id_1*, our right is Node *id_2*	The node has discovered its neighboring nodes in the cluster (node *id_1* and node *id_2*). *node_id*, *own_id*, and *dynamic_id* should always be the same; if they are not, this indicates a serious misconfiguration of the cluster nodes.	`FIND_NEIGHBOURS`	`StartUp`	8	`INFO`
Node *node_id*: *type* shutdown initiated	The node has received a shutdown signal. The *type* of shutdown is either `Cluster` or `Node`.	`NDBStopStarted`	`StartUp`	1	`INFO`
Node *node_id*: Node shutdown completed [, *action*] [Initiated by signal *signal*.]	The node has been shut down. This report may include an *action*, which if present is one of `restarting`, `no start`, or `initial`. The report may also include a reference to an `NDB` Protocol *signal*; for possible signals, refer to Operations and Signals.	`NDBStopCompleted`	`StartUp`	1	`INFO`
Node *node_id*: Forced node shutdown completed [, *action*].	The node has been forcibly shut down. The *action* (one of `restarting`, `no start`,	`NDBStopForced`	`StartUp`	1	`ALERT`

Log Message	Description	Event Name	Event Type	Priority	Severity
`[Occured during startphase start_phase.]` `[ Initiated by signal.]` `[Caused by error error_code:` `'error_message(error_classification).` `error_status'.` `[(extra info extra_code)]]`	or `initial`) subsequently being taken, if any, is also reported. If the shutdown occurred while the node was starting, the report includes the `start_phase` during which the node failed. If this was a result of a `signal` sent to the node, this information is also provided (see Operations and Signals, for more information). If the error causing the failure is known, this is also included; for more information about `NDB` error messages and classifications, see MySQL Cluster API Errors.				
`Node node_id:` `Node shutdown aborted`	The node shutdown process was aborted by the user.	`NDBStopAborted`	`StartUp`	1	`INFO`
`Node node_id:` `StartLog: [GCI Keep: keep_pos LastCompleted: last_pos NewestRestorable restore_pos]`	This reports global checkpoints referenced during a node start. The redo log prior to `keep_pos` is dropped. `last_pos` is the last global checkpoint in which data node the participated; `restore_pos` is the global checkpoint which is actually used to restore all data nodes.	`StartREDOLog`	`StartUp`	4	`INFO`
`startup_message` [*Listed separately; see below.*]	There are a number of possible startup messages that	`StartReport`	`StartUp`	4	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
	can be logged under different circumstances. These are listed separately; see Section 17.5.7.2, "MySQL Cluster Log Startup Messages".				
Node `node_id`: Node restart completed copy of dictionary information	Copying of data dictionary information to the restarted node has been completed.	NR_CopyDict	NodeRestart	8	INFO
Node `node_id`: Node restart completed copy of distribution information	Copying of data distribution information to the restarted node has been completed.	NR_CopyDistr	NodeRestart	8	INFO
Node `node_id`: Node restart starting to copy the fragments to Node `node_id`	Copy of fragments to starting data node `node_id` has begun	NR_CopyFragsStarted	NodeRestart	8	INFO
Node `node_id`: Table ID = `table_id`, fragment ID = `fragment_id` have been copied to Node `node_id`	Fragment `fragment_id` from table `table_id` has been copied to data node `node_id`	NR_CopyFragDone	NodeRestart	10	INFO
Node `node_id`: Node restart completed copying the fragments to Node `node_id`	Copying of all table fragments to restarting data node `node_id` has been completed	NR_CopyFragsCompleted	NodeRestart	8	INFO
Node `node_id`: Node `node1_id` completed failure of Node `node2_id`	Data node `node1_id` has detected the failure of data node `node2_id`	NodeFailCompleted	NodeRestart	8	ALERT
All nodes completed failure of Node `node_id`	All (remaining) data nodes have detected the failure of data node `node_id`	NodeFailCompleted	NodeRestart	8	ALERT

Log Message	Description	Event Name	Event Type	Priority	Severity
`Node failure of node_id block completed`	The failure of data node `node_id` has been detected in the `block`NDB kernel block, where block is 1 of `DBTC`, `DBDICT`, `DBDIH`, or `DBLQH`; for more information, see [NDB Kernel Blocks](#)	`NodeFailCompleted`	`NodeRestart`	8	`ALERT`
`Node mgm_node_id: Node data_node_id has failed. The Node state at failure was state_code`	A data node has failed. Its state at the time of failure is described by an arbitration state code `state_code`: possible state code values can be found in the file `include/kernel/signaldata/ArbitSignalData.hpp`.	`NODE_FAILREP`	`NodeRestart`	8	`ALERT`
`President restarts arbitration thread [state=state_code]` or `Prepare arbitrator node node_id [ticket=ticket_id]` or `Receive arbitrator node node_id [ticket=ticket_id]` or `Started arbitrator node node_id [ticket=ticket_id]` or `Lost arbitrator node node_id - process failure [state=state_code]` or `Lost arbitrator node node_id - process exit [state=state_code]` or `Lost arbitrator`	This is a report on the current state and progress of arbitration in the cluster. `node_id` is the node ID of the management node or SQL node selected as the arbitrator. `state_code` is an arbitration state code, as found in `include/kernel/signaldata/ArbitSignalData.hpp`. When an error has occurred, an `error_message`, also defined in `ArbitSignalData.hpp`, is provided. `ticket_id` is a unique identifier handed out by the arbitrator when it is selected to all the nodes that participated	`ArbitState`	`NodeRestart`	6	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
node *node_id* – *error_message* [state=*state_code*]	in its selection; this is used to ensure that each node requesting arbitration was one of the nodes that took part in the selection process.				
Arbitration check lost – less than 1/2 nodes left or Arbitration check won – all node groups and more than 1/2 nodes left or Arbitration check won – node group majority or Arbitration check lost – missing node group or Network partitioning – arbitration required or Arbitration won – positive reply from node *node_id* or Arbitration lost – negative reply from node *node_id* or Network partitioning – no arbitrator available or Network partitioning – no arbitrator configured or Arbitration failure – *error_message* [state=*state_code*]	This message reports on the result of arbitration. In the event of arbitration failure, an *error_message* and an arbitration *state_code* are provided; definitions for both of these are found in include/kernel/ signaldata/ ArbitSignalData.hpp.	ArbitResult	NodeRestart	2	ALERT
Node *node_id*: GCP Take over started	This node is attempting to assume	GCP_TakeoverStarted	NodeRestart	7	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
	responsibility for the next global checkpoint (that is, it is becoming the master node)				
Node `node_id`: GCP Take over completed	This node has become the master, and has assumed responsibility for the next global checkpoint	`GCP_TakeoverCompleted`	`NodeRestart`	7	`INFO`
Node `node_id`: LCP Take over started	This node is attempting to assume responsibility for the next set of local checkpoints (that is, it is becoming the master node)	`LCP_TakeoverStarted`	`NodeRestart`	7	`INFO`
Node `node_id`: LCP Take over completed	This node has become the master, and has assumed responsibility for the next set of local checkpoints	`LCP_TakeoverCompleted`	`NodeRestart`	7	`INFO`
Node `node_id`: Trans. Count = `transactions`, Commit Count = `commits`, Read Count = `reads`, Simple Read Count = `simple_reads`, Write Count = `writes`, AttrInfo Count = `AttrInfo_objects`, Concurrent Operations = `concurrent_operations`, Abort Count = `aborts`, Scans = `scans`, Range scans = `range_scans`	This report of transaction activity is given approximately once every 10 seconds	`TransReportCounters`	`Statistic`	8	`INFO`
Node `node_id`: Operations=`operations`	Number of operations performed by this	`OperationReportCounters`	`Statistic`	8	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
	node, provided approximately once every 10 seconds				
`Node node_id: Table with ID = table_id created`	A table having the table ID shown has been created	`TableCreated`	`Statistic`	7	`INFO`
`Node node_id: Mean loop Counter in doJob last 8192 times = count`		`JobStatistic`	`Statistic`	9	`INFO`
`Mean send size to Node = node_id last 4096 sends = bytes bytes`	This node is sending an average of `bytes` bytes per send to node `node_id`	`SendBytesStatistic`	`Statistic`	9	`INFO`
`Mean receive size to Node = node_id last 4096 sends = bytes bytes`	This node is receiving an average of `bytes` of data each time it receives data from node `node_id`	`ReceiveBytesStatistic`	`Statistic`	9	`INFO`
`Node node_id: Data usage is data_memory_percent% (data_pages_used 32K pages of total data_pages_total) / Node node_id: Index usage is index_memory_percent% (index_pages_used 8K pages of total index_pages_total)`	This report is generated when a `DUMP 1000` command is issued in the cluster management client; for more information, see DUMP 1000, in MySQL Cluster Internals	`MemoryUsage`	`Statistic`	5	`INFO`
`Node node1_id: Transporter to node node2_id reported error error_code: error_message`	A transporter error occurred while communicating with node `node2_id`; for a listing of transporter error codes and messages, see NDB Transporter Errors, in MySQL Cluster Internals	`TransporterError`	`Error`	2	`ERROR`

Log Message	Description	Event Name	Event Type	Priority	Severity
Node `node1_id`: Transporter to node `node2_id` reported error `error_code`: `error_message`	A warning of a potential transporter problem while communicating with node `node2_id`; for a listing of transporter error codes and messages, see NDB Transporter Errors, for more information	`TransporterWarning`	`Error`	8	`WARNING`
Node `node1_id`: Node `node2_id` missed heartbeat `heartbeat_id`	This node missed a heartbeat from node `node2_id`	`MissedHeartbeat`	`Error`	8	`WARNING`
Node `node1_id`: Node `node2_id` declared dead due to missed heartbeat	This node has missed at least 3 heartbeats from node `node2_id`, and so has declared that node "dead"	`DeadDueToHeartbeat`	`Error`	8	`ALERT`
Node `node1_id`: Node Sent Heartbeat to node = `node2_id`	This node has sent a heartbeat to node `node2_id`	`SentHeartbeat`	`Info`	12	`INFO`
Node `node_id`: Event buffer status: used=`bytes_used` (`percent_used`%) alloc=`bytes_alloc` (`percent_available`%) max=`bytes_available` apply_gci=`latest_restorable_GCI` latest_gci=`latest_GCI`	This report is seen during heavy event buffer usage, for example, when many updates are being applied in a relatively short period of time; the report shows the number of bytes and the percentage of event buffer memory used, the bytes allocated and percentage still available, and the latest and latest restorable global checkpoints	`EventBufferStatus`	`Info`	7	`INFO`
Node `node_id`: Entering single user mode, Node `node_id`:	These reports are written to the cluster log when entering and exiting	`SingleUser`	`Info`	7	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
`Entered single user mode Node API_node_id has exclusive access`, `Node node_id: Entering single user mode`	single user mode; `API_node_id` is the node ID of the API or SQL having exclusive access to the cluster (for more information, see Section 17.5.8, "MySQL Cluster Single User Mode"); the message `Unknown single user report API_node_id` indicates an error has taken place and should never be seen in normal operation				
`Node node_id: Backup backup_id started from node mgm_node_id`	A backup has been started using the management node having `mgm_node_id`; this message is also displayed in the cluster management client when the `START BACKUP` command is issued; for more information, see Section 17.5.3.2, "Using The MySQL Cluster Management Client to Create a Backup"	`BackupStarted`	`Backup`	7	`INFO`
`Node node_id: Backup backup_id started from node mgm_node_id completed. StartGCP: start_gcp StopGCP: stop_gcp #Records: records #LogRecords:`	The backup having the ID `backup_id` has been completed; for more information, see Section 17.5.3.2, "Using The MySQL Cluster Management Client to Create a Backup"	`BackupCompleted`	`Backup`	7	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
log_records Data: *data_bytes* bytes Log: *log_bytes* bytes					
Node *node_id*: Backup request from *mgm_node_id* failed to start. Error: *error_code*	The backup failed to start; for error codes, see MGM API Errors	BackupFailedToStart	Backup	7	ALERT
Node *node_id*: Backup *backup_id* started from *mgm_node_id* has been aborted. Error: *error_code*	The backup was terminated after starting, possibly due to user intervention	BackupAborted	Backup	7	ALERT

17.5.7.2 MySQL Cluster Log Startup Messages

Possible startup messages with descriptions are provided in the following list:

- Initial start, waiting for %s to connect, nodes [all: %s connected: %s no-wait: %s]

- Waiting until nodes: %s connects, nodes [all: %s connected: %s no-wait: %s]

- Waiting %u sec for nodes %s to connect, nodes [all: %s connected: %s no-wait: %s]

- Waiting for non partitioned start, nodes [all: %s connected: %s missing: %s no-wait: %s]

- Waiting %u sec for non partitioned start, nodes [all: %s connected: %s missing: %s no-wait: %s]

- Initial start with nodes %s [missing: %s no-wait: %s]

- Start with all nodes %s

- Start with nodes %s [missing: %s no-wait: %s]

- Start potentially partitioned with nodes %s [missing: %s no-wait: %s]

- Unknown startreport: 0x%x [%s %s %s %s]

17.5.7.3 MySQL Cluster: NDB Transporter Errors

This section lists error codes, names, and messages that are written to the cluster log in the event of transporter errors.

Error Code	Error Name	Error Text
0x00	**TE_NO_ERROR**	No error
0x01	**TE_ERROR_CLOSING_SOCKET**	Error found during closing of socket
0x02	**TE_ERROR_IN_SELECT_BEFORE_ACCEPT**	Error found before accept. The transporter will retry
0x03	**TE_INVALID_MESSAGE_LENGTH**	Error found in message (invalid message length)
0x04	**TE_INVALID_CHECKSUM**	Error found in message (checksum)
0x05	**TE_COULD_NOT_CREATE_SOCKET**	Error found while creating socket(can't create socket)
0x06	**TE_COULD_NOT_BIND_SOCKET**	Error found while binding server socket
0x07	**TE_LISTEN_FAILED**	Error found while listening to server socket
0x08	**TE_ACCEPT_RETURN_ERROR**	Error found during accept(accept return error)
0x0b	**TE_SHM_DISCONNECT**	The remote node has disconnected
0x0c	**TE_SHM_IPC_STAT**	Unable to check shm segment
0x0d	**TE_SHM_UNABLE_TO_CREATE_SEGMENT**	Unable to create shm segment
0x0e	**TE_SHM_UNABLE_TO_ATTACH_SEGMENT**	Unable to attach shm segment
0x0f	**TE_SHM_UNABLE_TO_REMOVE_SEGMENT**	Unable to remove shm segment
0x10	**TE_TOO_SMALL_SIGID**	Sig ID too small
0x11	**TE_TOO_LARGE_SIGID**	Sig ID too large
0x12	**TE_WAIT_STACK_FULL**	Wait stack was full
0x13	**TE_RECEIVE_BUFFER_FULL**	Receive buffer was full
0x14	**TE_SIGNAL_LOST_SEND_BUFFER_FULL**	Send buffer was full,and trying to force send fails
0x15	**TE_SIGNAL_LOST**	Send failed for unknown reason(signal lost)

Error Code	Error Name	Error Text
0x16	**TE_SEND_BUFFER_FULL**	The send buffer was full, but sleeping for a while solved
0x0017	**TE_SCI_LINK_ERROR**	There is no link from this node to the switch
0x18	**TE_SCI_UNABLE_TO_START_SEQUENCE**	Could not start a sequence, because system resources are exumed or no sequence has been created
0x19	**TE_SCI_UNABLE_TO_REMOVE_SEQUENCE**	Could not remove a sequence
0x1a	**TE_SCI_UNABLE_TO_CREATE_SEQUENCE**	Could not create a sequence, because system resources are exempted. Must reboot
0x1b	**TE_SCI_UNRECOVERABLE_DATA_TFX_ERROR**	Tried to send data on redundant link but failed
0x1c	**TE_SCI_CANNOT_INIT_LOCALSEGMENT**	Cannot initialize local segment
0x1d	**TE_SCI_CANNOT_MAP_REMOTESEGMENT**	Cannot map remote segment
0x1e	**TE_SCI_UNABLE_TO_UNMAP_SEGMENT**	Cannot free the resources used by this segment (step 1)
0x1f	**TE_SCI_UNABLE_TO_REMOVE_SEGMENT**	Cannot free the resources used by this segment (step 2)
0x20	**TE_SCI_UNABLE_TO_DISCONNECT_SEGMENT**	Cannot disconnect from a remote segment
0x21	**TE_SHM_IPC_PERMANENT**	Shm ipc Permanent error
0x22	**TE_SCI_UNABLE_TO_CLOSE_CHANNEL**	Unable to close the sci channel and the resources allocated

17.5.8 MySQL Cluster Single User Mode

Single user mode enables the database administrator to restrict access to the database system to a single API node, such as a MySQL server (SQL node) or an instance of `ndb_restore`. When entering single user mode, connections to all other API nodes are closed gracefully and all running transactions are aborted. No new transactions are permitted to start.

Once the cluster has entered single user mode, only the designated API node is granted access to the database.

You can use the `ALL STATUS` command in the `ndb_mgm` client to see when the cluster has entered single user mode. Beginning with MySQL Cluster NDB 7.1.1, you can also check the `status` column of the `ndbinfo.nodes` table (see Section 17.5.10.13, "The ndbinfo nodes Table", for more information).

Example:

```
ndb_mgm> ENTER SINGLE USER MODE 5
```

After this command has executed and the cluster has entered single user mode, the API node whose node ID is 5 becomes the cluster's only permitted user.

The node specified in the preceding command must be an API node; attempting to specify any other type of node will be rejected.

> **Note**
>
> When the preceding command is invoked, all transactions running on the designated node are aborted, the connection is closed, and the server must be restarted.

The command `EXIT SINGLE USER MODE` changes the state of the cluster's data nodes from single user mode to normal mode. API nodes—such as MySQL Servers—waiting for a connection (that is, waiting for the cluster to become ready and available), are again permitted to connect. The API node denoted as the single-user node continues to run (if still connected) during and after the state change.

Example:

```
ndb_mgm> EXIT SINGLE USER MODE
```

There are two recommended ways to handle a node failure when running in single user mode:

• Method 1:

  1. Finish all single user mode transactions

  2. Issue the `EXIT SINGLE USER MODE` command

  3. Restart the cluster's data nodes

• Method 2:

  Restart database nodes prior to entering single user mode.

17.5.9 Quick Reference: MySQL Cluster SQL Statements

This section discusses several SQL statements that can prove useful in managing and monitoring a MySQL server that is connected to a MySQL Cluster, and in some cases provide information about the cluster itself.

• `SHOW ENGINE NDB STATUS`, `SHOW ENGINE NDBCLUSTER STATUS`

  The output of this statement contains information about the server's connection to the cluster, creation and usage of MySQL Cluster objects, and binary logging for MySQL Cluster replication.

  See Section 13.7.5.16, "SHOW ENGINE Syntax", for a usage example and more detailed information.

• `SHOW ENGINES`

This statement can be used to determine whether or not clustering support is enabled in the MySQL server, and if so, whether it is active.

See Section 13.7.5.17, "SHOW ENGINES Syntax", for more detailed information.

> **Note**
>
> In MySQL 5.1 and later, this statement does not support a `LIKE` clause. However, you can use `LIKE` to filter queries against the `INFORMATION_SCHEMA.ENGINES` table, as discussed in the next item.

- `SELECT * FROM INFORMATION_SCHEMA.ENGINES [WHERE ENGINE LIKE 'NDB%']`

  This is the equivalent of `SHOW ENGINES`, but uses the `ENGINES` table of the `INFORMATION_SCHEMA` database (available beginning with MySQL 5.1.5). Unlike the case with the `SHOW ENGINES` statement, it is possible to filter the results using a `LIKE` clause, and to select specific columns to obtain information that may be of use in scripts. For example, the following query shows whether the server was built with `NDB` support and, if so, whether it is enabled:

  ```
  mysql> SELECT SUPPORT FROM INFORMATION_SCHEMA.ENGINES
      ->    WHERE ENGINE LIKE 'NDB%';
  +---------+
  | support |
  +---------+
  | ENABLED |
  +---------+
  ```

  See Section 20.6, "The INFORMATION_SCHEMA ENGINES Table", for more information.

- `SHOW VARIABLES LIKE 'NDB%'`

  This statement provides a list of most server system variables relating to the `NDB` storage engine, and their values, as shown here:

  ```
  mysql> SHOW VARIABLES LIKE 'NDB%';
  +-----------------------------------+-------+
  | Variable_name                     | Value |
  +-----------------------------------+-------+
  | ndb_autoincrement_prefetch_sz     | 32    |
  | ndb_cache_check_time              | 0     |
  | ndb_extra_logging                 | 0     |
  | ndb_force_send                    | ON    |
  | ndb_index_stat_cache_entries      | 32    |
  | ndb_index_stat_enable             | OFF   |
  | ndb_index_stat_update_freq        | 20    |
  | ndb_report_thresh_binlog_epoch_slip | 3   |
  | ndb_report_thresh_binlog_mem_usage | 10   |
  | ndb_use_copying_alter_table       | OFF   |
  | ndb_use_exact_count               | ON    |
  | ndb_use_transactions              | ON    |
  +-----------------------------------+-------+
  ```

  See Section 5.1.4, "Server System Variables", for more information.

- `SELECT * FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES WHERE VARIABLE_NAME LIKE 'NDB%';`

  This statement is the equivalent of the `SHOW` command described in the previous item, and provides almost identical output, as shown here:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES
    ->   WHERE VARIABLE_NAME LIKE 'NDB%';
+------------------------------------+----------------+
| VARIABLE_NAME                      | VARIABLE_VALUE |
+------------------------------------+----------------+
| NDB_AUTOINCREMENT_PREFETCH_SZ      | 32             |
| NDB_CACHE_CHECK_TIME               | 0              |
| NDB_EXTRA_LOGGING                  | 0              |
| NDB_FORCE_SEND                     | ON             |
| NDB_INDEX_STAT_CACHE_ENTRIES       | 32             |
| NDB_INDEX_STAT_ENABLE              | OFF            |
| NDB_INDEX_STAT_UPDATE_FREQ         | 20             |
| NDB_REPORT_THRESH_BINLOG_EPOCH_SLIP | 3             |
| NDB_REPORT_THRESH_BINLOG_MEM_USAGE | 10             |
| NDB_USE_COPYING_ALTER_TABLE        | OFF            |
| NDB_USE_EXACT_COUNT                | ON             |
| NDB_USE_TRANSACTIONS               | ON             |
+------------------------------------+----------------+
```

Unlike the case with the SHOW command, it is possible to select individual columns. For example:

```
mysql> SELECT VARIABLE_VALUE
    ->   FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES
    ->   WHERE VARIABLE_NAME = 'ndb_force_send';
+----------------+
| VARIABLE_VALUE |
+----------------+
| ON             |
+----------------+
```

See Section 20.9, "The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables", and Section 5.1.4, "Server System Variables", for more information.

- SHOW STATUS LIKE 'NDB%'

This statement shows at a glance whether or not the MySQL server is acting as a cluster SQL node, and if so, it provides the MySQL server's cluster node ID, the host name and port for the cluster management server to which it is connected, and the number of data nodes in the cluster, as shown here:

```
mysql> SHOW STATUS LIKE 'NDB%';
+--------------------------+---------------+
| Variable_name            | Value         |
+--------------------------+---------------+
| Ndb_cluster_node_id      | 10            |
| Ndb_config_from_host     | 192.168.0.103 |
| Ndb_config_from_port     | 1186          |
| Ndb_number_of_data_nodes | 4             |
+--------------------------+---------------+
```

If the MySQL server was built with clustering support, but it is not connected to a cluster, all rows in the output of this statement contain a zero or an empty string:

```
mysql> SHOW STATUS LIKE 'NDB%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| Ndb_cluster_node_id      | 0     |
| Ndb_config_from_host     |       |
| Ndb_config_from_port     | 0     |
| Ndb_number_of_data_nodes | 0     |
```

```
+-------------------------+-------+
```

See also Section 13.7.5.37, "SHOW STATUS Syntax".

- `SELECT * FROM INFORMATION_SCHEMA.GLOBAL_STATUS WHERE VARIABLE_NAME LIKE 'NDB%';`

  Beginning with MySQL 5.1.12, this statement provides similar output to the `SHOW` command discussed in the previous item. However, unlike the case with `SHOW STATUS`, it is possible using the `SELECT` to extract values in SQL for use in scripts for monitoring and automation purposes.

  See Section 20.8, "The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables", for more information.

Beginning with MySQL Cluster NDB 7.1.1, you can also query the tables in the `ndbinfo` information database for real-time data about many MySQL Cluster operations. See Section 17.5.10, "The ndbinfo MySQL Cluster Information Database".

17.5.10 The ndbinfo MySQL Cluster Information Database

`ndbinfo` is a database containing information specific to MySQL Cluster, available beginning with MySQL Cluster NDB 7.1.1.

This database contains a number of tables, each providing a different sort of data about MySQL Cluster node status, resource usage, and operations. You can find more detailed information about each of these tables in the next several sections.

`ndbinfo` is included with MySQL Cluster support in the MySQL Server; no special compilation or configuration steps are required; the tables are created by the MySQL Server when it connects to the cluster. You can verify that `ndbinfo` support is active in a given MySQL Server instance using `SHOW PLUGINS`; if `ndbinfo` support is enabled, you should see a row containing `ndbinfo` in the `Name` column and `ACTIVE` in the `Status` column, as shown here (emphasized text):

```
mysql> SHOW PLUGINS;
+------------+----------+----------------+---------+---------+
| Name       | Status   | Type           | Library | License |
+------------+----------+----------------+---------+---------+
| binlog     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| partition  | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| ARCHIVE    | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| BLACKHOLE  | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| CSV        | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| FEDERATED  | DISABLED | STORAGE ENGINE | NULL    | GPL     |
| MEMORY     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| InnoDB     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| MyISAM     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| MRG_MYISAM | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| ndbcluster | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| ndbinfo    | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
+------------+----------+----------------+---------+---------+
12 rows in set (0.00 sec)
```

You can also do this by checking the output of `SHOW ENGINES` for a row that has `ndbinfo` for `Engine` and `YES` for `Support`, as shown here (emphasized text):

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
      Engine: ndbcluster
     Support: YES
     Comment: Clustered, fault-tolerant tables
```

```
Transactions: YES
          XA: NO
   Savepoints: NO
*************************** 2. row ***************************
      Engine: MRG_MYISAM
     Support: YES
     Comment: Collection of identical MyISAM tables
Transactions: NO
          XA: NO
   Savepoints: NO
*************************** 3. row ***************************
      Engine: ndbinfo
     Support: YES
     Comment: MySQL Cluster system information storage engine
Transactions: NO
          XA: NO
   Savepoints: NO
*************************** 4. row ***************************
      Engine: CSV
     Support: YES
     Comment: CSV storage engine
Transactions: NO
          XA: NO
   Savepoints: NO
*************************** 5. row ***************************
      Engine: MEMORY
     Support: YES
     Comment: Hash based, stored in memory, useful for temporary tables
Transactions: NO
          XA: NO
   Savepoints: NO
*************************** 6. row ***************************
      Engine: FEDERATED
     Support: NO
     Comment: Federated MySQL storage engine
Transactions: NULL
          XA: NULL
   Savepoints: NULL
*************************** 7. row ***************************
      Engine: ARCHIVE
     Support: YES
     Comment: Archive storage engine
Transactions: NO
          XA: NO
   Savepoints: NO
*************************** 8. row ***************************
      Engine: InnoDB
     Support: YES
     Comment: Supports transactions, row-level locking, and foreign keys
Transactions: YES
          XA: YES
   Savepoints: YES
*************************** 9. row ***************************
      Engine: MyISAM
     Support: DEFAULT
     Comment: Default engine as of MySQL 3.23 with great performance
Transactions: NO
          XA: NO
   Savepoints: NO
*************************** 10. row ***************************
      Engine: BLACKHOLE
     Support: YES
     Comment: /dev/null storage engine (anything you write to it disappears)
Transactions: NO
          XA: NO
   Savepoints: NO
10 rows in set (0.00 sec)
```

If `ndbinfo` support is enabled, then you can access `ndbinfo` using SQL statements in `mysql` or another MySQL client. For example, you can see `ndbinfo` listed in the output of `SHOW DATABASES`, as shown here (emphasized text):

```
mysql> SHOW DATABASES;
+--------------------+
| Database           |
+--------------------+
| information_schema |
| mysql              |
| ndbinfo            |
| test               |
+--------------------+
4 rows in set (0.00 sec)
```

If the `mysqld` process was not started with the `--ndbcluster` option, `ndbinfo` is not available and is not displayed by `SHOW DATABASES`. If `mysqld` was formerly connected to a MySQL Cluster but the cluster becomes unavailable (due to events such as cluster shutdown, loss of network connectivity, and so forth), `ndbinfo` and its tables remain visible, but an attempt to access any tables (other than `blocks` or `config_params`) fails with `Got error 157 'Connection to NDB failed' from NDBINFO`.

With the exception of the `blocks` and `config_params` tables, what we refer to as `ndbinfo` "tables" are actually views generated from internal `NDB` tables not normally visible to the MySQL Server.

All `ndbinfo` tables are read-only, and are generated on demand when queried. Because many of them are generated in parallel by the data nodes while other are specific to a given SQL node, they are not guaranteed to provide a consistent snapshot.

In addition, pushing down of joins is not supported on `ndbinfo` tables; so joining large `ndbinfo` tables can require transfer of a large amount of data to the requesting API node, even when the query makes use of a `WHERE` clause.

Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, `ndbinfo` tables are not included in the query cache. (Bug #59831)

You can select the `ndbinfo` database with a `USE` statement, and then issue a `SHOW TABLES` statement to obtain a list of tables, just as for any other database, like this:

```
mysql> USE ndbinfo;
Database changed

mysql> SHOW TABLES;
+----------------------+
| Tables_in_ndbinfo    |
+----------------------+
| blocks               |
| cluster_operations   |
| cluster_transactions |
| config_params        |
| counters             |
| diskpagebuffer       |
| logbuffers           |
| logspaces            |
| memoryusage          |
| nodes                |
| resources            |
| server_operations    |
| server_transactions  |
| threadblocks         |
| threadstat           |
```

```
| transporters         |
+----------------------+
16 rows in set (0.04 sec)
```

The `diskpagebuffer` table was added in MySQL Cluster NDB 7.1.9.

The `cluster_operations`, `cluster_transactions`, `server_operations`, `server_transactions`, `threadblocks`, and `threadstat` tables were added in MySQL Cluster NDB 7.1.17.

In early versions of MySQL Cluster NDB 7.1, there was an additional `pools` table in the `ndbinfo` database; however, this table was removed in MySQL Cluster NDB 7.1.3.

You can execute `SELECT` statements against these tables, just as you would normally expect:

```
mysql> SELECT * FROM memoryusage;
+---------+---------------------+--------+------------+------------+-------------+
| node_id | memory_type         | used   | used_pages | total      | total_pages |
+---------+---------------------+--------+------------+------------+-------------+
|       5 | Data memory         | 753664 |         23 | 1073741824 |       32768 |
|       5 | Index memory        | 163840 |         20 | 1074003968 |      131104 |
|       5 | Long message buffer |   2304 |          9 |   67108864 |      262144 |
|       6 | Data memory         | 753664 |         23 | 1073741824 |       32768 |
|       6 | Index memory        | 163840 |         20 | 1074003968 |      131104 |
|       6 | Long message buffer |   2304 |          9 |   67108864 |      262144 |
+---------+---------------------+--------+------------+------------+-------------+
6 rows in set (0.02 sec)
```

More complex queries, such as the two following `SELECT` statements using the `memoryusage` table, are possible:

```
mysql> SELECT SUM(used) as 'Data Memory Used, All Nodes'
    >      FROM memoryusage
    >      WHERE memory_type = 'Data memory';
+-----------------------------+
| Data Memory Used, All Nodes |
+-----------------------------+
|                        6460 |
+-----------------------------+
1 row in set (0.37 sec)

mysql> SELECT SUM(max) as 'Total IndexMemory Available'
    >      FROM memoryusage
    >      WHERE memory_type = 'Index memory';
+-----------------------------+
| Total IndexMemory Available |
+-----------------------------+
|                       25664 |
+-----------------------------+
1 row in set (0.33 sec)
```

`ndbinfo` table and column names are case sensitive (as is the name of the `ndbinfo` database itself). These identifiers are in lowercase. Trying to use the wrong lettercase results in an error, as shown in this example:

```
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+
| node_id | uptime | status  | start_phase |
+---------+--------+---------+-------------+
|       1 |  13602 | STARTED |           0 |
|       2 |     16 | STARTED |           0 |
```

```
+---------+--------+---------+-------------+
2 rows in set (0.04 sec)

mysql> SELECT * FROM Nodes;
ERROR 1146 (42S02): Table 'ndbinfo.Nodes' doesn't exist
```

Beginning with MySQL Cluster NDB 7.1.7, `mysqldump` ignores `ndbinfo` entirely, and excludes it from any output. This is true even when using the `--databases` or `--all-databases` option.

MySQL Cluster also maintains tables in the `INFORMATION_SCHEMA` information database, including the `FILES` table which contains information about files used for MySQL Cluster Disk Data storage. For more information, see Section 20.26, "INFORMATION_SCHEMA Tables for MySQL Cluster".

17.5.10.1 The ndbinfo arbitrator_validity_detail Table

The `arbitrator_validity_detail` table shows the view that each data node in the cluster of the arbitrator. It is a subset of the `membership` table.

The following table provides information about the columns in the `arbitrator_validity_detail` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	This node's node ID
arbitrator	integer	Node ID of arbitrator
arb_ticket	string	Internal identifier used to track arbitration
arb_connected	Yes or No	Whether this node is connected to the arbitrator
arb_state	Enumeration (see text)	Arbitration state

The node ID is the same as that reported by `ndb_mgm -e "SHOW"`.

All nodes should show the same `arbitrator` and `arb_ticket` values as well as the same `arb_state` value. Possible `arb_state` values are `ARBIT_NULL`, `ARBIT_INIT`, `ARBIT_FIND`, `ARBIT_PREP1`, `ARBIT_PREP2`, `ARBIT_START`, `ARBIT_RUN`, `ARBIT_CHOOSE`, `ARBIT_CRASH`, and `UNKNOWN`.

`arb_connected` shows whether the current node is connected to the `arbitrator`.

Like the `membership` and `arbitrator_validity_summary` tables, this table was added in MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26.

17.5.10.2 The ndbinfo arbitrator_validity_summary Table

The `arbitrator_validity_summary` table provides a composite view of the arbitrator with regard to the cluster's data nodes.

The following table provides information about the columns in the `arbitrator_validity_summary` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
arbitrator	integer	Node ID of arbitrator

Column Name	Type	Description
arb_ticket	string	Internal identifier used to track arbitration
arb_connected	Yes or No	Whether this arbitrator is connected to the cluster
consensus_count	integer	Number of data nodes that see this node as arbitrator

In normal operations, this table should have only 1 row for any appreciable length of time. If it has more than 1 row for longer than a few moments, then either not all nodes are connected to the arbitrator, or all nodes are connected, but do not agree on the same arbitrator.

The `arbitrator` column shows the arbitrator's node ID.

`arb_ticket` is the internal identifier used by this arbitrator.

`arb_connected` shows whether this node is connected to the cluster as an arbitrator.

Like the `membership` and `arbitrator_validity_detail` tables, this table was added in MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26.

17.5.10.3 The ndbinfo blocks Table

The `blocks` table is a static table which simply contains the names and internal IDs of all NDB kernel blocks (see NDB Kernel Blocks). It is for use by the other `ndbinfo` tables (most of which are actually views) in mapping block numbers to block names for producing human-readable output.

The following table provides information about the columns in the `blocks` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
block_number	integer	Block number
block_name	string	Block name

To obtain a list of all block names, simply execute `SELECT block_name FROM ndbinfo.blocks`. Although this is a static table, its content can vary between different MySQL Cluster releases.

17.5.10.4 The ndbinfo cluster_operations Table

The `cluster_operations` table provides a per-operation (stateful primary key op) view of all activity in the MySQL Cluster from the point of view of the local data management (LQH) blocks (see The DBLQH Block).

The following table provides information about the columns in the `cluster_operations` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	Node ID of reporting LQH block

Column Name	Type	Description
block_instance	integer	LQH block instance
transid	integer	Transaction ID
operation_type	string	Operation type (see text for possible values)
state	string	Operation state (see text for possible values)
tableid	integer	Table ID
fragmentid	integer	Fragment ID
client_node_id	integer	Client node ID
client_block_ref	integer	Client block reference
tc_node_id	integer	Transaction coordinator node ID
tc_block_no	integer	Transaction coordinator block number
tc_block_instance	integer	Transaction coordinator block instance

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's getTransactionId() method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The operation_type column can take any one of the values READ, READ-SH, READ-EX, INSERT, UPDATE, DELETE, WRITE, UNLOCK, REFRESH, SCAN, SCAN-SH, SCAN-EX, or <unknown>.

The state column can have any one of the values ABORT_QUEUED, ABORT_STOPPED, COMMITTED, COMMIT_QUEUED, COMMIT_STOPPED, COPY_CLOSE_STOPPED, COPY_FIRST_STOPPED, COPY_STOPPED, COPY_TUPKEY, IDLE, LOG_ABORT_QUEUED, LOG_COMMIT_QUEUED, LOG_COMMIT_QUEUED_WAIT_SIGNAL, LOG_COMMIT_WRITTEN, LOG_COMMIT_WRITTEN_WAIT_SIGNAL, LOG_QUEUED, PREPARED, PREPARED_RECEIVED_COMMIT, SCAN_CHECK_STOPPED, SCAN_CLOSE_STOPPED, SCAN_FIRST_STOPPED, SCAN_RELEASE_STOPPED, SCAN_STATE_USED, SCAN_STOPPED, SCAN_TUPKEY, STOPPED, TC_NOT_CONNECTED, WAIT_ACC, WAIT_ACC_ABORT, WAIT_AI_AFTER_ABORT, WAIT_ATTR, WAIT_SCAN_AI, WAIT_TUP, WAIT_TUPKEYINFO, WAIT_TUP_COMMIT, or WAIT_TUP_TO_ABORT. (If the MySQL Server is running with ndbinfo_show_hidden enabled, you can view this list of states by selecting from the ndb $dblqh_tcconnect_state table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of ndb_show_tables.

The fragid is the same as the partition number seen in the output of ndb_desc --extra-partition-info (short form -p).

In client_node_id and client_block_ref, client refers to a MySQL Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

This table was added in MySQL Cluster NDB 7.1.17.

17.5.10.5 The ndbinfo cluster_transactions Table

The cluster_transactions table shows information about all ongoing transactions in a MySQL Cluster.

The following table provides information about the columns in the cluster_transactions table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	Node ID of transaction coordinator
block_instance	integer	TC block instance
transid	integer	Transaction ID
state	string	Operation state (see text for possible values)
count_operations	integer	Number of stateful primary key operations in transaction (includes reads with locks, as well as DML operations)
outstanding_operations	integer	Operations still being executed in local data management blocks
inactive_seconds	integer	Time spent waiting for API
client_node_id	integer	Client node ID
client_block_ref	integer	Client block reference

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `state` column can have any one of the values `CS_ABORTING`, `CS_COMMITTING`, `CS_COMMIT_SENT`, `CS_COMPLETE_SENT`, `CS_COMPLETING`, `CS_CONNECTED`, `CS_DISCONNECTED`, `CS_FAIL_ABORTED`, `CS_FAIL_ABORTING`, `CS_FAIL_COMMITTED`, `CS_FAIL_COMMITTING`, `CS_FAIL_COMPLETED`, `CS_FAIL_PREPARED`, `CS_PREPARE_TO_COMMIT`, `CS_RECEIVING`, `CS_REC_COMMITTING`, `CS_RESTART`, `CS_SEND_FIRE_TRIG_REQ`, `CS_STARTED`, `CS_START_COMMITTING`, `CS_START_SCAN`, `CS_WAIT_ABORT_CONF`, `CS_WAIT_COMMIT_CONF`, `CS_WAIT_COMPLETE_CONF`, `CS_WAIT_FIRE_TRIG_REQ`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb$dbtc_apiconnect_state` table, which is normally hidden.)

In `client_node_id` and `client_block_ref`, `client` refers to a MySQL Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

This table was added in MySQL Cluster NDB 7.1.17.

17.5.10.6 The ndbinfo config_params Table

The `config_params` table is a static table which provides the names and internal ID numbers of all MySQL Cluster configuration parameters.

The following table provides information about the columns in the `config_params` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
param_number	integer	The parameter's internal ID number
param_name	string	The name of the parameter

Although this is a static table, its content can vary between MySQL Cluster installations, since supported parameters can vary due to differences between software releases, cluster hardware configurations, and other factors.

17.5.10.7 The ndbinfo counters Table

The `counters` table provides running totals of events such as reads and writes for specific kernel blocks and data nodes. Counts are kept from the most recent node start or restart; a node start or restart resets all counters on that node. Not all kernel blocks have all types of counters.

The following table provides information about the columns in the `counters` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The data node ID
`block_name`	string	Name of the associated NDB kernel block (see NDB Kernel Blocks).
`block_instance`	integer	Block instance
`counter_id`	integer	The counter's internal ID number; normally an integer between 1 and 10, inclusive.
`counter_name`	string	The name of the counter. See text for names of individual counters and the NDB kernel block with which each counter is associated.
`val`	integer	The counter's value

Each counter is associated with a particular NDB kernel block. Prior to MySQL Cluster NDB 7.2.0, this was limited to either the `DBLQH` kernel block or the `DBTC` kernel block.

The `OPERATIONS` counter is associated with the `DBLQH` (local query handler) kernel block (see The DBLQH Block). A primary-key read counts as one operation, as does a primary-key update. For reads, there is one operation in `DBLQH` per operation in `DBTC`. For writes, there is one operation counted per replica.

The `ATTRINFO`, `TRANSACTIONS`, `COMMITS`, `READS`, `LOCAL_READS`, `SIMPLE_READS`, `WRITES`, `LOCAL_WRITES`, `ABORTS`, `TABLE_SCANS`, and `RANGE_SCANS` counters are associated with the DBTC (transaction co-ordinator) kernel block (see The DBTC Block).

`LOCAL_WRITES` and `LOCAL_READS` are primary-key operations using a transaction coordinator in a node that also holds the primary replica of the record.

The `READS` counter includes all reads. `LOCAL_READS` includes only those reads of the primary replica on the same node as this transaction coordinator. `SIMPLE_READS` includes only those reads in which the read operation is the beginning and ending operation for a given transaction. Simple reads do not hold locks but are part of a transaction, in that they observe uncommitted changes made by the transaction containing them but not of any other uncommitted transactions. Such reads are "simple" from the point of view of the TC block; since they hold no locks they are not durable, and once `DBTC` has routed them to the relevant LQH block, it holds no state for them.

`ATTRINFO` keeps a count of the number of times an interpreted program is sent to the data node. See NDB Protocol Messages, for more information about `ATTRINFO` messages in the `NDB` kernel.

MySQL Cluster NDB 7.2.0, as part of its implementation of distributed pushed-down joins, adds the `LOCAL_TABLE_SCANS_SENT`, `READS_RECEIVED`, `PRUNED_RANGE_SCANS_RECEIVED`, `RANGE_SCANS_RECEIVED`, `LOCAL_READS_SENT`, `CONST_PRUNED_RANGE_SCANS_RECEIVED`, `LOCAL_RANGE_SCANS_SENT`, `REMOTE_READS_SENT`, `REMOTE_RANGE_SCANS_SENT`,

`READS_NOT_FOUND`, `SCAN_BATCHES_RETURNED`, `TABLE_SCANS_RECEIVED`, and `SCAN_ROWS_RETURNED` counters. These counters are associated with the `DBSPJ` (select push-down join) kernel block (see The DBSPJ Block).

A number of counters increasing the visibility of transporter overload and send buffer sizing when troubleshooting such issues were added in MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26. (Bug #15935206) For each LQH instance, there is one instance of each counter in the following list:

- `LQHKEY_OVERLOAD`: Number of primary key requests rejected at the LQH block instance due to transporter overload

- `LQHKEY_OVERLOAD_TC`: Count of instances of `LQHKEY_OVERLOAD` where the TC node transporter was overloaded

- `LQHKEY_OVERLOAD_READER`: Count of instances of `LQHKEY_OVERLOAD` where the API reader (reads only) node was overloaded.

- `LQHKEY_OVERLOAD_NODE_PEER`: Count of instances of `LQHKEY_OVERLOAD` where the next backup data node (writes only) was overloaded

- `LQHKEY_OVERLOAD_SUBSCRIBER`: Count of instances of `LQHKEY_OVERLOAD` where a event subscriber (writes only) was overloaded.

- `LQHSCAN_SLOWDOWNS`: Count of instances where a fragment scan batch size was reduced due to scanning API transporter overload.

17.5.10.8 The ndbinfo diskpagebuffer Table

The `diskpagebuffer` table provides statistics about disk page buffer usage by MySQL Cluster Disk Data tables.

The following table provides information about the columns in the `diskpagebuffer` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The data node ID
`block_instance`	integer	Block instance
`pages_written`	integer	Number of pages written to disk.
`pages_written_lcp`	integer	Number of pages written by local checkpoints.
`pages_read`	integer	Number of pages read from disk
`log_waits`	integer	Number of page writes waiting for log to be written to disk
`page_requests_direct_return`	integer	Number of requests for pages that were available in buffer
`page_requests_wait_queue`	integer	Number of requests that had to wait for pages to become available in buffer
`page_requests_wait_io`	integer	Number of requests that had to be read from pages on disk (pages were unavailable in buffer)

You can use this table with MySQL Cluster Disk Data tables to determine whether `DiskPageBufferMemory` is sufficiently large to allow data to be read from the buffer rather from disk; minimizing disk seeks can help improve performance of such tables.

You can determine the proportion of reads from `DiskPageBufferMemory` to the total number of reads using a query such as this one, which obtains this ratio as a percentage:

```
SELECT
  node_id,
  100 * page_requests_direct_return /
    (page_requests_direct_return + page_requests_wait_io)
      AS hit_ratio
FROM ndbinfo.diskpagebuffer;
```

The result from this query should be similar to what is shown here, with one row for each data node in the cluster (in this example, the cluster has 4 data nodes):

```
+---------+-----------+
| node_id | hit_ratio |
+---------+-----------+
|       5 |   97.6744 |
|       6 |   97.6879 |
|       7 |   98.1776 |
|       8 |   98.1343 |
+---------+-----------+
4 rows in set (0.00 sec)
```

`hit_ratio` values approaching 100% indicate that only a very small number of reads are being made from disk rather than from the buffer, which means that Disk Data read performance is approaching an optimum level. If any of these values are less than 95%, this is a strong indicator that the setting for `DiskPageBufferMemory` needs to be increased in the `config.ini` file.

Note

A change in `DiskPageBufferMemory` requires a rolling restart of all of the cluster's data nodes before it takes effect.

17.5.10.9 The ndbinfo logbuffers Table

The `logbuffer` table provides information on MySQL Cluster log buffer usage.

The following table provides information about the columns in the `logbuffers` table. For each column, the table shows the name, data type, and a brief description.

Column Name	Type	Description
node_id	integer	The ID of this data node.
log_type	string	Type of log; one of: `REDO` or `DD-UNDO`.
log_id	integer	The log ID.
log_part	integer	The log part number.
total	integer	Total space available for this log.
used	integer	Space used by this log.

17.5.10.10 The ndbinfo logspaces Table

This table provides information about MySQL Cluster log space usage.

The following table provides information about the columns in the `logspaces` table. For each column, the table shows the name, data type, and a brief description.

Column Name	Type	Description
`node_id`	integer	The ID of this data node.
`log_type`	string	Type of log; one of: `REDO` or `DD-UNDO`.
`log_id`	integer	The log ID.
`log_part`	integer	The log part number.
`total`	integer	Total space available for this log.
`used`	integer	Space used by this log.

17.5.10.11 The ndbinfo membership Table

The `membership` table describes the view that each data node has of all the others in the cluster, including node group membership, president node, arbitrator, arbitrator successor, arbitrator connection states, and other information.

The following table provides information about the columns in the `membership` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	This node's node ID
`group_id`	integer	Node group to which this node belongs
`left node`	integer	Node ID of the previous node
`right_node`	integer	Node ID of the next node
`president`	integer	President's node ID
`successor`	integer	Node ID of successor to president
`succession_order`	integer	Order in which this node succeeds to presidency
`Conf_HB_order`	integer	-
`arbitrator`	integer	Node ID of arbitrator
`arb_ticket`	string	Internal identifier used to track arbitration
`arb_state`	Enumeration (see text)	Arbitration state
`arb_connected`	`Yes` or `No`	Whether this node is connected to the arbitrator
`connected_rank1_arbs`	List of node IDs	Connected arbitrators of rank 1
`connected_rank2_arbs`	List of node IDs	Connected arbitrators of rank 1

The node ID and node group ID are the same as reported by `ndb_mgm -e "SHOW"`.

`left_node` and `right_node` are defined in terms of a model that connects all data nodes in a circle, in order of their node IDs, similar to the ordering of the numbers on a clock dial, as shown here:

Figure 17.9 Circular Arrangement of MySQL Cluster Nodes
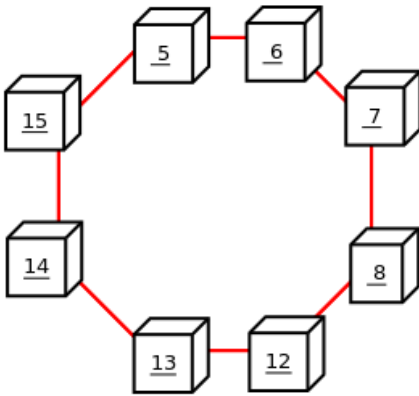
In this example, we have 8 data nodes, numbered 5, 6, 7, 8, 12, 13, 14, and 15, ordered clockwise in a circle. We determine "left" and "right" from the interior of the circle. The node to the left of node 5 is node 15, and the node to the right of node 5 is node 6. You can see all these relationships by running the following query and observing the output:

```
mysql> SELECT node_id,left_node,right_node
    -> FROM ndbinfo.membership;
+---------+-----------+------------+
| node_id | left_node | right_node |
+---------+-----------+------------+
|       5 |        15 |          6 |
|       6 |         5 |          7 |
|       7 |         6 |          8 |
|       8 |         7 |         12 |
|      12 |         8 |         13 |
|      13 |        12 |         14 |
|      14 |        13 |         15 |
|      15 |        14 |          5 |
+---------+-----------+------------+
8 rows in set (0.00 sec)
```

The designations "left" and "right" are used in the event log in the same way.

The `president` node is the node viewed by the current node as responsible for setting an arbitrator (see MySQL Cluster Start Phases). If the president fails or becomes disconnected, the current node expects the node whose ID is shown in the `successor` column to become the new president. The `succession_order` column shows the place in the succession queue that the current node views itself as having.

In a normal MySQL Cluster, all data nodes should see the same node as `president`, and the same node (other than the president) as its `successor`. In addition, the current president should see itself as `1` in the order of succession, the `successor` node should see itself as `2`, and so on.

All nodes should show the same `arb_ticket` values as well as the same `arb_state` values. Possible `arb_state` values are `ARBIT_NULL`, `ARBIT_INIT`, `ARBIT_FIND`, `ARBIT_PREP1`, `ARBIT_PREP2`, `ARBIT_START`, `ARBIT_RUN`, `ARBIT_CHOOSE`, `ARBIT_CRASH`, and `UNKNOWN`.

`arb_connected` shows whether this node is connected to the node shown as this node's `arbitrator`.

The `connected_rank1_arbs` and `connected_rank2_arbs` columns each display a list of 0 or more arbitrators having an `ArbitrationRank` equal to 1, or to 2, respectively.

> **Note**
>
> Both management nodes and API nodes are eligible to become arbitrators.

Like the `arbitrator_validity_detail` and `arbitrator_validity_summary` tables, this table was added in MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26.

17.5.10.12 The ndbinfo memoryusage Table

Querying this table provides information similar to that provided by the `ALL REPORT MemoryUsage` command in the `ndb_mgm` client, or logged by `ALL DUMP 1000`.

The following table provides information about the columns in the `memoryusage` table in MySQL Cluster NDB 7.1.3 and later. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The node ID of this data node.
`memory_type`	string	One of `Data memory`, `Index memory`, or (*MySQL Cluster NDB 7.1.31 and later*) `Long message buffer`.
`used`	integer	Number of bytes currently used for data memory or index memory by this data node.
`used_pages`	integer	Number of pages currently used for data memory or index memory by this data node; see text.
`total`	integer	Total number of bytes of data memory or index memory available for this data node; see text.
`total_pages`	integer	Total number of memory pages available for data memory or index memory on this data node; see text.

The `total` column represents the total amount of memory in bytes available for the given resource (data memory or index memory) on a particular data node. This number should be approximately equal to the setting of the corresponding configuration parameter in the `config.ini` file.

Suppose that the cluster has 2 data nodes having node IDs `5` and `6`, and the `config.ini` file contains the following:

```
[ndbd default]
DataMemory = 1G
IndexMemory = 1G
```

Suppose also that the value of the `LongMessageBuffer` configuration parameter is allowed to assume its default (64 MB in MySQL Cluster NDB 7.1.31 and later).

The following query shows approximately the same values:

```
mysql> SELECT node_id, memory_type, total
     > FROM ndbinfo.memoryusage;
```

```
+---------+---------------------+------------+
| node_id | memory_type         | total      |
+---------+---------------------+------------+
|       5 | Data memory         | 1073741824 |
|       5 | Index memory        | 1074003968 |
|       5 | Long message buffer |   67108864 |
|       6 | Data memory         | 1073741824 |
|       6 | Index memory        | 1074003968 |
|       6 | Long message buffer |   67108864 |
+---------+---------------------+------------+
6 rows in set (0.00 sec)
```

In this case, the `total` column values for index memory are slightly higher than the value set of `IndexMemory` due to internal rounding.

For the `used_pages` and `total_pages` columns, resources are measured in pages, which are 32K in size for `DataMemory` and 8K for `IndexMemory`. For long message buffer memory, the page size is 256 bytes.

Long message buffer information can be found in this table beginning with MySQL Cluster NDB 7.1.31; in earlier versions, only data memory and index memory were included.

MySQL Cluster NDB 7.1.2 and earlier.   The remainder of this section provides information about the `memoryusage` table as implemented prior to MySQL Cluster NDB 7.1.3. (If you are using MySQL Cluster NDB 7.1.3 or later, refer to the beginning of this section.) For each column, the table shown here provides the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	The node ID of this data node.
memory_type	string	One of `Data memory` or `Index memory`
used	integer	Number of memory pages used; see text.
max	integer	Total number of memory pages available; see text.

For the `used` and `max` columns, resources are measured in pages, which (in MySQL Cluster NDB 7.1.2 and earlier) are 16K in size for `DataMemory` and 8K for `IndexMemory`. This example shows how to use this information in obtaining totals for `DataMemory`, `IndexMemory`, or both, which you can do by summing across data nodes and table columns, like this:

```
mysql> USE ndbinfo;
Database changed
mysql> SET @IPAGE := 8 * 1024;
Query OK, 0 rows affected (0.03 sec)

mysql> SET @DPAGE := 2 * @IPAGE;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT
    ->      @DPAGE * SUM(used) as 'Total DataMemory Used',
    ->      @DPAGE * SUM(max) as 'Total DataMemory Available',
    ->      @DPAGE * SUM(used) DIV COUNT(*) as 'Average DataMemory Used Per Node',
    ->      @DPAGE * SUM(max) DIV COUNT(*) as 'Average DataMemory Available Per Node'
    ->          FROM memoryusage WHERE memory_type = 'Data memory'\G
*************************** 1. row ***************************
          Total DataMemory Used: 106102784
     Total DataMemory Available: 209977344
```

```
      Average DataMemory Used Per Node: 53051392
 Average DataMemory Available Per Node: 104988672
1 row in set (0.34 sec)

mysql> SELECT
    ->      @IPAGE * SUM(used) as 'Total IndexMemory Used',
    ->      @IPAGE * SUM(max) as 'Total IndexMemory Available',
    ->      @IPAGE * SUM(used) DIV COUNT(*) as 'Average IndexMemory Used Per Node',
    ->      @IPAGE * SUM(max) DIV COUNT(*) as 'Average IndexMemory Available Per Node'
    ->      FROM memoryusage WHERE memory_type = 'INDEX_MEMORY'\G
*************************** 1. row ***************************
             Total IndexMemory Used: 376832
        Total IndexMemory Available: 210239488
     Average IndexMemory Used Per Node: 188416
 Average IndexMemory Available Per Node: 105119744
1 row in set (0.33 sec)
```

(We use `DIV` rather than `/` in both queries so that the results in all of the output columns are integers.)

Prior to MySQL Cluster NDB 7.1.2, the `memory_type` column was named `DATA_MEMORY`. (Bug #50926)

17.5.10.13 The ndbinfo nodes Table

This table contains information on the status of data nodes. For each data node that is running in the cluster, a corresponding row in this table provides the node's node ID, status, and uptime. For nodes that are starting, it also shows the current start phase.

The following table provides information about the columns in the `nodes` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	The data node's unique node ID in the cluster.
uptime	integer	Time since the node was last started, in seconds.
status	string	Current status of the data node; see text for possible values.
start_phase	integer	If the data node is starting, the current start phase.
config_generation	integer	The version of the cluster configuration file in use on this data node.

The `uptime` column shows the time in seconds that this node has been running since it was last started or restarted. This is a `BIGINT` value. This figure includes the time actually needed to start the node; in other words, this counter starts running the moment that `ndbd` or `ndbmtd` is first invoked; thus, even for a node that has not yet finished starting, `uptime` may show a non-zero value.

The `status` column shows the node's current status. This is one of: `NOTHING`, `CMVMI`, `STARTING`, `STARTED`, `SINGLEUSER`, `STOPPING_1`, `STOPPING_2`, `STOPPING_3`, or `STOPPING_4`. When the status is `STARTING`, you can see the current start phase in the `start_phase` column (see later in this section). `SINGLEUSER` is displayed in the `status` column for all data nodes when the cluster is in single user mode (see Section 17.5.8, "MySQL Cluster Single User Mode"). Seeing one of the `STOPPING` states does not necessarily mean that the node is shutting down but can mean rather that it is entering a new state; for example, if you put the cluster in single user mode, you can sometimes see data nodes report their state briefly as `STOPPING_2` before the status changes to `SINGLEUSER`.

The `start_phase` column uses the same range of values as those used in the output of the `ndb_mgm` client *node_id* `STATUS` command (see Section 17.5.2, "Commands in the MySQL Cluster Management Client"). If the node is not currently starting, then this column shows `0`. For a listing of MySQL Cluster start phases with descriptions, see Section 17.5.1, "Summary of MySQL Cluster Start Phases".

The `config_generation` column was added in MySQL Cluster NDB 7.0.24 and MySQL Cluster NDB 7.1.13. This column shows which version of the cluster configuration is in effect on each data node. This can be useful when performing a rolling restart of the cluster in order to make changes in configuration parameters. For example, from the output of the following `SELECT` statement, you can see that node 3 is not yet using the latest version of the cluster configuration (`6`) although nodes 1, 2, and 4 are doing so:

```
mysql> USE ndbinfo;
Database changed
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 |  10462 | STARTED |           0 |                 6 |
|       2 |  10460 | STARTED |           0 |                 6 |
|       3 |  10457 | STARTED |           0 |                 5 |
|       4 |  10455 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
2 rows in set (0.04 sec)
```

Therefore, for the case just shown, you should restart node 3 to complete the rolling restart of the cluster.

> **Note**
>
> When upgrading to MySQL Cluster NDB 7.0.24 or MySQL Cluster NDB 7.1.13 from a previous version of MySQL Cluster, you should run `mysql_upgrade` on all MySQL Servers that should connect to the cluster, in order to enable support for the new `config_generation` column. Otherwise, when you attempt to access this table, you get the warning `Table 'ndb$nodes' is defined differently in NDB, there are more columns available...`

Nodes that are stopped are not accounted for in this table. Suppose that you have a MySQL Cluster with 4 data nodes (node IDs 1, 2, 3 and 4), and all nodes are running normally, then this table contains 4 rows, 1 for each data node:

```
mysql> USE ndbinfo;
Database changed
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 |  11776 | STARTED |           0 |                 6 |
|       2 |  11774 | STARTED |           0 |                 6 |
|       3 |  11771 | STARTED |           0 |                 6 |
|       4 |  11769 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
4 rows in set (0.04 sec)
```

If you shut down one of the nodes, only the nodes that are still running are represented in the output of this `SELECT` statement, as shown here:

```
ndb_mgm> 2 STOP
Node 2: Node shutdown initiated
Node 2: Node shutdown completed.
```

```
Node 2 has shutdown.
```

```
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 |  11807 | STARTED |           0 |                 6 |
|       3 |  11802 | STARTED |           0 |                 6 |
|       4 |  11800 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
3 rows in set (0.02 sec)
```

17.5.10.14 The ndbinfo pools Table

> **Important**
>
> This table was part of the original `ndbinfo` implementation, but was later removed (in MySQL Cluster NDB 7.1.3). The information in this section is now obsolete, and subject to removal in a future version of the documentation.

The `pools` table was originally intended to provide information about `NDB` memory pool usage, but was later removed.

For each column, this table shows the name, data type, and a brief description of each `ndbinfo.pools` column (as it appeared prior to MySQL Cluster NDB 7.1.3). Additional information can be found in the notes afterward.

Column Name	Type	Description
`node_id`	integer	The data node's node ID.
`block_name`	string	Name of the NDB kernel block using this pool.
`block_instance`	integer	Kernel block instance ID.
`pool_name`	string	The name of the pool.
`used`	integer	Amount of the pool in use.
`total`	integer	Total size of the pool.
`high`	integer	The maximum used from this pool (since the node was last started).
`entry_size`	integer	The size of each object, in bytes.
`param_name1`	string	Name of a configuration parameter associated with this pool (or `NULL`); see text.
`param_name2`	string	Name of a configuration parameter associated with this pool (or `NULL`); see text.
`param_name3`	string	Name of a configuration parameter associated with this pool (or `NULL`); see text.
`param_name4`	string	Name of a configuration parameter associated with this pool (or `NULL`); see text.

The columns `param_name1`, `param_name2`, `param_name3`, and `param_name4` contain names of configuration parameters that are associated with a given pool. If no parameters are associated with the pool, then all 4 of these columns are `NULL`. For pools that are associated with configuration parameters, these columns are filled with non-`NULL` values, but not in any particular order.

You can use a query such as the one shown here to generate a table showing the associations of pools, NDB kernel blocks, and (where applicable) configuration parameters:

```
SELECT
    DISTINCT(pool_name) as 'Pool',
    block_name as 'Block',
    IF(
        (param_name1 && param_name2 && param_name3 && param_name4) IS NULL,
        '[NONE]',
        REPLACE(
            TRIM(
                CONCAT(
                    IFNULL(param_name1, ''),
                    IFNULL(CONCAT(' ', param_name2), ''),
                    IFNULL(CONCAT(' ', param_name3), ''),
                    IFNULL(CONCAT(' ', param_name4), '')
                )
            ), ' ', ', '
        )
    ) as 'Parameter(s)'
FROM pools ORDER BY pool_name;
```

You may also find the following stored procedure useful. It returns a list of pools associated with a given configuration parameter, along with the kernel blocks to which these pools belong. You can see here the statement used to create this stored procedure along with sample output for some typical parameters:

```
mysql> DELIMITER |
mysql> CREATE PROCEDURE get_pools (p VARCHAR(50))
    -> BEGIN
    ->     SELECT
    ->         DISTINCT(pool_name) as Pool,
    ->         block_name as Block
    ->     FROM ndbinfo.pools
    ->     WHERE p
    ->         IN (param_name1, param_name2, param_name3, param_name4)
    .>     ORDER BY Pool;
    -> END
    -> |
Query OK, 0 rows affected (0.02 sec)

mysql> DELIMITER ;

mysql> CALL get_pools('MaxNoOfTables');
+-----------------+------------+
| pool_name       | block_name |
+-----------------+------------+
| Table Record    | DBDICT     |
| DictObject      | DBDICT     |
| Index           | DBTC       |
| Table           | BACKUP     |
| Trigger         | BACKUP     |
| Fragment        | BACKUP     |
| Subscriber      | SUMA       |
| Table           | SUMA       |
| Subscription    | SUMA       |
| Index           | DBTUX      |
| Descriptor page | DBTUX      |
+-----------------+------------+
11 rows in set (0.30 sec)

Query OK, 0 rows affected (0.30 sec)

mysql> CALL get_pools('MaxNoOfOrderedIndexes');
+-----------------+------------+
```

```
| pool_name       | block_name |
+-----------------+------------+
| DictObject      | DBDICT     |
| Index           | DBTC       |
| Table           | BACKUP     |
| Trigger         | BACKUP     |
| Fragment        | BACKUP     |
| Index           | DBTUX      |
| Fragment        | DBTUX      |
| Descriptor page | DBTUX      |
+-----------------+------------+
8 rows in set (0.29 sec)
```

17.5.10.15 The ndbinfo resources Table

This table provides information about data node resource availability and usage.

These resources are sometimes known as *super-pools*.

The following table provides information about the columns in the `resources` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	The unique node ID of this data node.
resource_name	string	Name of the resource; see text.
reserved	integer	The amount reserved for this resource.
used	integer	The amount actually used by this resource.
max	integer	The maximum amount of this resource used, since the node was last started.

The `resource_name` can be one of `RESERVED`, `DISK_OPERATIONS`, `DISK_RECORDS`, `DATA_MEMORY`, `JOBBUFFER`, `FILE_BUFFERS`, or `TRANSPORTER_BUFFERS`.

17.5.10.16 The ndbinfo server_operations Table

The `server_operations` table contains entries for all ongoing `NDB` operations that the current SQL node (MySQL Server) is currently involved in. It effectively is a subset of the `cluster_operations` table, in which operations for other SQL and API nodes are not shown.

The following table provides information about the columns in the `server_operations` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
mysql_connection_id	integer	MySQL Server connection ID
node_id	integer	Node ID
block_instance	integer	Block instance
transid	integer	Transaction ID
operation_type	string	Operation type (see text for possible values)
state	string	Operation state (see text for possible values)

Column Name	Type	Description
`tableid`	integer	Table ID
`fragmentid`	integer	Fragment ID
`client_node_id`	integer	Client node ID
`client_block_ref`	integer	Client block reference
`tc_node_id`	integer	Transaction coordinator node ID
`tc_block_no`	integer	Transaction coordinator block number
`tc_block_instance`	integer	Transaction coordinator block instance

The `mysql_connection_id` is the same as the connection or session ID shown in the output of `SHOW PROCESSLIST`. It is obtained from the `INFORMATION_SCHEMA` table `NDB_TRANSID_MYSQL_CONNECTION_MAP`.

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `operation_type` column can take any one of the values `READ`, `READ-SH`, `READ-EX`, `INSERT`, `UPDATE`, `DELETE`, `WRITE`, `UNLOCK`, `REFRESH`, `SCAN`, `SCAN-SH`, `SCAN-EX`, or `<unknown>`.

The `state` column can have any one of the values `ABORT_QUEUED`, `ABORT_STOPPED`, `COMMITTED`, `COMMIT_QUEUED`, `COMMIT_STOPPED`, `COPY_CLOSE_STOPPED`, `COPY_FIRST_STOPPED`, `COPY_STOPPED`, `COPY_TUPKEY`, `IDLE`, `LOG_ABORT_QUEUED`, `LOG_COMMIT_QUEUED`, `LOG_COMMIT_QUEUED_WAIT_SIGNAL`, `LOG_COMMIT_WRITTEN`, `LOG_COMMIT_WRITTEN_WAIT_SIGNAL`, `LOG_QUEUED`, `PREPARED`, `PREPARED_RECEIVED_COMMIT`, `SCAN_CHECK_STOPPED`, `SCAN_CLOSE_STOPPED`, `SCAN_FIRST_STOPPED`, `SCAN_RELEASE_STOPPED`, `SCAN_STATE_USED`, `SCAN_STOPPED`, `SCAN_TUPKEY`, `STOPPED`, `TC_NOT_CONNECTED`, `WAIT_ACC`, `WAIT_ACC_ABORT`, `WAIT_AI_AFTER_ABORT`, `WAIT_ATTR`, `WAIT_SCAN_AI`, `WAIT_TUP`, `WAIT_TUPKEYINFO`, `WAIT_TUP_COMMIT`, or `WAIT_TUP_TO_ABORT`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb$dblqh_tcconnect_state` table, which is normally hidden.)

You can obtain the name of an `NDB` table from its table ID by checking the output of `ndb_show_tables`.

The `fragid` is the same as the partition number seen in the output of `ndb_desc --extra-partition-info` (short form `-p`).

In `client_node_id` and `client_block_ref`, `client` refers to a MySQL Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

This table was added in MySQL Cluster NDB 7.1.17.

17.5.10.17 The ndbinfo server_transactions Table

The `server_transactions` table is subset of the `cluster_transactions` table, but includes only those transactions in which the current SQL node (MySQL Server) is a participant, while including the relevant connection IDs.

The following table provides information about the columns in the `server_transactions` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`mysql_connection_id`	integer	MySQL Server connection ID
`node_id`	integer	Transaction coordinator node ID
`block_instance`	integer	Transaction coordinator block instance
`transid`	integer	Transaction ID
`state`	string	Operation state (see text for possible values)
`count_operations`	integer	Number of stateful operations in the transaction
`outstanding_operations`	integer	Operations still being executed by local data management layer (LQH blocks)
`inactive_seconds`	integer	Time spent waiting for API
`client_node_id`	integer	Client node ID
`client_block_ref`	integer	Client block reference

The `mysql_connection_id` is the same as the connection or session ID shown in the output of `SHOW PROCESSLIST`. It is obtained from the `INFORMATION_SCHEMA` table `NDB_TRANSID_MYSQL_CONNECTION_MAP`.

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `state` column can have any one of the values `CS_ABORTING`, `CS_COMMITTING`, `CS_COMMIT_SENT`, `CS_COMPLETE_SENT`, `CS_COMPLETING`, `CS_CONNECTED`, `CS_DISCONNECTED`, `CS_FAIL_ABORTED`, `CS_FAIL_ABORTING`, `CS_FAIL_COMMITTED`, `CS_FAIL_COMMITTING`, `CS_FAIL_COMPLETED`, `CS_FAIL_PREPARED`, `CS_PREPARE_TO_COMMIT`, `CS_RECEIVING`, `CS_REC_COMMITTING`, `CS_RESTART`, `CS_SEND_FIRE_TRIG_REQ`, `CS_STARTED`, `CS_START_COMMITTING`, `CS_START_SCAN`, `CS_WAIT_ABORT_CONF`, `CS_WAIT_COMMIT_CONF`, `CS_WAIT_COMPLETE_CONF`, `CS_WAIT_FIRE_TRIG_REQ`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb$dbtc_apiconnect_state` table, which is normally hidden.)

In `client_node_id` and `client_block_ref`, `client` refers to a MySQL Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

This table was added in MySQL Cluster NDB 7.1.17.

17.5.10.18 The ndbinfo threadblocks Table

The `threadblocks` table associates data nodes, threads, and instances of `NDB` kernel blocks.

The following table provides information about the columns in the `threadblocks` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	Node ID
`thr_no`	integer	Thread ID
`block_name`	string	Block name

Column Name	Type	Description
`block_instance`	integer	Block instance number

The `block_name` is one of the values found in the `block_name` column when selecting from the `ndbinfo.blocks` table. Although the list of possible values is static for a given MySQL Cluster release, the list may vary between releases.

This table was added in MySQL Cluster NDB 7.1.17.

17.5.10.19 The ndbinfo threadstat Table

The `threadstat` table provides a rough snapshot of statistics for threads running in the `NDB` kernel.

The following table provides information about the columns in the `threadstat` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	Node ID
`thr_no`	integer	Thread ID
`thr_nm`	string	Thread name
`c_loop`	string	Number of loops in main loop
`c_exec`	string	Number of signals executed
`c_wait`	string	Number of times waiting for additional input
`c_l_sent_prioa`	integer	Number of priority A signals sent to own node
`c_l_sent_priob`	integer	Number of priority B signals sent to own node
`c_r_sent_prioa`	integer	Number of priority A signals sent to remote node
`c_r_sent_priob`	integer	Number of priority B signals sent to remote node
`os_tid`	integer	OS thread ID
`os_now`	integer	OS time (ms)
`os_ru_utime`	integer	OS user CPU time (µs)
`os_ru_stime`	integer	OS system CPU time (µs)
`os_ru_minflt`	integer	OS page reclaims (soft page faults)
`os_ru_majflt`	integer	OS page faults (hard page faults)
`os_ru_nvcsw`	integer	OS voluntary context switches
`os_ru_nivcsw`	integer	OS involuntary context switches

`os_time` uses the system `gettimeofday()` call.

The values of the `os_ru_utime`, `os_ru_stime`, `os_ru_minflt`, `os_ru_majflt`, `os_ru_nvcsw`, and `os_ru_nivcsw` columns are obtained using the system `getrusage()` call, or the equivalent.

Since this table contains counts taken at a given point in time, for best results it is necessary to query this table periodically and store the results in an intermediate table or tables. The MySQL Server's Event

Scheduler can be employed to automate such monitoring. For more information, see Section 19.4, "Using the Event Scheduler".

This table was added in MySQL Cluster NDB 7.1.17.

17.5.10.20 The ndbinfo transporters Table

This table contains information about `NDB` transporters.

The following table provides information about the columns in the `transporters` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	This data node's unique node ID in the cluster.
`remote_node_id`	integer	The remote data node's node ID.
`status`	string	Status of the connection.
`remote_address`	string	Name or IP address of the remote host
`bytes_sent`	integer	Number of bytes sent using this connection
`bytes_received`		Number of bytes received using this connection
`connect_count`		Number of times connection established on this transporter
`overloaded`		1 if this transporter is currently overloaded, otherwise 0
`overload_count`		Number of times this transporter has entered overload state since connecting
`slowdown`		1 if this transporter is in scan slowdown state, otherwise 0
`slowdown_count`		Number of times this transporter has entered scan slowdown state since connecting

For each running data node in the cluster, the `transporters` table displays a row showing the status of each of that node's connections with all nodes in the cluster, *including itself*. This information is shown in the table's *status* column, which can have any one of the following values: `CONNECTING`, `CONNECTED`, `DISCONNECTING`, or `DISCONNECTED`.

Connections to API and management nodes which are configured but not currently connected to the cluster are shown with status `DISCONNECTED`. Rows where the `node_id` is that of a data nodes which is not currently connected are not shown in this table. (This is similar omission of disconnected nodes in the `ndbinfo.nodes` table.

The `remote_address`, `bytes_sent`, and `bytes_received` columns were added in MySQL Cluster NDB 7.0.36 and MySQL Cluster NDB 7.1.25. The `remote_address` is the host name or address for the node whose ID is shown in the `remote_node_id` column. The `bytes_sent` from this node and `bytes_received` by this node are the numbers, respectively, of bytes sent and received by the node using this connection since it was established; for nodes whose status is `CONNECTING` or `DISCONNECTED`, these columns always display `0`.

The `connect_count`, `overloaded`, `overload_count` ,`slowdown`, and `slowdown_count` columns were added in MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26. These counters are reset on

connection, and retain their values after the remote node disconnects. Also beginning with MySQL Cluster NDB 7.0.37 and MySQL Cluster NDB 7.1.26, the `bytes_send` and `bytes_received` counters are reset on connection as well, and so retain their values following disconnection. (Previously, the values in these columns were reset on disconnection.) (Bug #15935206)

Assume you have a 5-node cluster consisting of 2 data nodes, 2 SQL nodes, and 1 management node, as shown in the output of the `SHOW` command in the `ndb_mgm` client:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @10.100.10.1  (5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=2    @10.100.10.2  (5.1.77-ndb-7.1.37, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @10.100.10.10  (5.1.77-ndb-7.1.37)

[mysqld(API)]    2 node(s)
id=20   @10.100.10.20  (5.1.77-ndb-7.1.37)
id=21   @10.100.10.21  (5.1.77-ndb-7.1.37)
```

There are 10 rows in the `transporters` table—5 for the first data node, and 5 for the second—assuming that all data nodes are running, as shown here:

```
mysql> SELECT node_id, remote_node_id, status
    ->   FROM ndbinfo.transporters;
+---------+----------------+--------------+
| node_id | remote_node_id | status       |
+---------+----------------+--------------+
|       1 |              1 | DISCONNECTED |
|       1 |              2 | CONNECTED    |
|       1 |             10 | CONNECTED    |
|       1 |             20 | CONNECTED    |
|       1 |             21 | CONNECTED    |
|       2 |              1 | CONNECTED    |
|       2 |              2 | DISCONNECTED |
|       2 |             10 | CONNECTED    |
|       2 |             20 | CONNECTED    |
|       2 |             21 | CONNECTED    |
+---------+----------------+--------------+
10 rows in set (0.04 sec)
```

If you shut down one of the data nodes in this cluster using the command `2 STOP` in the `ndb_mgm` client, then repeat the previous query (again using the `mysql` client), this table now shows only 5 rows—1 row for each connection from the remaining management node to another node, including both itself and the data node that is currently offline—and displays `CONNECTING` for the status of each remaining connection to the data node that is currently offline, as shown here:

```
mysql> SELECT node_id, remote_node_id, status
    ->   FROM ndbinfo.transporters;
+---------+----------------+--------------+
| node_id | remote_node_id | status       |
+---------+----------------+--------------+
|       1 |              1 | DISCONNECTED |
|       1 |              2 | CONNECTING   |
|       1 |             10 | CONNECTED    |
|       1 |             20 | CONNECTED    |
|       1 |             21 | CONNECTED    |
```

```
+---------+----------------+---------------+
5 rows in set (0.02 sec)
```

17.5.11 MySQL Cluster Security Issues

This section discusses security considerations to take into account when setting up and running MySQL Cluster.

Topics covered in this section include the following:

• MySQL Cluster and network security issues

• Configuration issues relating to running MySQL Cluster securely

• MySQL Cluster and the MySQL privilege system

• MySQL standard security procedures as applicable to MySQL Cluster

17.5.11.1 MySQL Cluster Security and Networking Issues

In this section, we discuss basic network security issues as they relate to MySQL Cluster. It is extremely important to remember that MySQL Cluster "out of the box" is not secure; you or your network administrator must take the proper steps to ensure that your cluster cannot be compromised over the network.

Cluster communication protocols are inherently insecure, and no encryption or similar security measures are used in communications between nodes in the cluster. Because network speed and latency have a direct impact on the cluster's efficiency, it is also not advisable to employ SSL or other encryption to network connections between nodes, as such schemes will effectively slow communications.

It is also true that no authentication is used for controlling API node access to a MySQL Cluster. As with encryption, the overhead of imposing authentication requirements would have an adverse impact on Cluster performance.

In addition, there is no checking of the source IP address for either of the following when accessing the cluster:

• SQL or API nodes using "free slots" created by empty `[mysqld]` or `[api]` sections in the `config.ini` file

  This means that, if there are any empty `[mysqld]` or `[api]` sections in the `config.ini` file, then any API nodes (including SQL nodes) that know the management server's host name (or IP address) and port can connect to the cluster and access its data without restriction. (See Section 17.5.11.2, "MySQL Cluster and MySQL Privileges", for more information about this and related issues.)

> **Note**
>
> You can exercise some control over SQL and API node access to the cluster by specifying a `HostName` parameter for all `[mysqld]` and `[api]` sections in the `config.ini` file. However, this also means that, should you wish to connect an API node to the cluster from a previously unused host, you need to add an `[api]` section containing its host name to the `config.ini` file.
>
> More information is available elsewhere in this chapter about the `HostName` parameter. Also see Section 17.3.1, "Quick Test Setup of MySQL Cluster", for configuration examples using `HostName` with API nodes.

- Any `ndb_mgm` client

  This means that any cluster management client that is given the management server's host name (or IP address) and port (if not the standard port) can connect to the cluster and execute any management client command. This includes commands such as `ALL STOP` and `SHUTDOWN`.

For these reasons, it is necessary to protect the cluster on the network level. The safest network configuration for Cluster is one which isolates connections between Cluster nodes from any other network communications. This can be accomplished by any of the following methods:

1. Keeping Cluster nodes on a network that is physically separate from any public networks. This option is the most dependable; however, it is the most expensive to implement.

   We show an example of a MySQL Cluster setup using such a physically segregated network here:

   Figure 17.10 MySQL Cluster with Hardware Firewall
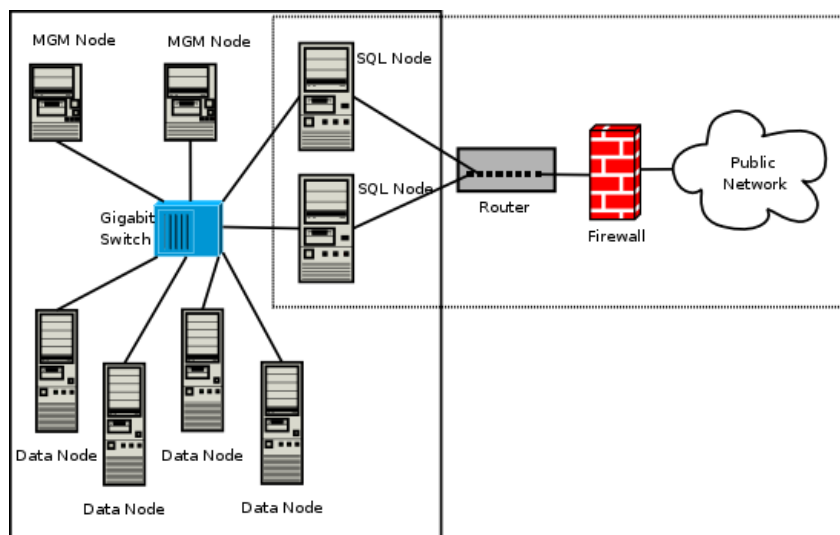
   This setup has two networks, one private (solid box) for the Cluster management servers and data nodes, and one public (dotted box) where the SQL nodes reside. (We show the management and data nodes connected using a gigabit switch since this provides the best performance.) Both networks are protected from the outside by a hardware firewall, sometimes also known as a *network-based firewall*.

   This network setup is safest because no packets can reach the cluster's management or data nodes from outside the network—and none of the cluster's internal communications can reach the outside —without going through the SQL nodes, as long as the SQL nodes do not permit any packets to be forwarded. This means, of course, that all SQL nodes must be secured against hacking attempts.

   > **Important**
   >
   > With regard to potential security vulnerabilities, an SQL node is no different from any other MySQL server. See Section 6.1.3, "Making MySQL Secure Against Attackers", for a description of techniques you can use to secure MySQL servers.

2. Using one or more software firewalls (also known as *host-based firewalls*) to control which packets pass through to the cluster from portions of the network that do not require access to it. In this type of setup, a software firewall must be installed on every host in the cluster which might otherwise be accessible from outside the local network.

The host-based option is the least expensive to implement, but relies purely on software to provide protection and so is the most difficult to keep secure.

This type of network setup for MySQL Cluster is illustrated here:

Figure 17.11 MySQL Cluster with Software Firewalls
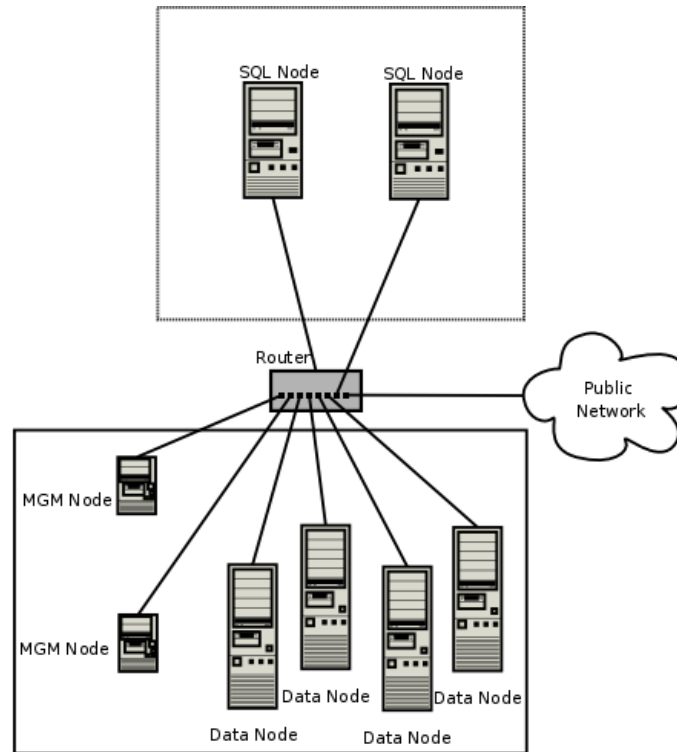
Using this type of network setup means that there are two zones of MySQL Cluster hosts. Each cluster host must be able to communicate with all of the other machines in the cluster, but only those hosting SQL nodes (dotted box) can be permitted to have any contact with the outside, while those in the zone containing the data nodes and management nodes (solid box) must be isolated from any machines that are not part of the cluster. Applications using the cluster and user of those applications must *not* be permitted to have direct access to the management and data node hosts.

To accomplish this, you must set up software firewalls that limit the traffic to the type or types shown in the following table, according to the type of node that is running on each cluster host computer:

Type of Node to be Accessed	Traffic to Permit
SQL or API node	• It originates from the IP address of a management or data node (using any TCP or UDP port). • It originates from within the network in which the cluster resides and is on the port that your application is using.
Data node or Management node	• It originates from the IP address of a management or data node (using any TCP or UDP port). • It originates from the IP address of an SQL or API node.

Any traffic other than that shown in the table for a given node type should be denied.

The specifics of configuring a firewall vary from firewall application to firewall application, and are beyond the scope of this Manual. `iptables` is a very common and reliable firewall application, which is often used with `APF` as a front end to make configuration easier. You can (and should) consult the documentation for the software firewall that you employ, should you choose to implement a MySQL Cluster network setup of this type, or of a "mixed" type as discussed under the next item.

3. It is also possible to employ a combination of the first two methods, using both hardware and software to secure the cluster—that is, using both network-based and host-based firewalls. This is between the first two schemes in terms of both security level and cost. This type of network setup keeps the cluster behind the hardware firewall, but permits incoming packets to travel beyond the router connecting all cluster hosts to reach the SQL nodes.

One possible network deployment of a MySQL Cluster using hardware and software firewalls in combination is shown here:

Figure 17.12 MySQL Cluster with a Combination of Hardware and Software Firewalls
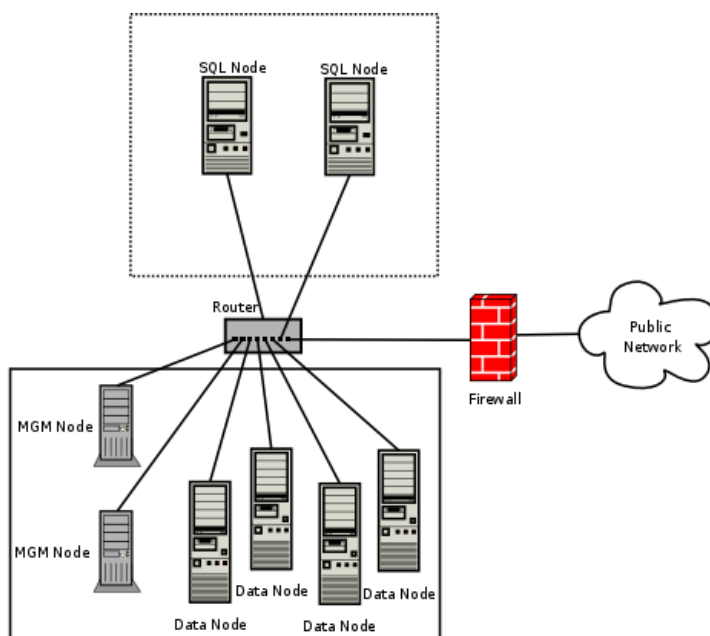
In this case, you can set the rules in the hardware firewall to deny any external traffic except to SQL nodes and API nodes, and then permit traffic to them only on the ports required by your application.

Whatever network configuration you use, remember that your objective from the viewpoint of keeping the cluster secure remains the same—to prevent any unessential traffic from reaching the cluster while ensuring the most efficient communication between the nodes in the cluster.

Because MySQL Cluster requires large numbers of ports to be open for communications between nodes, the recommended option is to use a segregated network. This represents the simplest way to prevent unwanted traffic from reaching the cluster.

Note

If you wish to administer a MySQL Cluster remotely (that is, from outside the local network), the recommended way to do this is to use `ssh` or another secure

> login shell to access an SQL node host. From this host, you can then run the management client to access the management server safely, from within the Cluster's own local network.
>
> Even though it is possible to do so in theory, it is *not* recommended to use `ndb_mgm` to manage a Cluster directly from outside the local network on which the Cluster is running. Since neither authentication nor encryption takes place between the management client and the management server, this represents an extremely insecure means of managing the cluster, and is almost certain to be compromised sooner or later.

17.5.11.2 MySQL Cluster and MySQL Privileges

In this section, we discuss how the MySQL privilege system works in relation to MySQL Cluster and the implications of this for keeping a MySQL Cluster secure.

Standard MySQL privileges apply to MySQL Cluster tables. This includes all MySQL privilege types (`SELECT` privilege, `UPDATE` privilege, `DELETE` privilege, and so on) granted on the database, table, and column level. As with any other MySQL Server, user and privilege information is stored in the `mysql` system database. The SQL statements used to grant and revoke privileges on `NDB` tables, databases containing such tables, and columns within such tables are identical in all respects with the `GRANT` and `REVOKE` statements used in connection with database objects involving any (other) MySQL storage engine. The same thing is true with respect to the `CREATE USER` and `DROP USER` statements.

It is important to keep in mind that, by default, the MySQL grant tables use the `MyISAM` storage engine. Because of this, those tables are not duplicated or shared among MySQL servers acting as SQL nodes in a MySQL Cluster. By way of example, suppose that two SQL nodes **A** and **B** are connected to the same MySQL Cluster, which has an `NDB` table named `mytable` in a database named `mydb`, and that you execute an SQL statement on server **A** that creates a new user `jon@localhost` and grants this user the `SELECT` privilege on that table:

```
mysql> GRANT SELECT ON mydb.mytable
    ->    TO jon@localhost IDENTIFIED BY 'mypass';
```

This user is *not* created on server **B**. For this to take place, the statement must also be run on server **B**. Similarly, statements run on server **A** and affecting the privileges of existing users on server **A** do not affect users on server **B** unless those statements are actually run on server **B** as well.

In other words, *changes in users and their privileges do not automatically propagate between SQL nodes by default*. Prior to MySQL Cluster NDB 7.2, any synchronization of privileges between SQL nodes must be done either manually or by scripting an application that periodically synchronizes the privilege tables on all SQL nodes in the cluster. In MySQL Cluster NDB 7.2 and later, you can enable automatic distribution of MySQL users and privileges across MySQL Cluster SQL nodes; see Section 17.5.14, "Distributed MySQL Privileges for MySQL Cluster", for details.

Conversely, because there is no way in MySQL to deny privileges (privileges can either be revoked or not granted in the first place, but not denied as such), there is no special protection for `NDB` tables on one SQL node from users that have privileges on another SQL node. (This is true even if you are not using the automatic distribution of user privileges available in MySQl Cluster NDB 7.2 and later.) The most far-reaching example of this is the MySQL `root` account, which can perform any action on any database object. In combination with empty `[mysqld]` or `[api]` sections of the `config.ini` file, this account can be especially dangerous. To understand why, consider the following scenario:

- The `config.ini` file contains at least one empty `[mysqld]` or `[api]` section. This means that the MySQL Cluster management server performs no checking of the host from which a MySQL Server (or other API node) accesses the MySQL Cluster.

- There is no firewall, or the firewall fails to protect against access to the MySQL Cluster from hosts external to the network.

- The host name or IP address of the MySQL Cluster's management server is known or can be determined from outside the network.

If these conditions are true, then anyone, anywhere can start a MySQL Server with `--ndbcluster --ndb-connectstring=`*`management_host`* and access this MySQL Cluster. Using the MySQL `root` account, this person can then perform the following actions:

- Execute a `SHOW DATABASES` statement to obtain a list of all `NDB` databases

- Execute a `SHOW TABLES FROM` *`some_database`* statement to obtain a list of all `NDB` tables in a given database

- Run any legal MySQL statements on any of those tables, such as:

  - `SELECT * FROM` *`some_table`* to read all the data from any table

  - `DELETE FROM` *`some_table`* to delete all the data from a table

  - `DESCRIBE` *`some_table`* or `SHOW CREATE TABLE` *`some_table`* to determine the table schema

  - `UPDATE` *`some_table`* `SET` *`column1`* `=` *`some_value`* to fill a table column with "garbage" data; this could actually cause much greater damage than simply deleting all the data

    More insidious variations might include statements like these:

    ```
    UPDATE some_table SET an_int_column = an_int_column + 1
    ```

    or

    ```
    UPDATE some_table SET a_varchar_column = REVERSE(a_varchar_column)
    ```

    Such malicious statements are limited only by the imagination of the attacker.

The only tables that would be safe from this sort of mayhem would be those tables that were created using storage engines other than `NDB`, and so not visible to a "rogue" SQL node.

> **Note**
>
> A user who can log in as `root` can also access the `INFORMATION_SCHEMA` database and its tables, and so obtain information about databases, tables, stored routines, scheduled events, and any other database objects for which metadata is stored in `INFORMATION_SCHEMA`.

It is also a very good idea to use different passwords for the `root` accounts on different cluster SQL nodes (unless you are using distributed privileges as supported in MySQL Cluster NDB 7.2 and later).

In sum, you cannot have a safe MySQL Cluster if it is directly accessible from outside your local network.

> **Important**
>
> *Never leave the MySQL root account password empty.* This is just as true when running MySQL as a MySQL Cluster SQL node as it is when running it as a standalone (non-Cluster) MySQL Server, and should be done as part of the MySQL

> installation process before configuring the MySQL Server as an SQL node in a MySQL Cluster.

Prior to MySQL Cluster NDB 7.2, you should never convert the system tables in the `mysql` database to use the `NDB` storage engine. There are a number of reasons why you should not do this, but the most important reason is this: *Many of the SQL statements that affect `mysql` tables storing information about user privileges, stored routines, scheduled events, and other database objects cease to function if these tables are changed to use any storage engine other than `MyISAM`.* This is a consequence of various MySQL Server internals. Beginning with MySQL Cluster NDB 7.2, you can use a stored procedure provided for this purpose (see Section 17.5.14, "Distributed MySQL Privileges for MySQL Cluster"), but you are strongly advised not to attempt convert the system tables manually.

Otherwise, if you need to synchronize `mysql` system tables between SQL nodes, you can use standard MySQL replication to do so, or employ a script to copy table entries between the MySQL servers.

Summary. The two most important points to remember regarding the MySQL privilege system with regard to MySQL Cluster are:

1. **Prior to MySQL Cluster NDB 7.2.** Users and privileges established on one SQL node do not automatically exist or take effect on other SQL nodes in the cluster. Conversely, removing a user or privilege on one SQL node in the cluster does not remove the user or privilege from any other SQL nodes.

   In MySQL Cluster NDB 7.2 and later. You can distribute MySQL users and privileges among SQL nodes using the SQL script, and the stored procedures it contains, that are supplied for this purpose in the MySQL Cluster distribution.

2. Once a MySQL user is granted privileges on an `NDB` table from one SQL node in a MySQL Cluster, that user can "see" any data in that table regardless of the SQL node from which the data originated. (This is true even if you are not using the privilege distribution support available in MySQl Cluster NDB 7.2 or later.)

17.5.11.3 MySQL Cluster and MySQL Security Procedures

In this section, we discuss MySQL standard security procedures as they apply to running MySQL Cluster.

In general, any standard procedure for running MySQL securely also applies to running a MySQL Server as part of a MySQL Cluster. First and foremost, you should always run a MySQL Server as the `mysql` system user; this is no different from running MySQL in a standard (non-Cluster) environment. The `mysql` system account should be uniquely and clearly defined. Fortunately, this is the default behavior for a new MySQL installation. You can verify that the `mysqld` process is running as the system user `mysql` by using the system command such as the one shown here:

```
shell> ps aux | grep mysql
root     10467  0.0  0.1   3616  1380 pts/3    S    11:53   0:00 \
  /bin/sh ./mysqld_safe --ndbcluster --ndb-connectstring=localhost:1186
mysql    10512  0.2  2.5  58528 26636 pts/3    Sl   11:53   0:00 \
  /usr/local/mysql/libexec/mysqld --basedir=/usr/local/mysql \
  --datadir=/usr/local/mysql/var --user=mysql --ndbcluster \
  --ndb-connectstring=localhost:1186 --pid-file=/usr/local/mysql/var/mothra.pid \
  --log-error=/usr/local/mysql/var/mothra.err
jon      10579  0.0  0.0   2736   688 pts/0    S+   11:54   0:00 grep mysql
```

If the `mysqld` process is running as any other user than `mysql`, you should immediately shut it down and restart it as the `mysql` user. If this user does not exist on the system, the `mysql` user account should be created, and this user should be part of the `mysql` user group; in this case, you should also make sure that the MySQL data directory on this system (as set using the `--datadir` option for `mysqld`) is owned

by the `mysql` user, and that the SQL node's `my.cnf` file includes `user=mysql` in the `[mysqld]` section. Alternatively, you can start the MySQL server process with `--user=mysql` on the command line, but it is preferable to use the `my.cnf` option, since you might forget to use the command-line option and so have `mysqld` running as another user unintentionally. The `mysqld_safe` startup script forces MySQL to run as the `mysql` user.

> **Important**
>
> Never run `mysqld` as the system root user. Doing so means that potentially any file on the system can be read by MySQL, and thus—should MySQL be compromised—by an attacker.

As mentioned in the previous section (see Section 17.5.11.2, "MySQL Cluster and MySQL Privileges"), you should always set a root password for the MySQL Server as soon as you have it running. You should also delete the anonymous user account that is installed by default. You can accomplish these tasks using the following statements:

```
shell> mysql -u root

mysql> UPDATE mysql.user
    ->     SET Password=PASSWORD('secure_password')
    ->     WHERE User='root';

mysql> DELETE FROM mysql.user
    ->     WHERE User='';

mysql> FLUSH PRIVILEGES;
```

Be very careful when executing the `DELETE` statement not to omit the `WHERE` clause, or you risk deleting *all* MySQL users. Be sure to run the `FLUSH PRIVILEGES` statement as soon as you have modified the `mysql.user` table, so that the changes take immediate effect. Without `FLUSH PRIVILEGES`, the changes do not take effect until the next time that the server is restarted.

> **Note**
>
> Many of the MySQL Cluster utilities such as `ndb_show_tables`, `ndb_desc`, and `ndb_select_all` also work without authentication and can reveal table names, schemas, and data. By default these are installed on Unix-style systems with the permissions `wxr-xr-x` (755), which means they can be executed by any user that can access the `mysql/bin` directory.
>
> See Section 17.4, "MySQL Cluster Programs", for more information about these utilities.

17.5.12 MySQL Cluster Disk Data Tables

Beginning with MySQL 5.1.6, it is possible to store the nonindexed columns of `NDB` tables on disk, rather than in RAM as with previous versions of MySQL Cluster.

As part of implementing MySQL Cluster Disk Data work, a number of improvements were made in MySQL Cluster for the efficient handling of very large amounts (terabytes) of data during node recovery and restart. These include a "no-steal" algorithm for synchronizing a starting node with very large data sets. For more information, see the paper *Recovery Principles of MySQL Cluster 5.1*, by MySQL Cluster developers Mikael Ronström and Jonas Oreland.

MySQL Cluster Disk Data performance can be influenced by a number of configuration parameters. For information about these parameters and their effects, see *MySQL Cluster Disk Data configuration parameters* and *MySQL Cluster Disk Data storage and* `GCP Stop` *errors*

The performance of a MySQL Cluster that uses Disk Data storage can also be greatly improved by separating data node file systems from undo log files and tablespace data files, which can be done using symbolic links. For more information, see Section 17.5.12.2, "Using Symbolic Links with Disk Data Objects".

17.5.12.1 MySQL Cluster Disk Data Objects

MySQL Cluster Disk Data storage is implemented using a number of *Disk Data objects*. These include the following:

- *Tablespaces* act as containers for other Disk Data objects.

- *Undo log files* undo information required for rolling back transactions.

- One or more undo log files are assigned to a *log file group*, which is then assigned to a tablespace.

- *Data files* store Disk Data table data. A data file is assigned directly to a tablespace.

Undo log files and data files are actual files in the file system of each data node; by default they are placed in `ndb_node_id_fs` in the `DataDir` specified in the MySQL Cluster `config.ini` file, and where `node_id` is the data node's node ID. It is possible to place these elsewhere by specifying either an absolute or relative path as part of the filename when creating the undo log or data file. Statements that create these files are shown later in this section.

MySQL Cluster tablespaces and log file groups are not implemented as files.

> **Important**
>
> Although not all Disk Data objects are implemented as files, they all share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group both named `dd1`.

Assuming that you have already set up a MySQL Cluster with all nodes (including management and SQL nodes) running MySQL 5.1.6 or newer, the basic steps for creating a Cluster table on disk are as follows:

1. Create a log file group, and assign one or more undo log files to it (an undo log file is also sometimes referred to as an *undofile*).

   > **Note**
   >
   > In MySQL 5.1 and later, undo log files are necessary only for Disk Data tables. They are no longer used for `NDBCLUSTER` tables that are stored only in memory.

2. Create a tablespace; assign the log file group, as well as one or more data files, to the tablespace.

3. Create a Disk Data table that uses this tablespace for data storage.

Each of these tasks can be accomplished using SQL statements in the `mysql` client or other MySQL client application, as shown in the example that follows.

1. We create a log file group named `lg_1` using `CREATE LOGFILE GROUP`. This log file group is to be made up of two undo log files, which we name `undo_1.log` and `undo_2.log`, whose initial sizes are 16 MB and 12 MB, respectively. (The default initial size for an undo log file is 128 MB.) Optionally, you can also specify a size for the log file group's undo buffer, or permit it to assume the default value of 8 MB. In this example, we set the UNDO buffer's size at 2 MB. A log file group must be created with an undo log file; so we add `undo_1.log` to `lg_1` in this `CREATE LOGFILE GROUP` statement:

```
CREATE LOGFILE GROUP lg_1
    ADD UNDOFILE 'undo_1.log'
    INITIAL_SIZE 16M
    UNDO_BUFFER_SIZE 2M
    ENGINE NDBCLUSTER;
```

To add `undo_2.log` to the log file group, use the following `ALTER LOGFILE GROUP` statement:

```
ALTER LOGFILE GROUP lg_1
    ADD UNDOFILE 'undo_2.log'
    INITIAL_SIZE 12M
    ENGINE NDBCLUSTER;
```

Some items of note:

- The `.log` file extension used here is not required. We use it merely to make the log files easily recognizable.

- Every `CREATE LOGFILE GROUP` and `ALTER LOGFILE GROUP` statement must include an `ENGINE` clause. In MySQL 5.1 (including MySQL Cluster NDB 6.X and 7.X through 7.1), the permitted values for this clause are `NDBCLUSTER` and `NDB`.

    > **Important**
    >
    > In MySQL 5.1.8 and later, there can exist only one log file group in the same MySQL Cluster at any given time.

- When you add an undo log file to a log file group using `ADD UNDOFILE 'filename'`, a file with the name `filename` is created in the `ndb_node_id_fs` directory within the `DataDir` of each data node in the cluster, where `node_id` is the node ID of the data node. Each undo log file is of the size specified in the SQL statement. For example, if a MySQL Cluster has 4 data nodes, then the `ALTER LOGFILE GROUP` statement just shown creates 4 undo log files, 1 each on in the data directory of each of the 4 data nodes; each of these files is named `undo_2.log` and each file is 12 MB in size.

- `UNDO_BUFFER_SIZE` is limited by the amount of system memory available.

- For more information about the `CREATE LOGFILE GROUP` statement, see Section 13.1.14, "CREATE LOGFILE GROUP Syntax". For more information about `ALTER LOGFILE GROUP`, see Section 13.1.3, "ALTER LOGFILE GROUP Syntax".

2. Now we can create a tablespace, which contains files to be used by MySQL Cluster Disk Data tables for storing their data. A tablespace is also associated with a particular log file group. When creating a new tablespace, you must specify the log file group which it is to use for undo logging; you must also specify a data file. You can add more data files to the tablespace after the tablespace is created; it is also possible to drop data files from a tablespace (an example of dropping data files is provided later in this section).

    Assume that we wish to create a tablespace named `ts_1` which uses `lg_1` as its log file group. This tablespace is to contain two data files named `data_1.dat` and `data_2.dat`, whose initial sizes are 32 MB and 48 MB, respectively. (The default value for `INITIAL_SIZE` is 128 MB.) We can do this using two SQL statements, as shown here:

```
CREATE TABLESPACE ts_1
    ADD DATAFILE 'data_1.dat'
    USE LOGFILE GROUP lg_1
    INITIAL_SIZE 32M
    ENGINE NDBCLUSTER;
```

```
ALTER TABLESPACE ts_1
    ADD DATAFILE 'data_2.dat'
    INITIAL_SIZE 48M
    ENGINE NDBCLUSTER;
```

The `CREATE TABLESPACE` statement creates a tablespace `ts_1` with the data file `data_1.dat`, and associates `ts_1` with log file group `lg_1`. The `ALTER TABLESPACE` adds the second data file (`data_2.dat`).

Some items of note:

- As is the case with the `.log` file extension used in this example for undo log files, there is no special significance for the `.dat` file extension; it is used merely for easy recognition of data files.

- When you add a data file to a tablespace using `ADD DATAFILE 'filename'`, a file with the name `filename` is created in the `ndb_node_id_fs` directory within the `DataDir` of each data node in the cluster, where `node_id` is the node ID of the data node. Each data file is of the size specified in the SQL statement. For example, if a MySQL Cluster has 4 data nodes, then the `ALTER TABLESPACE` statement just shown creates 4 data files, 1 each in the data directory of each of the 4 data nodes; each of these files is named `data_2.dat` and each file is 48 MB in size.

- All `CREATE TABLESPACE` and `ALTER TABLESPACE` statements must contain an `ENGINE` clause; only tables using the same storage engine as the tablespace can be created in the tablespace. In MySQL 5.1 (including MySQL Cluster NDB 6.X and 7.X through 7.1), the only permitted values for this clause are `NDBCLUSTER` and `NDB`.

- For more information about the `CREATE TABLESPACE` and `ALTER TABLESPACE` statements, see Section 13.1.18, "CREATE TABLESPACE Syntax", and Section 13.1.8, "ALTER TABLESPACE Syntax".

3. Now it is possible to create a table whose nonindexed columns are stored on disk in the tablespace `ts_1`:

```
CREATE TABLE dt_1 (
    member_id INT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    last_name VARCHAR(50) NOT NULL,
    first_name VARCHAR(50) NOT NULL,
    dob DATE NOT NULL,
    joined DATE NOT NULL,
    INDEX(last_name, first_name)
    )
    TABLESPACE ts_1 STORAGE DISK
    ENGINE NDBCLUSTER;
```

The `TABLESPACE ... STORAGE DISK` option tells the `NDBCLUSTER` storage engine to use tablespace `ts_1` for disk data storage.

> **Note**
>
> Beginning with MySQL Cluster NDB 6.2.5 and MySQL Cluster NDB 6.3.2, it is also possible to specify whether an individual column is stored on disk or in memory by using a `STORAGE` clause as part of the column's definition in a `CREATE TABLE` or `ALTER TABLE` statement. `STORAGE DISK` causes the column to be stored on disk, and `STORAGE MEMORY` causes in-memory storage to be used. See Section 13.1.17, "CREATE TABLE Syntax", for more information.

Once table `ts_1` has been created as shown, you can perform `INSERT`, `SELECT`, `UPDATE`, and `DELETE` statements on it just as you would with any other MySQL table.

For table `dt_1` as it has been defined here, only the `dob` and `joined` columns are stored on disk. This is because there are indexes on the `id`, `last_name`, and `first_name` columns, and so data belonging to these columns is stored in RAM. In MySQL 5.1 (including MySQL Cluster NDB 6.X and 7.X through 7.1), only nonindexed columns can be held on disk; indexes and indexed column data continue to be stored in memory. This tradeoff between the use of indexes and conservation of RAM is something you must keep in mind as you design Disk Data tables.

Performance note.   The performance of a cluster using Disk Data storage is greatly improved if Disk Data files are kept on a separate physical disk from the data node file system. This must be done for each data node in the cluster to derive any noticeable benefit.

You may use absolute and relative file system paths with `ADD UNDOFILE` and `ADD DATAFILE`. Relative paths are calculated relative to the data node's data directory. You may also use symbolic links; see Section 17.5.12.2, "Using Symbolic Links with Disk Data Objects", for more information and examples.

A log file group, a tablespace, and any Disk Data tables using these must be created in a particular order. The same is true for dropping any of these objects:

* A log file group cannot be dropped as long as any tablespaces are using it.

* A tablespace cannot be dropped as long as it contains any data files.

* You cannot drop any data files from a tablespace as long as there remain any tables which are using the tablespace.

* Beginning with MySQL 5.1.12, it is no longer possible to drop files created in association with a different tablespace than the one with which the files were created. (Bug #20053)

For example, to drop all the objects created so far in this section, you would use the following statements:

```
mysql> DROP TABLE dt_1;

mysql> ALTER TABLESPACE ts_1
    -> DROP DATAFILE 'data_2.dat'
    -> ENGINE NDBCLUSTER;

mysql> ALTER TABLESPACE ts_1
    -> DROP DATAFILE 'data_1.dat'
    -> ENGINE NDBCLUSTER;

mysql> DROP TABLESPACE ts_1
    -> ENGINE NDBCLUSTER;

mysql> DROP LOGFILE GROUP lg_1
    -> ENGINE NDBCLUSTER;
```

These statements must be performed in the order shown, except that the two `ALTER TABLESPACE ...  DROP DATAFILE` statements may be executed in either order.

You can obtain information about data files used by Disk Data tables by querying the `FILES` table in the `INFORMATION_SCHEMA` database. An extra "`NULL` row" was added to this table in MySQL 5.1.14 for providing additional information about undo log files. For more information and examples of use, see Section 20.26.1, "The INFORMATION_SCHEMA FILES Table".

Beginning with MySQL Cluster NDB 6.3.27 and MySQL Cluster NDB 7.0.8, it is also possible to view information about allocated and free disk space for each Disk Data table or table partition using the `ndb_desc` utility. For more information, see Section 17.4.10, "`ndb_desc` — Describe NDB Tables".

17.5.12.2 Using Symbolic Links with Disk Data Objects

The performance of a MySQL Cluster that uses Disk Data storage can be greatly improved by separating data node file systems from undo log files and tablespace data files and placing these on different disks. Previous to MySQL Cluster NDB 6.2.17, MySQL Cluster NDB 6.3.22, and MySQL Cluster NDB 6.4.3, there was no direct support for this in MySQL Cluster, but it was possible to achieve this separation using symbolic links as described in this section.

Beginning with MySQL Cluster NDB 6.2.17, MySQL Cluster NDB 6.3.22, and MySQL Cluster NDB 6.4.3, the data node configuration parameters `FileSystemPathDD`, `FileSystemPathDataFiles`, and `FileSystemPathUndoFiles` make the use of symbolic links for this purpose unnecessary. For information about these parameters, see Disk Data file system parameters.

Each data node in the cluster creates a file system in the directory named `ndb_node_id_fs` under the data node's `DataDir` as defined in the `config.ini` file. In this example, we assume that each data node host has 3 disks, aliased as `/data0`, `/data1`, and `/data2`, and that the cluster's `config.ini` includes the following:

```
[ndbd default]
DataDir= /data0
```

Our objective is to place all Disk Data log files in `/data1`, and all Disk Data data files in `/data2`, on each data node host.

> **Note**
>
> In this example, we assume that the cluster's data node hosts are all using Linux operating systems. For other platforms, you may need to substitute you operating system's commands for those shown here.

To accomplish this, perform the following steps:

- Under the data node file system create symbolic links pointing to the other drives:

```
shell> cd /data0/ndb_2_fs
shell> ls
D1  D10  D11  D2  D8  D9  LCP
shell> ln -s /data0 dnlogs
shell> ln -s /data1 dndata
```

You should now have two symbolic links:

```
shell> ls -l --hide=D*
lrwxrwxrwx 1 user group   30 2007-03-19 13:58 dndata -> /data1
lrwxrwxrwx 1 user group   30 2007-03-19 13:59 dnlogs -> /data2
```

We show this only for the data node with node ID 2; however, you must do this for *each* data node.

- Now, in the `mysql` client, create a log file group and tablespace using the symbolic links, as shown here:

```
mysql> CREATE LOGFILE GROUP lg1
    ->    ADD UNDOFILE 'dnlogs/undo1.log'
    ->    INITIAL_SIZE 150M
```

```
        ->     UNDO_BUFFER_SIZE = 1M
        ->     ENGINE=NDBCLUSTER;

mysql> CREATE TABLESPACE ts1
    ->     ADD DATAFILE 'dndata/data1.log'
    ->     USE LOGFILE GROUP lg1
    ->     INITIAL_SIZE 1G
    ->     ENGINE=NDBCLUSTER;
```

Verify that the files were created and placed correctly as shown here:

```
shell> cd /data1
shell> ls -l
total 2099304
-rw-rw-r--  1 user group 157286400 2007-03-19 14:02 undo1.dat

shell> cd /data2
shell> ls -l
total 2099304
-rw-rw-r--  1 user group 1073741824 2007-03-19 14:02 data1.dat
```

- If you are running multiple data nodes on one host, you must take care to avoid having them try to use the same space for Disk Data files. You can make this easier by creating a symbolic link in each data node file system. Suppose you are using `/data0` for both data node file systems, but you wish to have the Disk Data files for both nodes on `/data1`. In this case, you can do something similar to what is shown here:

```
shell> cd /data0
shell> ln -s /data1/dn2 ndb_2_fs/dd
shell> ln -s /data1/dn3 ndb_3_fs/dd
shell> ls -l --hide=D* ndb_2_fs
lrwxrwxrwx 1 user group   30 2007-03-19 14:22 dd -> /data1/dn2
shell> ls -l --hide=D* ndb_3_fs
lrwxrwxrwx 1 user group   30 2007-03-19 14:22 dd -> /data1/dn3
```

- Now you can create a logfile group and tablespace using the symbolic link, like this:

```
mysql> CREATE LOGFILE GROUP lg1
    ->     ADD UNDOFILE 'dd/undo1.log'
    ->     INITIAL_SIZE 150M
    ->     UNDO_BUFFER_SIZE = 1M
    ->     ENGINE=NDBCLUSTER;

mysql> CREATE TABLESPACE ts1
    ->     ADD DATAFILE 'dd/data1.log'
    ->     USE LOGFILE GROUP lg1
    ->     INITIAL_SIZE 1G
    ->     ENGINE=NDBCLUSTER;
```

Verify that the files were created and placed correctly as shown here:

```
shell> cd /data1
shell> ls
dn2        dn3
shell> ls dn2
undo1.log        data1.log
shell> ls dn3
undo1.log        data1.log
```

17.5.12.3 MySQL Cluster Disk Data Storage Requirements

The following items apply to Disk Data storage requirements:

- Variable-length columns of Disk Data tables take up a fixed amount of space. For each row, this is equal to the space required to store the largest possible value for that column.

  For general information about calculating these values, see Section 11.7, "Data Type Storage Requirements".

  You can obtain an estimate the amount of space available in data files and undo log files by querying the `INFORMATION_SCHEMA.FILES` table. For more information and examples, see Section 20.26.1, "The INFORMATION_SCHEMA FILES Table".

  > **Note**
  >
  > The `OPTIMIZE TABLE` statement does not have any effect on Disk Data tables.

- In a Disk Data table, the first 256 bytes of a `TEXT` or `BLOB` column are stored in memory; only the remainder is stored on disk.

- Each row in a Disk Data table uses 8 bytes in memory to point to the data stored on disk. This means that, in some cases, converting an in-memory column to the disk-based format can actually result in greater memory usage. For example, converting a `CHAR(4)` column from memory-based to disk-based format increases the amount of `DataMemory` used per row from 4 to 8 bytes.

  > **Important**
  >
  > Starting the cluster with the `--initial` option does *not* remove Disk Data files. You must remove these manually prior to performing an initial restart of the cluster.

Performance of Disk Data tables can be improved by minimizing the number of disk seeks by making sure that `DiskPageBufferMemory` is of sufficient size. You can query the `diskpagebuffer` table to help determine whether the value for this parameter needs to be increased.

17.5.13 Adding MySQL Cluster Data Nodes Online

This section describes how to add MySQL Cluster data nodes "online"—that is, without needing to shut down the cluster completely and restart it as part of the process. This capability is available in MySQL Cluster NDB 7.0 (beginning with MySQL Cluster NDB 6.4.0) and later MySQL Cluster release series.

> **Important**
>
> Currently, you must add new data nodes to a MySQL Cluster as part of a new node group. In addition, it is not possible to change the number of replicas (or the number of nodes per node group) online.

17.5.13.1 Adding MySQL Cluster Data Nodes Online: General Issues

This section provides general information about the behavior of and current limitations in adding MySQL Cluster nodes online.

Redistribution of Data. The ability to add new nodes online includes a means to reorganize `NDBCLUSTER` table data and indexes so that they are distributed across all data nodes, including the new ones, by means of the `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement. Table reorganization of both in-memory and Disk Data tables is supported. This redistribution does not currently

include unique indexes (only ordered indexes are redistributed). Prior to MySQL Cluster NDB 7.0.40 and MySQL Cluster NDB 7.1.28, `BLOB` table data is also not redistributed using this method (Bug #13714148).

The redistribution for `NDBCLUSTER` tables already existing before the new data nodes were added is not automatic, but can be accomplished using simple SQL statements in `mysql` or another MySQL client application. However, all data and indexes added to tables created after a new node group has been added are distributed automatically among all cluster data nodes, including those added as part of the new node group.

Partial starts. It is possible to add a new node group without all of the new data nodes being started. It is also possible to add a new node group to a degraded cluster—that is, a cluster that is only partially started, or where one or more data nodes are not running. In the latter case, the cluster must have enough nodes running to be viable before the new node group can be added.

Effects on ongoing operations. Normal DML operations using MySQL Cluster data are not prevented by the creation or addition of a new node group, or by table reorganization. However, it is not possible to perform DDL concurrently with table reorganization—that is, no other DDL statements can be issued while an `ALTER TABLE ... REORGANIZE PARTITION` statement is executing. In addition, during the execution of `ALTER TABLE ... REORGANIZE PARTITION` (or the execution of any other DDL statement), it is not possible to restart cluster data nodes.

Failure handling. Failures of data nodes during node group creation and table reorganization are handled as shown in the following table:

Failure occurs during:	Failure occurs in:		
	"Old" data nodes	**"New" data nodes**	**System**

Node group creation	• **If a node other than the master fails:** The creation of the node group is always rolled forward.
	
	• **If the master fails:**
	
	  • **If the internal commit point has been reached:** The creation of the node group is rolled forward.
	
	  • **If the internal commit point has not yet been reached.** The creation of the node group is rolled back
		• **If a node other than the master fails:** The creation of the node group is always rolled forward.
		
		• **If the master fails:**
		
		  • **If the internal commit point has been reached:** The creation of the node group is rolled forward.
		
		  • **If the internal commit point has not yet been reached.** The creation of the node group is rolled back
			• **If the execution of CREATE NODEGROUP has reached the internal commit point:** When restarted, the cluster includes the new node group. Otherwise it without.
			
			• **If the execution of CREATE NODEGROUP has not yet reached the internal commit point:** When restarted, the cluster does not include the new node group.

Table reorganization	• **If a node other than the master fails:** The table reorganization is always rolled forward. • **If the master fails:**	• **If a node other than the master fails:** The table reorganization is always rolled forward. • **If the master fails:**	• **If the execution of an ALTER ONLINE TABLE table REORGANIZE PARTITION statement has reached the internal commit**

Failure occurs during:	Failure occurs in:		
	"Old" data nodes	**"New" data nodes**	**System**
	• **If the internal commit point has been reached:** The table reorganization is rolled forward. • **If the internal commit point has not yet been reached.** The table reorganization is rolled back.	• **If the internal commit point has been reached:** The table reorganization is rolled forward. • **If the internal commit point has not yet been reached.** The table reorganization is rolled back.	**point:** When the cluster is restarted, the data and indexes belonging to *table* are distributed using the "new" data nodes. • **If the execution of an ALTER ONLINE TABLE table REORGANIZE PARTITION statement has not yet reached the internal commit point:** When the cluster is restarted, the data and indexes belonging to *table* are distributed using only the "old" data nodes.

Dropping node groups. The `ndb_mgm` client supports a `DROP NODEGROUP` command, but it is possible to drop a node group only when no data nodes in the node group contain any data. Since there is currently no way to "empty" a specific data node or node group, this command works only the following two cases:

1. After issuing `CREATE NODEGROUP` in the `ndb_mgm` client, but before issuing any `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements in the `mysql` client.

2. After dropping all `NDBCLUSTER` tables using `DROP TABLE`.

   `TRUNCATE TABLE` does not work for this purpose because the data nodes continue to store the table definitions.

17.5.13.2 Adding MySQL Cluster Data Nodes Online: Basic procedure

In this section, we list the basic steps required to add new data nodes to a MySQL Cluster. For a detailed example, see Section 17.5.13.3, "Adding MySQL Cluster Data Nodes Online: Detailed Example".

> **Note**
>
> Beginning with MySQL Cluster NDB 7.0.4, this procedure applies whether you are using `ndbd` or `ndbmtd` binaries for the data node processes. Previously, this did not work with multi-threaded data nodes. (Bug #43108)

Assuming that you already have a running MySQL Cluster, adding data nodes online requires the following steps:

1. Edit the cluster configuration `config.ini` file, adding new `[ndbd]` sections corresponding to the nodes to be added. In the case where the cluster uses multiple management servers, these changes need to be made to all `config.ini` files used by the management servers.

   You must be careful that node IDs for any new data nodes added in the `config.ini` file do not overlap node IDs used by existing nodes. In the event that you have API nodes using dynamically

allocated node IDs and these IDs match node IDs that you want to use for new data nodes, it is possible to force any such API nodes to "migrate", as described later in this procedure.

2. Perform a rolling restart of all MySQL Cluster management servers.

> **Important**
>
> All management servers must be restarted with the `--reload` or `--initial` option to force the reading of the new configuration.

3. Perform a rolling restart of all existing MySQL Cluster data nodes. It is not necessary (or usually even desirable) to use `--initial` when restarting the existing data nodes.

   If you are using API nodes with dynamically allocated IDs matching any node IDs that you wish to assign to new data nodes, you must restart all API nodes (including SQL nodes) before restarting any of the data nodes processes in this step. This causes any API nodes with node IDs that were previously not explicitly assigned to relinquish those node IDs and acquire new ones.

4. Perform a rolling restart of any SQL or API nodes connected to the MySQL Cluster.

5. Start the new data nodes.

   The new data nodes may be started in any order. They can also be started concurrently, as long as they are started after the rolling restarts of all existing data nodes have been completed, and before proceeding to the next step.

6. Execute one or more `CREATE NODEGROUP` commands in the MySQL Cluster management client to create the new node group or node groups to which the new data nodes will belong.

7. Redistribute the cluster's data among all data nodes (including the new ones) by issuing an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement in the `mysql` client for each `NDBCLUSTER` table.

> **Note**
>
> This needs to be done only for tables already existing at the time the new node group is added. Data in tables created after the new node group is added is distributed automatically; however, data added to any given table `tbl` that existed before the new nodes were added is not distributed using the new nodes until that table has been reorganized using `ALTER ONLINE TABLE tbl REORGANIZE PARTITION`.

8. Reclaim the space freed on the "old" nodes by issuing, for each `NDBCLUSTER` table, an `OPTIMIZE TABLE` statement in the `mysql` client.

You can add all the nodes desired, then issue several `CREATE NODEGROUP` commands in succession to add the new node groups to the cluster. Prior to MySQL Cluster NDB 7.0.16 and MySQL Cluster NDB 7.1.5, when adding multiple new node groups to a MySQL Cluster, it was necessary to add only the nodes to be assigned to a given new node group, create that node group using `CREATE NODEGROUP`, then repeat this process for each new node group to be added to the cluster. (Bug #54497)

17.5.13.3 Adding MySQL Cluster Data Nodes Online: Detailed Example

In this section we provide a detailed example illustrating how to add new MySQL Cluster data nodes online, starting with a MySQL Cluster having 2 data nodes in a single node group and concluding with a cluster having 4 data nodes in 2 node groups.

Starting configuration.   For purposes of illustration, we assume a minimal configuration, and that the cluster uses a `config.ini` file containing only the following information:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 192.168.0.1

[ndbd]
Id = 2
HostName = 192.168.0.2

[mgm]
HostName = 192.168.0.10
Id = 10

[api]
Id=20
HostName = 192.168.0.20

[api]
Id=21
HostName = 192.168.0.21
```

> **Note**
>
> We have left a gap in the sequence between data node IDs and other nodes. This make it easier later to assign node IDs that are not already in use to data nodes which are newly added.

We also assume that you have already started the cluster using the appropriate command line or `my.cnf` options, and that running `SHOW` in the management client produces output similar to what is shown here:

```
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: 192.168.0.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @192.168.0.1  (5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=2    @192.168.0.2  (5.1.77-ndb-7.1.37, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @192.168.0.10  (5.1.77-ndb-7.1.37)

[mysqld(API)]   2 node(s)
id=20   @192.168.0.20  (5.1.77-ndb-7.1.37)
id=21   @192.168.0.21  (5.1.77-ndb-7.1.37)
```

Finally, we assume that the cluster contains a single `NDBCLUSTER` table created as shown here:

```
USE n;

CREATE TABLE ips (
    id BIGINT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    country_code CHAR(2) NOT NULL,
    type CHAR(4) NOT NULL,
```

```
    ip_address varchar(15) NOT NULL,
    addresses BIGINT UNSIGNED DEFAULT NULL,
    date BIGINT UNSIGNED DEFAULT NULL
)   ENGINE NDBCLUSTER;
```

The memory usage and related information shown later in this section was generated after inserting approximately 50000 rows into this table.

> **Note**
>
> In this example, we show the single-threaded `ndbd` being used for the data node processes. However—beginning with MySQL Cluster NDB 7.0.4—you can also apply this example, if you are using the multi-threaded `ndbmtd` by substituting `ndbmtd` for `ndbd` wherever it appears in the steps that follow. (Bug #43108)

Step 1: Update configuration file.   Open the cluster global configuration file in a text editor and add `[ndbd]` sections corresponding to the 2 new data nodes. (We give these data nodes IDs 3 and 4, and assume that they are to be run on host machines at addresses 192.168.0.3 and 192.168.0.4, respectively.) After you have added the new sections, the contents of the `config.ini` file should look like what is shown here, where the additions to the file are shown in bold type:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 192.168.0.1

[ndbd]
Id = 2
HostName = 192.168.0.2

[ndbd]
Id = 3
HostName = 192.168.0.3

[ndbd]
Id = 4
HostName = 192.168.0.4

[mgm]
HostName = 192.168.0.10
Id = 10

[api]
Id=20
HostName = 192.168.0.20

[api]
Id=21
HostName = 192.168.0.21
```

Once you have made the necessary changes, save the file.

Step 2: Restart the management server.   Restarting the cluster management server requires that you issue separate commands to stop the management server and then to start it again, as follows:

1. Stop the management server using the management client `STOP` command, as shown here:

```
ndb_mgm> 10 STOP
Node 10 has shut down.
Disconnecting to allow Management Server to shutdown

shell>
```

2. Because shutting down the management server causes the management client to terminate, you must start the management server from the system shell. For simplicity, we assume that `config.ini` is in the same directory as the management server binary, but in practice, you must supply the correct path to the configuration file. You must also supply the `--reload` or `--initial` option so that the management server reads the new configuration from the file rather than its configuration cache. If your shell's current directory is also the same as the directory where the management server binary is located, then you can invoke the management server as shown here:

```
shell> ndb_mgmd -f config.ini --reload
2008-12-08 17:29:23 [MgmSrvr] INFO     -- NDB Cluster Management Server. 5.1.77-ndb-7.1.37
2008-12-08 17:29:23 [MgmSrvr] INFO     -- Reading cluster configuration from 'config.ini'
```

If you check the output of SHOW in the management client after restarting the ndb_mgm process, you should now see something like this:

```
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: 192.168.0.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @192.168.0.1  (5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=2    @192.168.0.2  (5.1.77-ndb-7.1.37, Nodegroup: 0)
id=3 (not connected, accepting connect from 192.168.0.3)
id=4 (not connected, accepting connect from 192.168.0.4)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @192.168.0.10  (5.1.77-ndb-7.1.37)

[mysqld(API)]   2 node(s)
id=20   @192.168.0.20  (5.1.77-ndb-7.1.37)
id=21   @192.168.0.21  (5.1.77-ndb-7.1.37)
```

Step 3: Perform a rolling restart of the existing data nodes.   This step can be accomplished entirely within the cluster management client using the RESTART command, as shown here:

```
ndb_mgm> 1 RESTART
Node 1: Node shutdown initiated
Node 1: Node shutdown completed, restarting, no start.
Node 1 is being restarted

ndb_mgm> Node 1: Start initiated (version 7.1.37)
Node 1: Started (version 7.1.37)

ndb_mgm> 2 RESTART
Node 2: Node shutdown initiated
Node 2: Node shutdown completed, restarting, no start.
Node 2 is being restarted

ndb_mgm> Node 2: Start initiated (version 7.1.37)

ndb_mgm> Node 2: Started (version 7.1.37)
```

Important

After issuing each `X RESTART` command, wait until the management client reports `Node X: Started (version ...)` *before* proceeding any further.

Beginning with MySQL Cluster NDB 7.0.24 and MySQL Cluster NDB 7.1.13, you can verify that all existing data nodes were restarted using the updated configuration by checking the `ndbinfo.nodes` table in the `mysql` client.

Step 4: Perform a rolling restart of all cluster API nodes.   Shut down and restart each MySQL server acting as an SQL node in the cluster using `mysqladmin shutdown` followed by `mysqld_safe` (or another startup script). This should be similar to what is shown here, where `password` is the MySQL `root` password for a given MySQL server instance:

```
shell> mysqladmin -uroot -ppassword shutdown
081208 20:19:56 mysqld_safe mysqld from pid file
/usr/local/mysql/var/tonfisk.pid ended
shell> mysqld_safe --ndbcluster --ndb-connectstring=192.168.0.10 &
081208 20:20:06 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
081208 20:20:06 mysqld_safe Starting mysqld daemon with databases
from /usr/local/mysql/var
```

Of course, the exact input and output depend on how and where MySQL is installed on the system, as well as which options you choose to start it (and whether or not some or all of these options are specified in a `my.cnf` file).

Step 5: Perform an initial start of the new data nodes.   From a system shell on each of the hosts for the new data nodes, start the data nodes as shown here, using the `--initial` option:

```
shell> ndbd -c 192.168.0.10 --initial
```

Note

Unlike the case with restarting the existing data nodes, you can start the new data nodes concurrently; you do not need to wait for one to finish starting before starting the other.

Wait until both of the new data nodes have started before proceeding with the next step. Once the new data nodes have started, you can see in the output of the management client `SHOW` command that they do not yet belong to any node group (as indicated with bold type here):

```
ndb_mgm> SHOW
Connected to Management Server at: 192.168.0.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @192.168.0.1  (5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=2    @192.168.0.2  (5.1.77-ndb-7.1.37, Nodegroup: 0)
id=3    @192.168.0.3  (5.1.77-ndb-7.1.37, no nodegroup)
id=4    @192.168.0.4  (5.1.77-ndb-7.1.37, no nodegroup)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @192.168.0.10  (5.1.77-ndb-7.1.37)

[mysqld(API)]   2 node(s)
id=20   @192.168.0.20  (5.1.77-ndb-7.1.37)
id=21   @192.168.0.21  (5.1.77-ndb-7.1.37)
```

Step 6: Create a new node group.   You can do this by issuing a `CREATE NODEGROUP` command in the cluster management client. This command takes as its argument a comma-separated list of the node IDs of the data nodes to be included in the new node group, as shown here:

```
ndb_mgm> CREATE NODEGROUP 3,4
Nodegroup 1 created
```

By issuing `SHOW` again, you can verify that data nodes 3 and 4 have joined the new node group (again indicated in bold type):

```
ndb_mgm> SHOW
Connected to Management Server at: 192.168.0.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @192.168.0.1  (5.1.77-ndb-7.1.37, Nodegroup: 0, *)
id=2    @192.168.0.2  (5.1.77-ndb-7.1.37, Nodegroup: 0)
id=3    @192.168.0.3  (5.1.77-ndb-7.1.37, Nodegroup: 1)
id=4    @192.168.0.4  (5.1.77-ndb-7.1.37, Nodegroup: 1)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @192.168.0.10  (5.1.77-ndb-7.1.37)

[mysqld(API)]    2 node(s)
id=20   @192.168.0.20  (5.1.77-ndb-7.1.37)
id=21   @192.168.0.21  (5.1.77-ndb-7.1.37)
```

Step 7: Redistribute cluster data.   When a node group is created, existing data and indexes are not automatically distributed to the new node group's data nodes, as you can see by issuing the appropriate `REPORT` command in the management client:

```
ndb_mgm> ALL REPORT MEMORY

Node 1: Data usage is 5%(177 32K pages of total 3200)
Node 1: Index usage is 0%(108 8K pages of total 12832)
Node 2: Data usage is 5%(177 32K pages of total 3200)
Node 2: Index usage is 0%(108 8K pages of total 12832)
Node 3: Data usage is 0%(0 32K pages of total 3200)
Node 3: Index usage is 0%(0 8K pages of total 12832)
Node 4: Data usage is 0%(0 32K pages of total 3200)
Node 4: Index usage is 0%(0 8K pages of total 12832)
```

By using `ndb_desc` with the `-p` option, which causes the output to include partitioning information, you can see that the table still uses only 2 partitions (in the `Per partition info` section of the output, shown here in bold text):

```
shell> ndb_desc -c 192.168.0.10 -d n ips -p
-- ips --
Version: 1
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 6
Number of primary keys: 1
Length of frm data: 340
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
```

```
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Bigint PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
country_code Char(2;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
type Char(4;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
ip_address Varchar(15;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
addresses Bigunsigned NULL AT=FIXED ST=MEMORY
date Bigunsigned NULL AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex

-- Per partition info --
Partition    Row count    Commit count   Frag fixed memory    Frag varsized memory
0            26086        26086          1572864              557056
1            26329        26329          1605632              557056

NDBT_ProgramExit: 0 - OK
```

You can cause the data to be redistributed among all of the data nodes by performing, for each NDBCLUSTER table, an ALTER ONLINE TABLE ... REORGANIZE PARTITION statement in the mysql client. After issuing the statement ALTER ONLINE TABLE ips REORGANIZE PARTITION, you can see using ndb_desc that the data for this table is now stored using 4 partitions, as shown here (with the relevant portions of the output in bold type):

```
shell> ndb_desc -c 192.168.0.10 -d n ips -p
-- ips --
Version: 16777217
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 6
Number of primary keys: 1
Length of frm data: 341
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 4
TableStatus: Retrieved
-- Attributes --
id Bigint PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
country_code Char(2;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
type Char(4;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
ip_address Varchar(15;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
addresses Bigunsigned NULL AT=FIXED ST=MEMORY
date Bigunsigned NULL AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex

-- Per partition info --
Partition    Row count    Commit count   Frag fixed memory    Frag varsized memory
0            12981        52296          1572864              557056
1            13236        52515          1605632              557056
2            13105        13105          819200               294912
3            13093        13093          819200               294912

NDBT_ProgramExit: 0 - OK
```

> **Note**
>
> Normally, `ALTER [ONLINE] TABLE` *`table_name`* `REORGANIZE PARTITION` is used with a list of partition identifiers and a set of partition definitions to create a new partitioning scheme for a table that has already been explicitly partitioned. Its use here to redistribute data onto a new MySQL Cluster node group is an exception in this regard; when used in this way, only the name of the table is used following the `TABLE` keyword, and no other keywords or identifiers follow `REORGANIZE PARTITION`.
>
> Prior to MySQL Cluster NDB 6.4.3, `ALTER ONLINE TABLE ... REORGANIZE PARTITION` with no *`partition_names`* `INTO (`*`partition_definitions`*`)` option did not work correctly with Disk Data tables or with in-memory `NDBCLUSTER` tables having one or more disk-based columns. (Bug #42549)
>
> For more information, see Section 13.1.7, "ALTER TABLE Syntax".

In addition, for each table, the `ALTER ONLINE TABLE` statement should be followed by an `OPTIMIZE TABLE` to reclaim wasted space. You can obtain a list of all `NDBCLUSTER` tables using the following query against the `INFORMATION_SCHEMA.TABLES` table:

```
SELECT TABLE_SCHEMA, TABLE_NAME
    FROM INFORMATION_SCHEMA.TABLES
    WHERE ENGINE = 'NDBCLUSTER';
```

> **Note**
>
> The `INFORMATION_SCHEMA.TABLES.ENGINE` value for a MySQL Cluster table is always `NDBCLUSTER`, regardless of whether the `CREATE TABLE` statement used to create the table (or `ALTER TABLE` statement used to convert an existing table from a different storage engine) used `NDB` or `NDBCLUSTER` in its `ENGINE` option.

You can see after performing these statements in the output of `ALL REPORT MEMORY` that the data and indexes are now redistributed between all cluster data nodes, as shown here:

```
ndb_mgm> ALL REPORT MEMORY

Node 1: Data usage is 5%(176 32K pages of total 3200)
Node 1: Index usage is 0%(76 8K pages of total 12832)
Node 2: Data usage is 5%(176 32K pages of total 3200)
Node 2: Index usage is 0%(76 8K pages of total 12832)
Node 3: Data usage is 2%(80 32K pages of total 3200)
Node 3: Index usage is 0%(51 8K pages of total 12832)
Node 4: Data usage is 2%(80 32K pages of total 3200)
Node 4: Index usage is 0%(50 8K pages of total 12832)
```

> **Note**
>
> Since only one DDL operation on `NDBCLUSTER` tables can be executed at a time, you must wait for each `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement to finish before issuing the next one.

It is not necessary to issue `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements for `NDBCLUSTER` tables created *after* the new data nodes have been added; data added to such tables is distributed among all data nodes automatically. However, in `NDBCLUSTER` tables that existed *prior to* the addition of the new nodes, neither existing nor new data is distributed using the new nodes until these tables have been reorganized using `ALTER ONLINE TABLE ... REORGANIZE PARTITION`.

Alternative procedure, without rolling restart.   It is possible to avoid the need for a rolling restart by configuring the extra data nodes, but not starting them, when first starting the cluster. We assume, as before, that you wish to start with two data nodes—nodes 1 and 2—in one node group and later to expand the cluster to four data nodes, by adding a second node group consisting of nodes 3 and 4:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 192.168.0.1

[ndbd]
Id = 2
HostName = 192.168.0.2

[ndbd]
Id = 3
HostName = 192.168.0.3
Nodegroup = 65536    # MySQL Cluster NDB 7.0.24 and later;
                     # MySQL Cluster NDB 7.1.13 and later

[ndbd]
Id = 4
HostName = 192.168.0.4
Nodegroup = 65536    # MySQL Cluster NDB 7.0.24 and later;
                     # MySQL Cluster NDB 7.1.13 and later

[mgm]
HostName = 192.168.0.10
Id = 10

[api]
Id=20
HostName = 192.168.0.20

[api]
Id=21
HostName = 192.168.0.21
```

Prior to MySQL Cluster NDB 7.0.24 and MySQL Cluster NDB 7.1.13, you must perform the initial start of the cluster using the `--nowait-nodes` option with `ndbd` (or `ndbmtd` in MySQL Cluster NDB 7.0.4 and later) for each of the data nodes that you wish to have online immediately, so that the cluster does not wait for the remaining nodes to start:

```
shell> ndbd -c 192.168.0.10 --initial --nowait-nodes=3,4
```

Beginning with MySQL Cluster NDB 7.0.24 and MySQL Cluster NDB 7.1.13, the data nodes to be brought online at a later time (nodes 3 and 4) can be configured with `NodeGroup = 65536`, in which case it is not necessary to start the nodes to be started immediately (nodes 1 and 2) with the `--nowait-nodes` option, so nodes 1 and 2 can each be started as shown here:

```
shell> ndbd -c 192.168.0.10 --initial
```

The data nodes configured with `NodeGroup = 65536` are treated by the management server as though you had started nodes 1 and 2 using `--nowait-nodes=3,4` after waiting for a period of time determined by the setting for the `StartNoNodeGroupTimeout` data node configuration parameter (also introduced

in MySQL Cluster NDB 7.0.24 and MySQL Cluster NDB 7.1.13). By default, this is 15 seconds (15000 milliseconds).

> **Note**
>
> `StartNoNodegroupTimeout` must be the same for all data nodes in the cluster; for this reason, you should always set it in the `[ndbd default]` section of the `config.ini` file, rather than for individual data nodes.

When you are ready to add the second node group, you need only perform the following additional steps:

1. Start data nodes 3 and 4, invoking the data node process once for each new node:

    ```
    shell> ndbd -c 192.168.0.10 --initial
    ```

2. Issue the appropriate `CREATE NODEGROUP` command in the management client:

    ```
    ndb_mgm> CREATE NODEGROUP 3,4
    ```

3. In the `mysql` client, issue `ALTER ONLINE TABLE ... REORGANIZE PARTITION` and `OPTIMIZE TABLE` statements for each existing `NDBCLUSTER` table. (As noted elsewhere in this section, existing MySQL Cluster tables cannot use the new nodes for data distribution until this has been done.)

17.5.14 Distributed MySQL Privileges for MySQL Cluster

MySQL Cluster NDB 7.2 introduces support for distributing MySQL users and privileges across all SQL nodes in a MySQL Cluster. This support is not enabled by default; you should follow the procedure outlined in this section in order to do so.

Normally, each MySQL server's user privilege tables in the `mysql` database must use the `MyISAM` storage engine, which means that a user account and its associated privileges created on one SQL node are not available on the cluster's other SQL nodes. In MySQL Cluster NDB 7.2 and later, an SQL file `ndb_dist_priv.sql` is provided with the MySQL Cluster distribution. This file can be found in the `share/mysql` directory in the MySQL installation directory.

The first step in enabling distributed privileges is to load this script into a MySQL Server that functions as an SQL node (which we refer to after this as the *target* SQL node or MySQL Server). You can do this by executing the following command from the system shell on the target SQL node after changing to its MySQL installation directory (where `options` stands for any additional options needed to connect to this SQL node):

```
shell> mysql options -uroot < share/mysql/ndb_dist_priv.sql
```

Importing `ndb_dist_priv.sql` creates a number of stored routines (six stored procedures and one stored function) in the `mysql` database on the target SQL node. After connecting to the SQL node in the `mysql` client (as the MySQL `root` user), you can verify that these were created as shown here:

```
mysql> SELECT ROUTINE_NAME, ROUTINE_SCHEMA, ROUTINE_TYPE
    ->     FROM INFORMATION_SCHEMA.ROUTINES
    ->     WHERE ROUTINE_NAME LIKE 'mysql_cluster%'
    ->     ORDER BY ROUTINE_TYPE;
+------------------------------------------+----------------+--------------+
| ROUTINE_NAME                             | ROUTINE_SCHEMA | ROUTINE_TYPE |
+------------------------------------------+----------------+--------------+
| mysql_cluster_privileges_are_distributed | mysql          | FUNCTION     |
| mysql_cluster_backup_privileges          | mysql          | PROCEDURE    |
| mysql_cluster_move_grant_tables          | mysql          | PROCEDURE    |
```

```
| mysql_cluster_move_privileges             | mysql          | PROCEDURE     |
| mysql_cluster_restore_local_privileges    | mysql          | PROCEDURE     |
| mysql_cluster_restore_privileges          | mysql          | PROCEDURE     |
| mysql_cluster_restore_privileges_from_local | mysql        | PROCEDURE     |
+-------------------------------------------+----------------+---------------+

7 rows in set (0.01 sec)
```

The stored procedure named `mysql_cluster_move_privileges` creates backup copies of the existing privilege tables, then converts them to `NDB`.

`mysql_cluster_move_privileges` performs the backup and conversion in two steps. The first step is to call `mysql_cluster_backup_privileges`, which creates two sets of copies in the `mysql` database:

- A set of local copies that use the `MyISAM` storage engine. Their names are generated by adding the suffix `_backup` to the original privilege table names.

- A set of distributed copies that use the `NDBCLUSTER` storage engine. These tables are named by prefixing `ndb_` and appending `_backup` to the names of the original tables.

After the copies are created, `mysql_cluster_move_privileges` invokes `mysql_cluster_move_grant_tables`, which contains the `ALTER TABLE ... ENGINE = NDB` statements that convert the mysql system tables to `NDB`.

Normally, you should not invoke either `mysql_cluster_backup_privileges` or `mysql_cluster_move_grant_tables` manually; these stored procedures are intended only for use by `mysql_cluster_move_privileges`.

Although the original privilege tables are backed up automatically, it is always a good idea to create backups manually of the existing privilege tables on all affected SQL nodes before proceeding. You can do this using `mysqldump` in a manner similar to what is shown here:

```
shell> mysqldump options -uroot \
    mysql host user db tables_priv columns_priv procs_priv proxies_priv > backup_file
```

To perform the conversion, you must be connected to the target SQL node using the `mysql` client (again, as the MySQL `root` user). Invoke the stored procedure like this:

```
mysql> CALL mysql.mysql_cluster_move_privileges();
Query OK, 0 rows affected (22.32 sec)
```

Depending on the number of rows in the privilege tables, this procedure may take some time to execute. If some of the privilege tables are empty, you may see one or more `No data - zero rows fetched, selected, or processed` warnings when `mysql_cluster_move_privileges` returns. In such cases, the warnings may be safely ignored. To verify that the conversion was successful, you can use the stored function `mysql_cluster_privileges_are_distributed` as shown here:

```
mysql> SELECT CONCAT(
    ->     'Conversion ',
    ->     IF(mysql.mysql_cluster_privileges_are_distributed(), 'succeeded', 'failed'),
    ->     '.')
    ->     AS Result;
+----------------------+
| Result               |
+----------------------+
| Conversion succeeded. |
+----------------------+
1 row in set (0.00 sec)
```

`mysql_cluster_privileges_are_distributed` checks for the existence of the distributed privilege tables and returns `1` if all of the privilege tables are distributed; otherwise, it returns `0`.

You can verify that the backups have been created using a query such as this one:

```
mysql> SELECT TABLE_NAME, ENGINE FROM INFORMATION_SCHEMA.TABLES
    ->       WHERE TABLE_SCHEMA = 'mysql' AND TABLE_NAME LIKE '%backup'
    ->       ORDER BY ENGINE;
+-------------------------+------------+
| TABLE_NAME              | ENGINE     |
+-------------------------+------------+
| host_backup             | MyISAM     |
| db_backup               | MyISAM     |
| columns_priv_backup     | MyISAM     |
| user_backup             | MyISAM     |
| tables_priv_backup      | MyISAM     |
| proxies_priv_backup     | MyISAM     |
| procs_priv_backup       | MyISAM     |
| ndb_user_backup         | ndbcluster |
| ndb_tables_priv_backup  | ndbcluster |
| ndb_proxies_priv_backup | ndbcluster |
| ndb_procs_priv_backup   | ndbcluster |
| ndb_host_backup         | ndbcluster |
| ndb_db_backup           | ndbcluster |
| ndb_columns_priv_backup | ndbcluster |
+-------------------------+------------+
14 rows in set (0.00 sec)
```

Once the conversion to distributed privileges has been made, any time a MySQL user account is created, dropped, or has its privileges updated on any SQL node, the changes take effect immediately on all other MySQL servers attached to the cluster. Once privileges are distributed, any new MySQL Servers that connect to the cluster automatically participate in the distribution.

> **Note**
>
> For clients connected to SQL nodes at the time that `mysql_cluster_move_privileges` is executed, you may need to execute `FLUSH PRIVILEGES` on those SQL nodes, or to disconnect and then reconnect the clients, in order for those clients to be able to see the changes in privileges.

All MySQL user privileges are distributed across all connected MySQL Servers. This includes any privileges associated with views and stored routines, even though distribution of views and stored routines themselves is not currently supported.

In the event that an SQL node becomes disconnected from the cluster while `mysql_cluster_move_privileges` is running, you must drop its privilege tables after reconnecting to the cluster, using a statement such as `DROP TABLE IF EXISTS mysql.user mysql.db mysql.tables_priv mysql.columns_priv mysql.procs_priv`. This causes the SQL node to use the shared privilege tables rather than its own local versions of them. This is not needed when connecting a new SQL node to the cluster for the first time.

In the event of an initial restart of the entire cluster (all data nodes shut down, then started again with `--initial`), the shared privilege tables are lost. If this happens, you can restore them using the original target SQL node either from the backups made by `mysql_cluster_move_privileges` or from a dump file created with `mysqldump`. If you need to use a new MySQL Server to perform the restoration, you should start it with `--skip-grant-tables` when connecting to the cluster for the first time; after this, you can restore the privilege tables locally, then distribute them again using `mysql_cluster_move_privileges`. After restoring and distributing the tables, you should restart this MySQL Server without the `--skip-grant-tables` option.

You can also restore the distributed tables using `ndb_restore --restore-privilege-tables` from a backup made using `START BACKUP` in the `ndb_mgm` client. (The `MyISAM` tables created by `mysql_cluster_move_privileges` are not backed up by the `START BACKUP` command.) `ndb_restore` does not restore the privilege tables by default; the `--restore-privilege-tables` option causes it to do so.

You can restore the SQL node's local privileges using either of two procedures. `mysql_cluster_restore_privileges` works as follows:

1. If copies of the `mysql.ndb_*_backup` tables are available, attempt to restore the system tables from these.

2. Otherwise, attempt to restore the system tables from the local backups named `*_backup` (without the `ndb_` prefix).

The other procedure, named `mysql_cluster_restore_local_privileges`, restores the system tables from the local backups only, without checking the `ndb_*` backups.

The system tables re-created by `mysql_cluster_restore_privileges` or `mysql_cluster_restore_local_privileges` use the MySQL server default storage engine; they are not shared or distributed in any way, and do not use MySQL Cluster's `NDB` storage engine.

The additional stored procedure `mysql_cluster_restore_privileges_from_local` is intended for the use of `mysql_cluster_restore_privileges` and `mysql_cluster_restore_local_privileges`. It should not be invoked directly.

> **Important**
>
> Applications that access MySQL Cluster data directly, including NDB API and ClusterJ applications, are not subject to the MySQL privilege system. This means that, once you have distributed the grant tables, they can be freely accessed by such applications, just as they can any other `NDB` tables. In particular, you should keep in mind that *NDB API and ClusterJ applications can read and write user names, host names, password hashes, and any other contents of the distributed grant tables without any restrictions*.

17.5.15 NDB API Statistics Counters and Variables

Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, a number of types of statistical counters relating to actions performed by or affecting `Ndb` objects are added. Such actions include starting and closing (or aborting) transactions; primary key and unique key operations; table, range, and pruned scans; threads blocked while waiting for the completion of various operations; and data and events sent and received by `NDBCLUSTER`. The counters are incremented inside the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes. `mysqld` exposes these counters as system status variables; their values can be read in the output of `SHOW STATUS`, or by querying the `INFORMATION_SCHEMA.SESSION_STATUS` or `INFORMATION_SCHEMA.GLOBAL_STATUS` table. By comparing the values before and after statements operating on `NDB` tables, you can observe the corresponding actions taken on the API level, and thus the cost of performing the statement.

You can list all of these status variables using the following `SHOW STATUS` statement:

```
mysql> SHOW STATUS LIKE 'ndb_api%';
+-----------------------------------------+----------+
| Variable_name                           | Value    |
+-----------------------------------------+----------+
| Ndb_api_wait_exec_complete_count_session | 0       |
| Ndb_api_wait_scan_result_count_session   | 0       |
```

```
| Ndb_api_wait_meta_request_count_session      | 0        |
| Ndb_api_wait_nanos_count_session             | 0        |
| Ndb_api_bytes_sent_count_session             | 0        |
| Ndb_api_bytes_received_count_session         | 0        |
| Ndb_api_trans_start_count_session            | 0        |
| Ndb_api_trans_commit_count_session           | 0        |
| Ndb_api_trans_abort_count_session            | 0        |
| Ndb_api_trans_close_count_session            | 0        |
| Ndb_api_pk_op_count_session                  | 0        |
| Ndb_api_uk_op_count_session                  | 0        |
| Ndb_api_table_scan_count_session             | 0        |
| Ndb_api_range_scan_count_session             | 0        |
| Ndb_api_pruned_scan_count_session            | 0        |
| Ndb_api_scan_batch_count_session             | 0        |
| Ndb_api_read_row_count_session               | 0        |
| Ndb_api_trans_local_read_row_count_session   | 0        |
| Ndb_api_event_data_count_injector            | 0        |
| Ndb_api_event_nondata_count_injector         | 0        |
| Ndb_api_event_bytes_count_injector           | 0        |
| Ndb_api_wait_exec_complete_count_slave       | 0        |
| Ndb_api_wait_scan_result_count_slave         | 0        |
| Ndb_api_wait_meta_request_count_slave        | 0        |
| Ndb_api_wait_nanos_count_slave               | 0        |
| Ndb_api_bytes_sent_count_slave               | 0        |
| Ndb_api_bytes_received_count_slave           | 0        |
| Ndb_api_trans_start_count_slave              | 0        |
| Ndb_api_trans_commit_count_slave             | 0        |
| Ndb_api_trans_abort_count_slave              | 0        |
| Ndb_api_trans_close_count_slave              | 0        |
| Ndb_api_pk_op_count_slave                    | 0        |
| Ndb_api_uk_op_count_slave                    | 0        |
| Ndb_api_table_scan_count_slave               | 0        |
| Ndb_api_range_scan_count_slave               | 0        |
| Ndb_api_pruned_scan_count_slave              | 0        |
| Ndb_api_scan_batch_count_slave               | 0        |
| Ndb_api_read_row_count_slave                 | 0        |
| Ndb_api_trans_local_read_row_count_slave     | 0        |
| Ndb_api_wait_exec_complete_count             | 2        |
| Ndb_api_wait_scan_result_count               | 3        |
| Ndb_api_wait_meta_request_count              | 27       |
| Ndb_api_wait_nanos_count                     | 45612023 |
| Ndb_api_bytes_sent_count                     | 992      |
| Ndb_api_bytes_received_count                 | 9640     |
| Ndb_api_trans_start_count                    | 2        |
| Ndb_api_trans_commit_count                   | 1        |
| Ndb_api_trans_abort_count                    | 0        |
| Ndb_api_trans_close_count                    | 2        |
| Ndb_api_pk_op_count                          | 1        |
| Ndb_api_uk_op_count                          | 0        |
| Ndb_api_table_scan_count                     | 1        |
| Ndb_api_range_scan_count                     | 0        |
| Ndb_api_pruned_scan_count                    | 0        |
| Ndb_api_scan_batch_count                     | 0        |
| Ndb_api_read_row_count                       | 1        |
| Ndb_api_trans_local_read_row_count           | 1        |
| Ndb_api_event_data_count                     | 0        |
| Ndb_api_event_nondata_count                  | 0        |
| Ndb_api_event_bytes_count                    | 0        |
+----------------------------------------------+----------+
60 rows in set (0.02 sec)
```

These status variables are also available from the SESSION_STATUS and GLOBAL_STATUS tables of the INFORMATION_SCHEMA database, as shown here:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.SESSION_STATUS
    ->     WHERE VARIABLE_NAME LIKE 'ndb_api%';
```

```
+--------------------------------------------+----------------+
| VARIABLE_NAME                              | VARIABLE_VALUE |
+--------------------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SESSION   | 2              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SESSION     | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SESSION    | 1              |
| NDB_API_WAIT_NANOS_COUNT_SESSION           | 8144375        |
| NDB_API_BYTES_SENT_COUNT_SESSION           | 68             |
| NDB_API_BYTES_RECEIVED_COUNT_SESSION       | 84             |
| NDB_API_TRANS_START_COUNT_SESSION          | 1              |
| NDB_API_TRANS_COMMIT_COUNT_SESSION         | 1              |
| NDB_API_TRANS_ABORT_COUNT_SESSION          | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SESSION          | 1              |
| NDB_API_PK_OP_COUNT_SESSION                | 1              |
| NDB_API_UK_OP_COUNT_SESSION                | 0              |
| NDB_API_TABLE_SCAN_COUNT_SESSION           | 0              |
| NDB_API_RANGE_SCAN_COUNT_SESSION           | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SESSION          | 0              |
| NDB_API_SCAN_BATCH_COUNT_SESSION           | 0              |
| NDB_API_READ_ROW_COUNT_SESSION             | 1              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SESSION | 1              |
| NDB_API_EVENT_DATA_COUNT_INJECTOR          | 0              |
| NDB_API_EVENT_NONDATA_COUNT_INJECTOR       | 0              |
| NDB_API_EVENT_BYTES_COUNT_INJECTOR         | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE     | 0              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE       | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SLAVE      | 0              |
| NDB_API_WAIT_NANOS_COUNT_SLAVE             | 0              |
| NDB_API_BYTES_SENT_COUNT_SLAVE             | 0              |
| NDB_API_BYTES_RECEIVED_COUNT_SLAVE         | 0              |
| NDB_API_TRANS_START_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_COMMIT_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_ABORT_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SLAVE            | 0              |
| NDB_API_PK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_UK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_TABLE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_RANGE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_SCAN_BATCH_COUNT_SLAVE             | 0              |
| NDB_API_READ_ROW_COUNT_SLAVE               | 0              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SLAVE   | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT           | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT             | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT            | 28             |
| NDB_API_WAIT_NANOS_COUNT                   | 53756398       |
| NDB_API_BYTES_SENT_COUNT                   | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT               | 9724           |
| NDB_API_TRANS_START_COUNT                  | 3              |
| NDB_API_TRANS_COMMIT_COUNT                 | 2              |
| NDB_API_TRANS_ABORT_COUNT                  | 0              |
| NDB_API_TRANS_CLOSE_COUNT                  | 3              |
| NDB_API_PK_OP_COUNT                        | 2              |
| NDB_API_UK_OP_COUNT                        | 0              |
| NDB_API_TABLE_SCAN_COUNT                   | 1              |
| NDB_API_RANGE_SCAN_COUNT                   | 0              |
| NDB_API_PRUNED_SCAN_COUNT                  | 0              |
| NDB_API_SCAN_BATCH_COUNT                   | 0              |
| NDB_API_READ_ROW_COUNT                     | 2              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT         | 2              |
| NDB_API_EVENT_DATA_COUNT                   | 0              |
| NDB_API_EVENT_NONDATA_COUNT                | 0              |
| NDB_API_EVENT_BYTES_COUNT                  | 0              |
+--------------------------------------------+----------------+
60 rows in set (0.00 sec)

mysql> SELECT * FROM INFORMATION_SCHEMA.GLOBAL_STATUS
```

```
    ->     WHERE VARIABLE_NAME LIKE 'ndb_api%';
+-------------------------------------------+----------------+
| VARIABLE_NAME                             | VARIABLE_VALUE |
+-------------------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SESSION  | 2              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SESSION    | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SESSION   | 1              |
| NDB_API_WAIT_NANOS_COUNT_SESSION          | 8144375        |
| NDB_API_BYTES_SENT_COUNT_SESSION          | 68             |
| NDB_API_BYTES_RECEIVED_COUNT_SESSION      | 84             |
| NDB_API_TRANS_START_COUNT_SESSION         | 1              |
| NDB_API_TRANS_COMMIT_COUNT_SESSION        | 1              |
| NDB_API_TRANS_ABORT_COUNT_SESSION         | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SESSION         | 1              |
| NDB_API_PK_OP_COUNT_SESSION               | 1              |
| NDB_API_UK_OP_COUNT_SESSION               | 0              |
| NDB_API_TABLE_SCAN_COUNT_SESSION          | 0              |
| NDB_API_RANGE_SCAN_COUNT_SESSION          | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SESSION         | 0              |
| NDB_API_SCAN_BATCH_COUNT_SESSION          | 0              |
| NDB_API_READ_ROW_COUNT_SESSION            | 1              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SESSION | 1             |
| NDB_API_EVENT_DATA_COUNT_INJECTOR         | 0              |
| NDB_API_EVENT_NONDATA_COUNT_INJECTOR      | 0              |
| NDB_API_EVENT_BYTES_COUNT_INJECTOR        | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE    | 0              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE      | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SLAVE     | 0              |
| NDB_API_WAIT_NANOS_COUNT_SLAVE            | 0              |
| NDB_API_BYTES_SENT_COUNT_SLAVE            | 0              |
| NDB_API_BYTES_RECEIVED_COUNT_SLAVE        | 0              |
| NDB_API_TRANS_START_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_COMMIT_COUNT_SLAVE          | 0              |
| NDB_API_TRANS_ABORT_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SLAVE           | 0              |
| NDB_API_PK_OP_COUNT_SLAVE                 | 0              |
| NDB_API_UK_OP_COUNT_SLAVE                 | 0              |
| NDB_API_TABLE_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_RANGE_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SLAVE           | 0              |
| NDB_API_SCAN_BATCH_COUNT_SLAVE            | 0              |
| NDB_API_READ_ROW_COUNT_SLAVE              | 0              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SLAVE  | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT          | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT            | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT           | 28             |
| NDB_API_WAIT_NANOS_COUNT                  | 53756398       |
| NDB_API_BYTES_SENT_COUNT                  | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT              | 9724           |
| NDB_API_TRANS_START_COUNT                 | 3              |
| NDB_API_TRANS_COMMIT_COUNT                | 2              |
| NDB_API_TRANS_ABORT_COUNT                 | 0              |
| NDB_API_TRANS_CLOSE_COUNT                 | 3              |
| NDB_API_PK_OP_COUNT                       | 2              |
| NDB_API_UK_OP_COUNT                       | 0              |
| NDB_API_TABLE_SCAN_COUNT                  | 1              |
| NDB_API_RANGE_SCAN_COUNT                  | 0              |
| NDB_API_PRUNED_SCAN_COUNT                 | 0              |
| NDB_API_SCAN_BATCH_COUNT                  | 0              |
| NDB_API_READ_ROW_COUNT                    | 2              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT        | 2              |
| NDB_API_EVENT_DATA_COUNT                  | 0              |
| NDB_API_EVENT_NONDATA_COUNT               | 0              |
| NDB_API_EVENT_BYTES_COUNT                 | 0              |
+-------------------------------------------+----------------+
60 rows in set (0.00 sec)
```

Each `Ndb` object has its own counters. NDB API applications can read the values of the counters for use in optimization or monitoring. For multi-threaded clients which use more than one `Ndb` object concurrently, it is also possible to obtain a summed view of counters from all `Ndb` objects belonging to a given `Ndb_cluster_connection`.

Four sets of these counters are exposed. One set applies to the current session only; the other 3 are global. *This is in spite of the fact that their values can be obtained as either session or global status variables in the `mysql` client*. This means that specifying the `SESSION` or `GLOBAL` keyword with `SHOW STATUS` has no effect on the values reported for NDB API statistics status variables, and the value for each of these variables is the same whether the value is obtained from the equivalent column of the `SESSION_STATUS` or the `GLOBAL_STATUS` table.

- *Session counters (session specific)*

  Session counters relate to the `Ndb` objects in use by (only) the current session. Use of such objects by other MySQL clients does not influence these counts.

  In order to minimize confusion with standard MySQL session variables, we refer to the variables that correspond to these NDB API session counters as "`_session` variables", with a leading underscore.

- *Slave counters (global)*

  This set of counters relates to the `Ndb` objects used by the replication slave SQL thread, if any. If this `mysqld` does not act as a replication slave, or does not use `NDB` tables, then all of these counts are 0.

  We refer to the related status variables as "`_slave` variables" (with a leading underscore).

- *Injector counters (global)*

  Injector counters relate to the `Ndb` object used to listen to cluster events by the binary log injector thread. Even when not writing a binary log, `mysqld` processes attached to a MySQL Cluster continue to listen for some events, such as schema changes.

  We refer to the status variables that correspond to NDB API injector counters as "`_injector` variables" (with a leading underscore).

- *Server (Global) counters (global)*

  This set of counters relates to all `Ndb` objects currently used by this `mysqld`. This includes all MySQL client applications, the slave SQL thread (if any), the binlog injector, and the `NDB` utility thread.

  We refer to the status variables that correspond to these counters as "global variables" or "`mysqld`-level variables".

You can obtain values for a particular set of variables by additionally filtering for the substring `session`, `slave`, or `injector` in the variable name (along with the common prefix `Ndb_api`). For `_session` variables, this can be done as shown here:

```
mysql> SHOW STATUS LIKE 'ndb_api%session';
+-----------------------------------------+---------+
| Variable_name                           | Value   |
+-----------------------------------------+---------+
| Ndb_api_wait_exec_complete_count_session | 2      |
| Ndb_api_wait_scan_result_count_session  | 0       |
| Ndb_api_wait_meta_request_count_session | 1       |
| Ndb_api_wait_nanos_count_session        | 8144375 |
| Ndb_api_bytes_sent_count_session        | 68      |
| Ndb_api_bytes_received_count_session    | 84      |
| Ndb_api_trans_start_count_session       | 1       |
```

```
| Ndb_api_trans_commit_count_session            | 1        |
| Ndb_api_trans_abort_count_session             | 0        |
| Ndb_api_trans_close_count_session             | 1        |
| Ndb_api_pk_op_count_session                   | 1        |
| Ndb_api_uk_op_count_session                   | 0        |
| Ndb_api_table_scan_count_session              | 0        |
| Ndb_api_range_scan_count_session              | 0        |
| Ndb_api_pruned_scan_count_session             | 0        |
| Ndb_api_scan_batch_count_session              | 0        |
| Ndb_api_read_row_count_session                | 1        |
| Ndb_api_trans_local_read_row_count_session    | 1        |
+-----------------------------------------------+----------+
18 rows in set (0.50 sec)
```

To obtain a listing of the NDB API `mysqld`-level status variables, filter for variable names beginning with `ndb_api` and ending in `_count`, like this:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.SESSION_STATUS
    ->     WHERE VARIABLE_NAME LIKE 'ndb_api%count';
+-----------------------------------+----------------+
| VARIABLE_NAME                     | VARIABLE_VALUE |
+-----------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT  | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT    | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT   | 28             |
| NDB_API_WAIT_NANOS_COUNT          | 53756398       |
| NDB_API_BYTES_SENT_COUNT          | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT      | 9724           |
| NDB_API_TRANS_START_COUNT         | 3              |
| NDB_API_TRANS_COMMIT_COUNT        | 2              |
| NDB_API_TRANS_ABORT_COUNT         | 0              |
| NDB_API_TRANS_CLOSE_COUNT         | 3              |
| NDB_API_PK_OP_COUNT               | 2              |
| NDB_API_UK_OP_COUNT               | 0              |
| NDB_API_TABLE_SCAN_COUNT          | 1              |
| NDB_API_RANGE_SCAN_COUNT          | 0              |
| NDB_API_PRUNED_SCAN_COUNT         | 0              |
| NDB_API_SCAN_BATCH_COUNT          | 0              |
| NDB_API_READ_ROW_COUNT            | 2              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT | 2             |
| NDB_API_EVENT_DATA_COUNT          | 0              |
| NDB_API_EVENT_NONDATA_COUNT       | 0              |
| NDB_API_EVENT_BYTES_COUNT         | 0              |
+-----------------------------------+----------------+
21 rows in set (0.09 sec)
```

Not all counters are reflected in all 4 sets of status variables. For the event counters `DataEventsRecvdCount`, `NondataEventsRecvdCount`, and `EventBytesRecvdCount`, only `_injector` and `mysqld`-level NDB API status variables are available:

```
mysql> SHOW STATUS LIKE 'ndb_api%event%';
+---------------------------------------+-------+
| Variable_name                         | Value |
+---------------------------------------+-------+
| Ndb_api_event_data_count_injector     | 0     |
| Ndb_api_event_nondata_count_injector  | 0     |
| Ndb_api_event_bytes_count_injector    | 0     |
| Ndb_api_event_data_count              | 0     |
| Ndb_api_event_nondata_count           | 0     |
| Ndb_api_event_bytes_count             | 0     |
+---------------------------------------+-------+
6 rows in set (0.00 sec)
```

`_injector` status variables are not implemented for any other NDB API counters, as shown here:

```
mysql> SHOW STATUS LIKE 'ndb_api%injector%';
+------------------------------------+-------+
| Variable_name                      | Value |
+------------------------------------+-------+
| Ndb_api_event_data_count_injector    | 0     |
| Ndb_api_event_nondata_count_injector | 0     |
| Ndb_api_event_bytes_count_injector   | 0     |
+------------------------------------+-------+
3 rows in set (0.00 sec)
```

The names of the status variables can easily be associated with the names of the corresponding counters. Each NDB API statistics counter is listed in the following table with a description as well as the names of any MySQL server status variables corresponding to this counter.

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
`WaitExecCompleteCount`	Number of times thread has been blocked while waiting for execution of an operation to complete. Includes all `execute()` calls as well as implicit executes for blob operations and auto-increment not visible to clients.
	• `Ndb_api_wait_exec_complete_count_session` • `Ndb_api_wait_exec_complete_count_slave` • [none] • `Ndb_api_wait_exec_complete_count`
`WaitScanResultCount`	Number of times thread has been blocked while waiting for a scan-based signal, such waiting for additional results, or for a scan to close.
	• `Ndb_api_wait_scan_result_count_session` • `Ndb_api_wait_scan_result_count_slave` • [none] • `Ndb_api_wait_scan_result_count`
`WaitMetaRequestCount`	Number of times thread has been blocked waiting for a metadata-based signal; this can occur when waiting for a DDL operation or for an epoch to be started (or ended).
	• `Ndb_api_wait_meta_request_count_session` • `Ndb_api_wait_meta_request_count_slave` • [none]

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
	• `Ndb_api_wait_meta_request_count`
`WaitNanosCount`	Total time (in nanoseconds) spent waiting for some type of signal from the data nodes.
	• `Ndb_api_wait_nanos_count_session` • `Ndb_api_wait_nanos_count_slave` • [none] • `Ndb_api_wait_nanos_count`
`BytesSentCount`	Amount of data (in bytes) sent to the data nodes
	• `Ndb_api_bytes_sent_count_session` • `Ndb_api_bytes_sent_count_slave` • [none] • `Ndb_api_bytes_sent_count`
`BytesRecvdCount`	Amount of data (in bytes) received from the data nodes
	• `Ndb_api_bytes_received_count_session` • `Ndb_api_bytes_received_count_slave` • [none] • `Ndb_api_bytes_received_count`
`TransStartCount`	Number of transactions started.
	• `Ndb_api_trans_start_count_session` • `Ndb_api_trans_start_count_slave` • [none] • `Ndb_api_trans_start_count`
`TransCommitCount`	Number of transactions committed.
	• `Ndb_api_trans_commit_count_session` • `Ndb_api_trans_commit_count_slave` • [none] • `Ndb_api_trans_commit_count`

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
TransAbortCount	Number of transactions aborted.
	• Ndb_api_trans_abort_count_session • Ndb_api_trans_abort_count_slave • [none] • Ndb_api_trans_abort_count
TransCloseCount	Number of transactions aborted. (This value may be greater than the sum of TransCommitCount and TransAbortCount.)
	• Ndb_api_trans_close_count_session • Ndb_api_trans_close_count_slave • [none] • Ndb_api_trans_close_count
PkOpCount	Number of operations based on or using primary keys. This count includes blob-part table operations, implicit unlocking operations, and auto-increment operations, as well as primary key operations normally visible to MySQL clients.
	• Ndb_api_pk_op_count_session • Ndb_api_pk_op_count_slave • [none] • Ndb_api_pk_op_count
UkOpCount	Number of operations based on or using unique keys.
	• Ndb_api_uk_op_count_session • Ndb_api_uk_op_count_slave • [none] • Ndb_api_uk_op_count
TableScanCount	Number of table scans that have been started. This includes scans of internal tables.
	• Ndb_api_table_scan_count_session • Ndb_api_table_scan_count_slave

Counter Name	Description
Counter Name	**Description**
	Status Variables (by statistic type):
	• **Session**
	• **Slave**
	• **Injector**
	• **Server**
	• [none]
	• Ndb_api_table_scan_count
RangeScanCount	Number of range scans that have been started.
	• Ndb_api_range_scan_count_session
	• Ndb_api_range_scan_count_slave
	• [none]
	• Ndb_api_range_scan_count
PrunedScanCount	Number of scans that have been pruned to a single partition.
	• Ndb_api_pruned_scan_count_session
	• Ndb_api_pruned_scan_count_slave
	• [none]
	• Ndb_api_pruned_scan_count
ScanBatchCount	Number of batches of rows received. (A *batch* in this context is a set of scan results from a single fragment.)
	• Ndb_api_scan_batch_count_session
	• Ndb_api_scan_batch_count_slave
	• [none]
	• Ndb_api_scan_batch_count
ReadRowCount	Total number of rows that have been read. Includes rows read using primary key, unique key, and scan operations.
	• Ndb_api_read_row_count_session
	• Ndb_api_read_row_count_slave
	• [none]
	• Ndb_api_read_row_count
TransLocalReadRowCount	Number of rows read from the data same node on which the transaction was being run.
	• Ndb_api_trans_local_read_row_count_session
	• Ndb_api_trans_local_read_row_count_slave

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
	• [none] • Ndb_api_trans_local_read_row_count
DataEventsRecvdCount	Number of row change events received.
	• [none] • [none] • Ndb_api_event_data_count_injector • Ndb_api_event_data_count
NondataEventsRecvdCount	Number of events received, other than row change events.
	• [none] • [none] • Ndb_api_event_nondata_count_injector • Ndb_api_event_nondata_count
EventBytesRecvdCount	Number of bytes of events received.
	• [none] • [none] • Ndb_api_event_bytes_count_injector • Ndb_api_event_bytes_count

To see all counts of committed transactions—that is, all `TransCommitCount` counter status variables—you can filter the results of `SHOW STATUS` for the substring `trans_commit_count`, like this:

```
mysql> SHOW STATUS LIKE '%trans_commit_count%';
+----------------------------------+-------+
| Variable_name                    | Value |
+----------------------------------+-------+
| Ndb_api_trans_commit_count_session | 1   |
| Ndb_api_trans_commit_count_slave   | 0   |
| Ndb_api_trans_commit_count         | 2   |
+----------------------------------+-------+
3 rows in set (0.00 sec)
```

From this you can determine that 1 transaction has been committed in the current `mysql` client session, and 2 transactions have been committed on this `mysqld` since it was last restarted.

You can see how various NDB API counters are incremented by a given SQL statement by comparing the values of the corresponding `_session` status variables immediately before and after performing the statement. In this example, after getting the initial values from `SHOW STATUS`, we create in the `test` database an `NDB` table, named `t`, that has a single column:

```
mysql> SHOW STATUS LIKE 'ndb_api%session%';
+-------------------------------------------+--------+
| Variable_name                             | Value  |
+-------------------------------------------+--------+
| Ndb_api_wait_exec_complete_count_session  | 2      |
| Ndb_api_wait_scan_result_count_session    | 0      |
| Ndb_api_wait_meta_request_count_session   | 3      |
| Ndb_api_wait_nanos_count_session          | 820705 |
| Ndb_api_bytes_sent_count_session          | 132    |
| Ndb_api_bytes_received_count_session      | 372    |
| Ndb_api_trans_start_count_session         | 1      |
| Ndb_api_trans_commit_count_session        | 1      |
| Ndb_api_trans_abort_count_session         | 0      |
| Ndb_api_trans_close_count_session         | 1      |
| Ndb_api_pk_op_count_session               | 1      |
| Ndb_api_uk_op_count_session               | 0      |
| Ndb_api_table_scan_count_session          | 0      |
| Ndb_api_range_scan_count_session          | 0      |
| Ndb_api_pruned_scan_count_session         | 0      |
| Ndb_api_scan_batch_count_session          | 0      |
| Ndb_api_read_row_count_session            | 1      |
| Ndb_api_trans_local_read_row_count_session | 1     |
+-------------------------------------------+--------+
18 rows in set (0.00 sec)

mysql> USE test;
Database changed
mysql> CREATE TABLE t (c INT) ENGINE NDBCLUSTER;
Query OK, 0 rows affected (0.85 sec)
```

Now you can execute a new `SHOW STATUS` statement and observe the changes, as shown here (with the changed rows highlighted in the output):

```
mysql> SHOW STATUS LIKE 'ndb_api%session%';
+-------------------------------------------+-----------+
| Variable_name                             | Value     |
+-------------------------------------------+-----------+
| Ndb_api_wait_exec_complete_count_session  | 8         |
| Ndb_api_wait_scan_result_count_session    | 0         |
| Ndb_api_wait_meta_request_count_session   | 17        |
| Ndb_api_wait_nanos_count_session          | 706871709 |
| Ndb_api_bytes_sent_count_session          | 2376      |
| Ndb_api_bytes_received_count_session      | 3844      |
| Ndb_api_trans_start_count_session         | 4         |
| Ndb_api_trans_commit_count_session        | 4         |
| Ndb_api_trans_abort_count_session         | 0         |
| Ndb_api_trans_close_count_session         | 4         |
| Ndb_api_pk_op_count_session               | 6         |
| Ndb_api_uk_op_count_session               | 0         |
| Ndb_api_table_scan_count_session          | 0         |
| Ndb_api_range_scan_count_session          | 0         |
| Ndb_api_pruned_scan_count_session         | 0         |
| Ndb_api_scan_batch_count_session          | 0         |
| Ndb_api_read_row_count_session            | 2         |
| Ndb_api_trans_local_read_row_count_session | 1        |
+-------------------------------------------+-----------+
18 rows in set (0.00 sec)
```

Similarly, you can see the changes in the NDB API statistics counters caused by inserting a row into `t`: Insert the row, then run the same `SHOW STATUS` statement used in the previous example, as shown here:

```
mysql> INSERT INTO t VALUES (100);
Query OK, 1 row affected (0.00 sec)

mysql> SHOW STATUS LIKE 'ndb_api%session%';
+------------------------------------------+-----------+
| Variable_name                            | Value     |
+------------------------------------------+-----------+
| Ndb_api_wait_exec_complete_count_session | 11        |
| Ndb_api_wait_scan_result_count_session   | 6         |
| Ndb_api_wait_meta_request_count_session  | 20        |
| Ndb_api_wait_nanos_count_session         | 707370418 |
| Ndb_api_bytes_sent_count_session         | 2724      |
| Ndb_api_bytes_received_count_session     | 4116      |
| Ndb_api_trans_start_count_session        | 7         |
| Ndb_api_trans_commit_count_session       | 6         |
| Ndb_api_trans_abort_count_session        | 0         |
| Ndb_api_trans_close_count_session        | 7         |
| Ndb_api_pk_op_count_session              | 8         |
| Ndb_api_uk_op_count_session              | 0         |
| Ndb_api_table_scan_count_session         | 1         |
| Ndb_api_range_scan_count_session         | 0         |
| Ndb_api_pruned_scan_count_session        | 0         |
| Ndb_api_scan_batch_count_session         | 0         |
| Ndb_api_read_row_count_session           | 3         |
| Ndb_api_trans_local_read_row_count_session | 2       |
+------------------------------------------+-----------+
18 rows in set (0.00 sec)
```

We can make a number of observations from these results:

- Although we created `t` with no explicit primary key, 5 primary key operations were performed in doing so (the difference in the "before" and "after" values of `Ndb_api_pk_op_count_session`, or 6 minus 1). This reflects the creation of the hidden primary key that is a feature of all tables using the `NDB` storage engine.

- By comparing successive values for `Ndb_api_wait_nanos_count_session`, we can see that the NDB API operations implementing the `CREATE TABLE` statement waited much longer (706871709 - 820705 = 706051004 nanoseconds, or approximately 0.7 second) for responses from the data nodes than those executed by the `INSERT` (707370418 - 706871709 = 498709 ns or roughly .0005 second). The execution times reported for these statements in the `mysql` client correlate roughly with these figures.

  On platforms without sufficient (nanosecond) time resolution, small changes in the value of the `WaitNanosCount` NDB API counter due to SQL statements that execute very quickly may not always be visible in the values of `Ndb_api_wait_nanos_count_session`, `Ndb_api_wait_nanos_count_slave`, or `Ndb_api_wait_nanos_count`.

- The `INSERT` statement incremented both the `ReadRowCount` and `TransLocalReadRowCount` NDB API statistics counters, as reflected by the increased values of `Ndb_api_read_row_count_session` and `Ndb_api_trans_local_read_row_count_session`.

17.6 MySQL Cluster Replication

Previous to MySQL 5.1.6, *asynchronous replication*, more usually referred to simply as "replication", was not available when using MySQL Cluster. MySQL 5.1.6 introduces master-slave replication of this type for MySQL Cluster databases. This section explains how to set up and manage a configuration wherein one group of computers operating as a MySQL Cluster replicates to a second computer or group of computers.

We assume some familiarity on the part of the reader with standard MySQL replication as discussed elsewhere in this Manual. (See Chapter 16, *Replication*).

Normal (non-clustered) replication involves a "master" server and a "slave" server, the master being the source of the operations and data to be replicated and the slave being the recipient of these. In MySQL Cluster, replication is conceptually very similar but can be more complex in practice, as it may be extended to cover a number of different configurations including replicating between two complete clusters. Although a MySQL Cluster itself depends on the NDB storage engine for clustering functionality, it is not necessary to use NDB as the storage engine for the slave's copies of the replicated tables (see Replication from NDB to other storage engines). However, for maximum availability, it is possible (and preferable) to replicate from one MySQL Cluster to another, and it is this scenario that we discuss, as shown in the following figure:

Figure 17.13 MySQL Cluster-to-Cluster Replication Layout
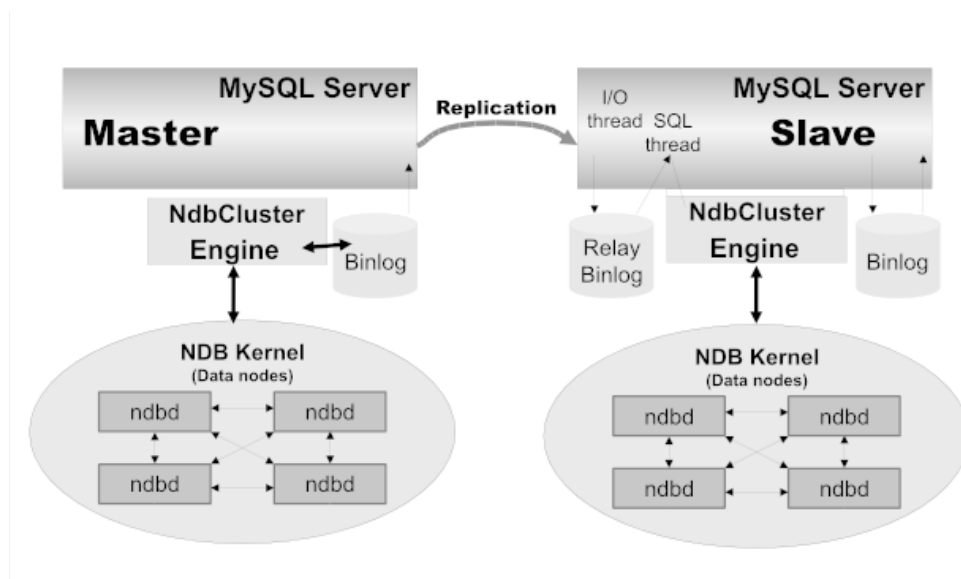
In this scenario, the replication process is one in which successive states of a master cluster are logged and saved to a slave cluster. This process is accomplished by a special thread known as the NDB binlog injector thread, which runs on each MySQL server and produces a binary log (`binlog`). This thread ensures that all changes in the cluster producing the binary log—and not just those changes that are effected through the MySQL Server—are inserted into the binary log with the correct serialization order. We refer to the MySQL replication master and replication slave servers as replication servers or replication nodes, and the data flow or line of communication between them as a *replication channel*.

For information about performing point-in-time recovery with MySQL Cluster and MySQL Cluster Replication, see Section 17.6.9.2, "Point-In-Time Recovery Using MySQL Cluster Replication".

NDB API _slave status variables. Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, NDB API counters provide enhanced monitoring capabilities on MySQL Cluster replication slaves. These are implelemented as NDB statistics `_slave` status variables, as seen in the output of `SHOW STATUS`, or in the results of queries against the `SESSION_STATUS` or `GLOBAL_STATUS` table in a `mysql` client session connected to a MySQL Server that is acting as a slave in MySQL Cluster Replication. By comparing the values of these status variables before and after the execution of statements affecting replicated NDB tables, you can observe the corresponding actions taken on the NDB API level by the slave, which can be useful when monitoring or troubleshooting MySQL Cluster Replication. Section 17.5.15, "NDB API Statistics Counters and Variables", provides additional information.

Replication from NDB to non-NDB tables. It is possible to replicate NDB tables from a MySQL Cluster acting as the master to tables using other MySQL storage engines such as InnoDB or MyISAM on a slave

`mysqld`. This is subject to a number of conditions; see Replication from NDB to other storage engines, and Replication from NDB to a nontransactional storage engine, for more information.

17.6.1 MySQL Cluster Replication: Abbreviations and Symbols

Throughout this section, we use the following abbreviations or symbols for referring to the master and slave clusters, and to processes and commands run on the clusters or cluster nodes:

Symbol or Abbreviation	Description (Refers to...)
`M`	The cluster serving as the (primary) replication master
`S`	The cluster acting as the (primary) replication slave
`shellM>`	Shell command to be issued on the master cluster
`mysqlM>`	MySQL client command issued on a single MySQL server running as an SQL node on the master cluster
`mysqlM*>`	MySQL client command to be issued on all SQL nodes participating in the replication master cluster
`shellS>`	Shell command to be issued on the slave cluster
`mysqlS>`	MySQL client command issued on a single MySQL server running as an SQL node on the slave cluster
`mysqlS*>`	MySQL client command to be issued on all SQL nodes participating in the replication slave cluster
`C`	Primary replication channel
`C'`	Secondary replication channel
`M'`	Secondary replication master
`S'`	Secondary replication slave

17.6.2 General Requirements for MySQL Cluster Replication

A replication channel requires two MySQL servers acting as replication servers (one each for the master and slave). For example, this means that in the case of a replication setup with two replication channels (to provide an extra channel for redundancy), there will be a total of four replication nodes, two per cluster.

Replication of a MySQL Cluster as described in this section and those following is dependent on row-based replication. This means that the replication master MySQL server must be started with `--binlog-format=ROW` or `--binlog-format=MIXED`, as described in Section 17.6.6, "Starting MySQL Cluster Replication (Single Replication Channel)". For general information about row-based replication, see Section 16.1.2, "Replication Formats".

> **Important**
>
> If you attempt to use MySQL Cluster Replication with `--binlog-format=STATEMENT`, replication fails to work properly because the `ndb_binlog_index` table on the master and the `epoch` column of the `ndb_apply_status` table on the slave are not updated (see Section 17.6.4, "MySQL Cluster Replication Schema and Tables"). Instead, only updates on the MySQL server acting as the replication master propagate to the slave, and no updates from any other SQL nodes on the master cluster are replicated.
>
> In all MySQL Cluster NDB 6.x and 7.x releases, the default value for the `--binlog-format` option is `MIXED`.

Each MySQL server used for replication in either cluster must be uniquely identified among all the MySQL replication servers participating in either cluster (you cannot have replication servers on both the master and slave clusters sharing the same ID). This can be done by starting each SQL node using the `--server-id=id` option, where `id` is a unique integer. Although it is not strictly necessary, we will assume for purposes of this discussion that all MySQL Cluster binaries are of the same release version.

It is generally true in MySQL Replication that both MySQL servers (`mysqld` processes) involved must be compatible with one another with respect to both the version of the replication protocol used and the SQL feature sets which they support (see Section 16.4.2, "Replication Compatibility Between MySQL Versions"). It is due to such differences between the binaries in the MySQL Cluster and MySQL Server 5.1 distributions that MySQL Cluster Replication has the additional requirement that both `mysqld` binaries come from a MySQL Cluster distribution. The simplest and easiest way to assure that the `mysqld` servers are compatible is to use the same MySQL Cluster distribution for all master and slave `mysqld` binaries.

We assume that the slave server or cluster is dedicated to replication of the master, and that no other data is being stored on it.

All `NDB` tables being replicated must be created using a MySQL server and client. Tables and other database objects created using the NDB API (with, for example, `Dictionary::createTable()`) are not visible to a MySQL server and so are not replicated. Updates by NDB API applications to existing tables that were created using a MySQL server can be replicated.

> **Note**
>
> It is possible to replicate a MySQL Cluster using statement-based replication. However, in this case, the following restrictions apply:
>
> - All updates to data rows on the cluster acting as the master must be directed to a single MySQL server.
>
> - It is not possible to replicate a cluster using multiple simultaneous MySQL replication processes.
>
> - Only changes made at the SQL level are replicated.
>
> These are in addition to the other limitations of statement-based replication as opposed to row-based replication; see Section 16.1.2.1, "Advantages and Disadvantages of Statement-Based and Row-Based Replication", for more specific information concerning the differences between the two replication formats.

17.6.3 Known Issues in MySQL Cluster Replication

This section discusses known problems or issues when using replication with MySQL Cluster in MySQL 5.1 (including MySQL Cluster NDB 6.X and 7.X through 7.1).

Loss of master-slave connection. A loss of connection can occur either between the replication master SQL node and the replication slave SQL node, or between the replication master SQL node and the data nodes in the master cluster. In the latter case, this can occur not only as a result of loss of physical connection (for example, a broken network cable), but due to the overflow of data node event buffers; if the SQL node is too slow to respond, it may be dropped by the cluster (this is controllable to some degree by adjusting the `MaxBufferedEpochs` and `TimeBetweenEpochs` configuration parameters). If this occurs, *it is entirely possible for new data to be inserted into the master cluster without being recorded in the replication master's binary log.* For this reason, to guarantee high availability, it is extremely important to maintain a backup replication channel, to monitor the primary channel, and to fail over to the secondary replication channel when necessary to keep the slave cluster synchronized with

the master. MySQL Cluster is not designed to perform such monitoring on its own; for this, an external application is required.

Prior to MySQL 5.1.18, a MySQL Cluster replication slave `mysqld` had no way of detecting that the connection from the master had been interrupted. For this reason, it was possible for the slave to become inconsistent with the master.

Beginning with MySQL 5.1.18, the replication master issues a "gap" event when connecting or reconnecting to the master cluster. (A gap event is a type of "incident event," which indicates an incident that occurs that affects the contents of the database but that cannot easily be represented as a set of changes. Examples of incidents are server crashes, database resynchronization, (some) software updates, and (some) hardware changes.) When the slave encounters a gap in the replication log, it stops with an error message. This message is available in the output of `SHOW SLAVE STATUS`, and indicates that the SQL thread has stopped due to an incident registered in the replication stream, and that manual intervention is required. See Section 17.6.8, "Implementing Failover with MySQL Cluster Replication", for more information about what to do in such circumstances.

> **Important**
>
> Because MySQL Cluster is not designed on its own to monitor replication status or provide failover, if high availability is a requirement for the slave server or cluster, then you must set up multiple replication lines, monitor the master `mysqld` on the primary replication line, and be prepared fail over to a secondary line if and as necessary. This must be done manually, or possibly by means of a third-party application. For information about implementing this type of setup, see Section 17.6.7, "Using Two Replication Channels for MySQL Cluster Replication", and Section 17.6.8, "Implementing Failover with MySQL Cluster Replication".
>
> However, if you are replicating from a standalone MySQL server to a MySQL Cluster, one channel is usually sufficient.

Multibyte character sets.   Previously, there were several known issues with regard to the use of multibyte characters sets with MySQL Cluster Replication. These were resolved in MySQL 5.1.21, MySQL Cluster NDB 6.2.14, and MySQL Cluster NDB 6.3.11. (See Bug #27404 and Bug #29562.)

Circular replication.   Prior to MySQL 5.1.18, circular replication was not supported with MySQL Cluster replication, due to the fact that all log events created in a particular MySQL Cluster were wrongly tagged with the server ID of the MySQL server used as master and not with the server ID of the originating server.

Beginning with MySQL 5.1.18, this limitation is lifted, as discussed in the next few paragraphs, in which we consider the example of a replication setup involving three MySQL Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication master for Cluster 2, Cluster 2 acts as the master for Cluster 3, and Cluster 3 acts as the master for Cluster 1. Each cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

Circular replication using these clusters is supported as long as the following conditions are met:

- The SQL nodes on all masters and slaves are the same

- All SQL nodes acting as replication masters and slaves are started using the `--log-slave-updates` option

This type of circular replication setup is shown in the following diagram:

Figure 17.14 MySQL Cluster Circular Replication With All Masters As Slaves
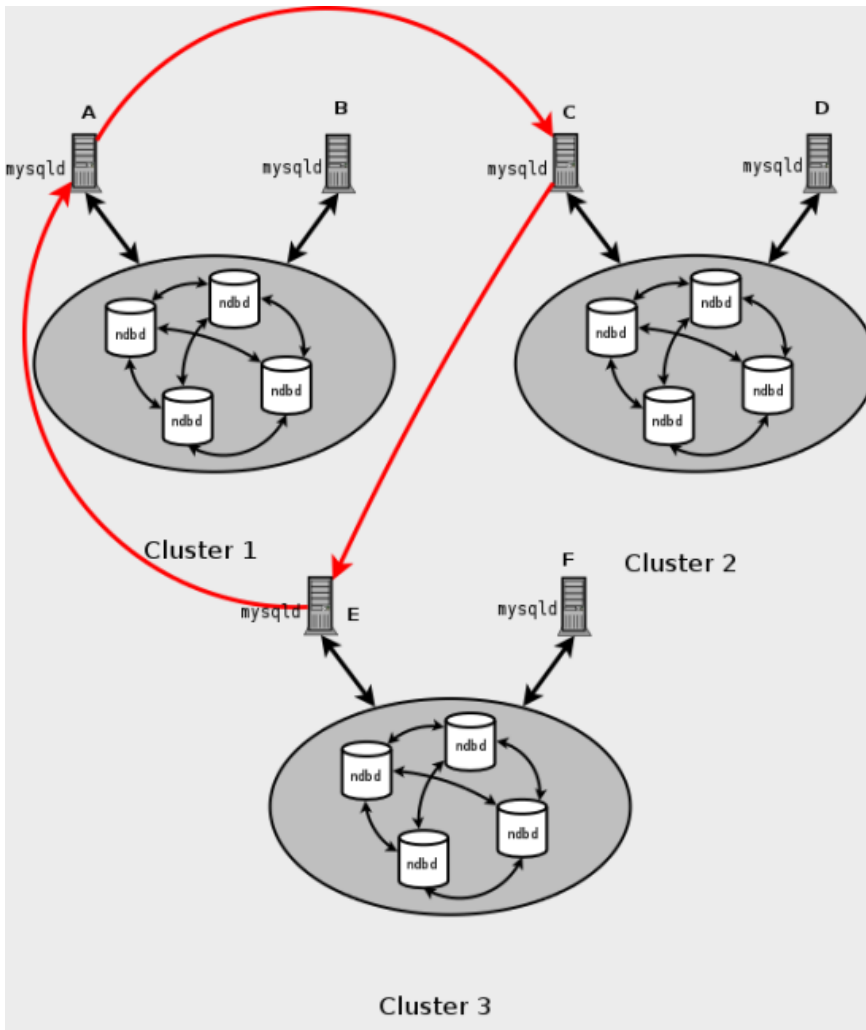
In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the red arrows in the diagram) directly connects all SQL nodes used as replication masters and slaves.

It should also be possible to set up circular replication in which not all master SQL nodes are also slaves, as shown here:

Figure 17.15 MySQL Cluster Circular Replication Where Not All Masters Are Slaves
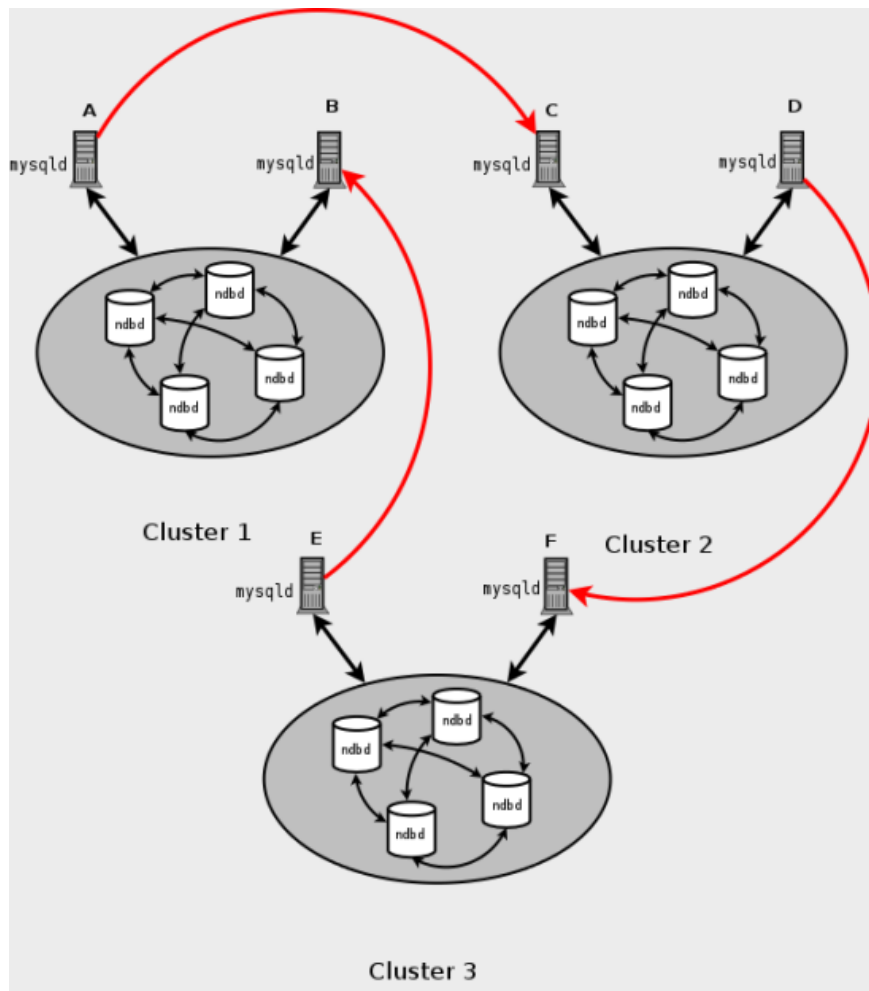
In this case, different SQL nodes in each cluster are used as replication masters and slaves. However, you must *not* start any of the SQL nodes using `--log-slave-updates`). This type of circular replication scheme for MySQL Cluster, in which the line of replication (again indicated by the red arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

> **Note**
>
> Beginning with MySQL 5.1.24, the `NDB` storage engine uses *idempotent execution mode*, which suppresses duplicate-key and other errors that otherwise break circular replication of MySQL Cluster. This is equivalent to setting the global `slave_exec_mode` system variable to `IDEMPOTENT`, although this is not necessary in MySQL Cluster replication, since MySQL Cluster now sets this variable automatically and ignores any attempts to set it explicitly. (Bug #31609)

MySQL Cluster replication and primary keys.   In MySQL 5.1.6, only those `NDB` tables having explicit primary keys could be replicated. This limitation was lifted in MySQL 5.1.7. However, in the event of a node failure, errors in replication of `NDB` tables without primary keys can still occur, due to the possibility of duplicate rows being inserted in such cases. For this reason, it is highly recommended that all `NDB` tables being replicated have primary keys.

MySQL Cluster Replication and Unique Keys.   Prior to MySQL Cluster NDB 7.0.25 and MySQL Cluster NDB 7.1.14, operations that updated values of unique key columns of `NDB` tables could result in duplicate-key errors when replicated. This was due to the ordering of row events in the binary log according to the partitioning of the base table, which meant that they could appear in a different order from that in which they were originally executed. (Bug #11756082)

In MySQL Cluster NDB 7.0.25, MySQL Cluster NDB 7.1.14, and later, this issue is solved for replication between `NDB` tables by deferring unique key checks until after all table row updates have been performed.

Deferring constraints in this way is currently supported only by `NDB`. Thus, updates of unique keys when replicating from `NDB` to a different storage engine such as `MyISAM` or `InnoDB` are still not supported.

The problem encountered when replicating without deferred checking of unique key updates can be illustrated using `NDB` table such as `t`, is created and populated on the master (and replicated to a slave that does not support deferred unique key updates) as shown here:

```
CREATE TABLE t (
    p INT PRIMARY KEY,
    c INT,
    UNIQUE KEY u (c)
)   ENGINE NDB;

INSERT INTO t
    VALUES (1,1), (2,2), (3,3), (4,4), (5,5);
```

The following `UPDATE` statement on `t` succeeded on the master, since the rows affected are processed in the order determined by the `ORDER BY` option, performed over the entire table:

```
UPDATE t SET c = c - 1 ORDER BY p;
```

However, the same statement failed with a duplicate key error or other constraint violation on the slave, because the ordering of the row updates was done for one partition at a time, rather than for the table as a whole.

> **Note**
>
> In MySQL 5.1.6 and later, every `NDB` table is implicitly partitioned by key when it is created. This also applies to all MySQL Cluster NDB 6.x and MySQL Cluster NDB 7.x releases. See Section 18.2.4, "KEY Partitioning", for more information.

Restarting with --initial.   Restarting the cluster with the `--initial` option causes the sequence of GCI and epoch numbers to start over from `0`. (This is generally true of MySQL Cluster and not limited to replication scenarios involving Cluster.) The MySQL servers involved in replication should in this case be restarted. After this, you should use the `RESET MASTER` and `RESET SLAVE` statements to clear the invalid `ndb_binlog_index` and `ndb_apply_status` tables, respectively.

auto_increment_offset and auto_increment_increment variables.   The use of the `auto_increment_offset` and `auto_increment_increment` server system variables is supported beginning with MySQL 5.1.20. Previously, these produced unpredictable results when used with `NDB` tables or MySQL Cluster replication.

Replication from NDB to other storage engines.   It is possible to replicate an `NDB` table on the master to a table using a different storage engine on the slave, taking into account the restrictions listed here:

- Multi-master and circular replication are not supported (tables on both the master and the slave must use the `NDB` storage engine for this to work).

- Using a storage engine which does not perform binary logging for slave tables requires special handling.

- Use of a nontransactional storage engine for slave tables also requires special handling.

- The master `mysqld` must be started with `--ndb-log-update-as-write=0` or `--ndb-log-update-as-write=OFF`.

The next few paragraphs provide additional information about each of the issues just described.

Multiple masters not supported when replicating NDB to other storage engines.   For replication from `NDB` to a different storage engine, the relationship between the two databases must be a simple master-slave one. This means that circular or master-master replication is not supported between MySQL Cluster and other storage engines.

In addition, it is not possible to configure more than one replication channel when replicating between `NDB` and a different storage engine. (However, a MySQL Cluster database *can* simultaneously replicate to multiple slave MySQL Cluster databases.) If the master uses `NDB` tables, it is still possible to have more than one MySQL Server maintain a binary log of all changes; however, for the slave to change masters (fail over), the new master-slave relationship must be explicitly defined on the slave.

Replicating NDB to a slave storage engine that does not perform binary logging.   If you attempt to replicate from a MySQL Cluster to a slave that uses a storage engine that does not handle its own binary logging, the replication process aborts with the error `Binary logging not possible ... Statement cannot be written atomically since more than one engine involved and at least one engine is self-logging` (Error `1595`). It is possible to work around this issue in one of the following ways:

- **Turn off binary logging on the slave.**   This can be accomplished by setting `sql_log_bin = 0`.

- **Change the storage engine used for the mysql.ndb_apply_status table.**   Causing this table to use an engine that does not handle its own binary logging can also eliminate the conflict. This can be done by issuing a statement such as `ALTER TABLE mysql.ndb_apply_status ENGINE=MyISAM` on the slave. It is safe to do this when using a non-`NDB` storage engine on the slave, since you do not then need to worry about keeping multiple slave SQL nodes synchronized.

- **Filter out changes to the mysql.ndb_apply_status table on the slave.**   This can be done by starting the slave SQL node with `--replicate-ignore-table=mysql.ndb_apply_status`. If you need for other tables to be ignored by replication, you might wish to use an appropriate `--replicate-wild-ignore-table` option instead.

> **⚠ Important**
>
> You should *not* disable replication or binary logging of `mysql.ndb_apply_status` or change the storage engine used for this table when replicating from one MySQL Cluster to another. See Replication and binary log filtering rules with replication between MySQL Clusters, for details.

Replication from NDB to a nontransactional storage engine.   When replicating from `NDB` to a nontransactional storage engine such as `MyISAM`, you may encounter unnecessary duplicate key errors when replicating `INSERT ... ON DUPLICATE KEY UPDATE` statements. You can suppress these in MySQL Cluster NDB 6.2 and later MySQL Cluster releases by using `--ndb-log-update-as-write=0`, which forces updates to be logged as writes (rather than as updates).

In addition, when replicating from `NDB` to a storage engine that does not implement transactions, if the slave fails to apply any row changes from a given transaction, it does not roll back the rest of the

transaction. (This is true when replicating tables using any transactional storage engine—not only `NDB`—to a nontransactional storage engine.) Because of this, it cannot be guaranteed that transactional consistency will be maintained on the slave in such cases.

Replication and binary log filtering rules with replication between MySQL Clusters.   If you are using any of the options `--replicate-do-*`, `--replicate-ignore-*`, `--binlog-do-db`, or `--binlog-ignore-db` to filter databases or tables being replicated, care must be taken not to block replication or binary logging of the `mysql.ndb_apply_status`, which is required for replication between MySQL Clusters to operate properly. In particular, you must keep in mind the following:

1. Using `--replicate-do-db=db_name` (and no other `--replicate-do-*` or `--replicate-ignore-*` options) means that *only* tables in database *db_name* are replicated. In this case, you should also use `--replicate-do-db=mysql`, `--binlog-do-db=mysql`, or `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated on slaves.

   Using `--binlog-do-db=db_name` (and no other `--binlog-do-db` options) means that changes *only* to tables in database *db_name* are written to the binary log. In this case, you should also use `--replicate-do-db=mysql`, `--binlog-do-db=mysql`, or `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated on slaves.

2. Using `--replicate-ignore-db=mysql` means that no tables in the `mysql` database are replicated. In this case, you should also use `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is replicated.

   Using `--binlog-ignore-db=mysql` means that no changes to tables in the `mysql` database are written to the binary log. In this case, you should also use `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is replicated.

You should also remember that each replication rule requires the following:

1. Its own `--replicate-do-*` or `--replicate-ignore-*` option, and that multiple rules cannot be expressed in a single replication filtering option. For information about these rules, see Section 16.1.3, "Replication and Binary Logging Options and Variables".

2. Its own `--binlog-do-db` or `--binlog-ignore-db` option, and that multiple rules cannot be expressed in a single binary log filtering option. For information about these rules, see Section 5.4.4, "The Binary Log".

If you are replicating a MySQL Cluster to a slave that uses a storage engine other than `NDB`, the considerations just given previously may not apply, as discussed elsewhere in this section.

MySQL Cluster Replication and IPv6.   Currently, the NDB API and MGM API do not support IPv6. However, beginning with MySQL Cluster NDB 6.4.1, MySQL Servers—including those acting as SQL nodes in a MySQL Cluster—can use IPv6 to contact other MySQL Servers. This means that you can replicate between MySQL Clusters using IPv6 to connect the master and slave SQL nodes as shown by the dotted arrow in the following diagram:

Figure 17.16 Replication Between SQL Nodes Connected Using IPv6
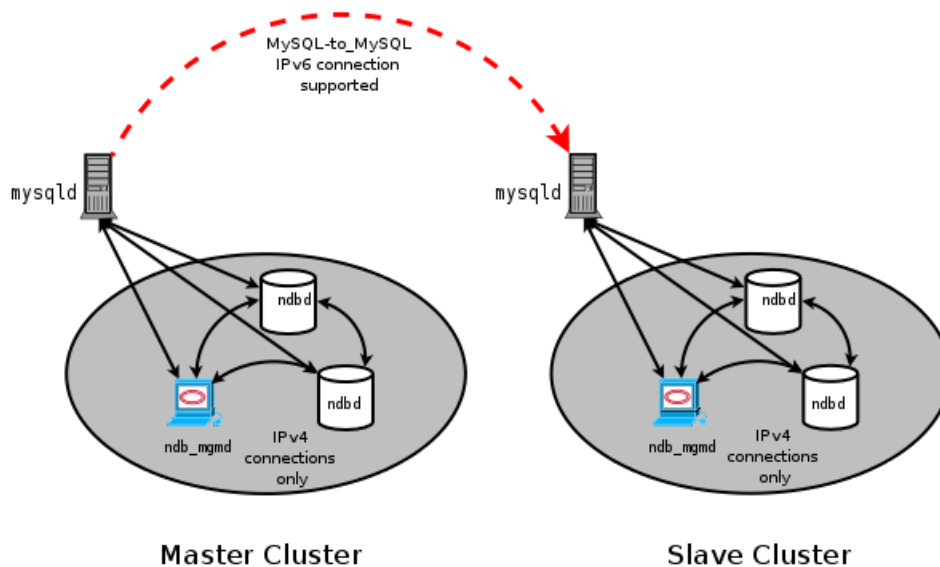
However, all connections originating *within* the MySQL Cluster—represented in the preceding diagram by solid arrows—must use IPv4. In other words, all MySQL Cluster data nodes, management servers, and management clients must be accessible from one another using IPv4. In addition, SQL nodes must use IPv4 to communicate with the cluster.

Since there is currently no support in the NDB and MGM APIs for IPv6, any applications written using these APIs must also make all connections using IPv4.

Attribute promotion and demotion.   Formerly, support in MySQL Cluster for type conversions between columns of similar but different types on the master and the slave was extremely limited. However, starting with MySQL Cluster NDB 6.3.33, 7.0.14, and 7.1.3, MySQL Cluster Replication includes support for attribute promotion and demotion. The implementation of the latter distinguishes between lossy and non-lossy type conversions, and their use on the slave can be controlled by setting the `slave_type_conversions` global server system variable.

For more information about attribute promotion and demotion in MySQL Cluster, see Attribute promotion and demotion (MySQL Cluster).

17.6.4 MySQL Cluster Replication Schema and Tables

Replication in MySQL Cluster makes use of a number of dedicated tables in the `mysql` database on each MySQL Server instance acting as an SQL node in both the cluster being replicated and the replication slave (whether the slave is a single server or a cluster). These tables are created during the MySQL installation process by the `mysql_install_db` script, and include a table for storing the binary log's indexing data. Since the `ndb_binlog_index` table is local to each MySQL server and does not participate in clustering, it uses the `MyISAM` storage engine. This means that it must be created separately on each `mysqld` participating in the master cluster. (However, the binary log itself contains updates from all MySQL servers in the cluster to be replicated.) This table is defined as follows:

```
CREATE TABLE `ndb_binlog_index` (
    `Position`  BIGINT(20) UNSIGNED NOT NULL,
    `File`      VARCHAR(255) NOT NULL,
    `epoch`     BIGINT(20) UNSIGNED NOT NULL,
```

```
    `inserts`   BIGINT(20) UNSIGNED NOT NULL,
    `updates`   BIGINT(20) UNSIGNED NOT NULL,
    `deletes`   BIGINT(20) UNSIGNED NOT NULL,
    `schemaops` BIGINT(20) UNSIGNED NOT NULL,
    `next_position` bigint(20) unsigned NOT NULL,
    `next_file` varchar(255) NOT NULL,
    PRIMARY KEY (`epoch`)
) ENGINE=MYISAM  DEFAULT CHARSET=latin1;
```

The size of this table is dependent on the number of epochs per binary log file and the number of binary log files. The number of epochs per binary log file normally depends on the amount of binary log generated per epoch and the size of the binary log file, with smaller epochs resulting in more epochs per file. You should be aware that empty epochs produce inserts to the `ndb_binlog_index` table, even when the `--ndb-log-empty-epochs` option is `OFF`, meaning that the number of entries per file depends on the length of time that the file is in use; that is,

```
[number of epochs per file] = [time spent per file] / TimeBetweenEpochs
```

A busy MySQL Cluster writes to the binary log regularly and presumably rotates binary log files more quickly than a quiet one. This means that a "quiet" MySQL Cluster with `--ndb-log-empty-epochs=ON` can actually have a much higher number of `ndb_binlog_index` rows per file than one with a great deal of activity.

When `mysqld` is started with the `--ndb-log-orig` option, the `orig_server_id` and `orig_epoch` columns store, respectively, the ID of the server on which the event originated and the epoch in which the event took place on the originating server, which is useful in MySQL Cluster replication setups employing multiple masters. The `SELECT` statement used to find the closest binlog position to the highest applied epoch on the slave in a multi-master setup (see Section 17.6.10, "MySQL Cluster Replication: Multi-Master and Circular Replication") employs these two columns, which are not indexed. This can lead to performance issues when trying to fail over, since the query must perform a table scan, especially when the master has been running with `--ndb-log-empty-epochs=ON`. You can improve multi-master failover times by adding an index to these columns, as shown here:

```
ALTER TABLE mysql.ndb_binlog_index
    ADD INDEX orig_lookup USING BTREE (orig_server_id, orig_epoch);
```

Adding this index provides no benefit when replicating from a single master to a single slave, since the query used to get the binary log position in such cases makes no use of `orig_server_id` or `orig_epoch`.

The `next_position` and `next_file` columns were added in MySQL Cluster NDB 7.2.6; see Section 17.6.8, "Implementing Failover with MySQL Cluster Replication", for more information about using these columns.

> **Important**
>
> Prior to MySQL 5.1.14, the `ndb_binlog_index` table was known as `binlog_index`, and was kept in a separate `cluster` database, which in MySQL 5.1.7 and earlier was known as the `cluster_replication` database. Similarly, the `ndb_apply_status` and `ndb_schema` tables were known as `apply_status` and `schema`, and were also found in the `cluster` (earlier `cluster_replication`) database. However, beginning with MySQL 5.1.14, all MySQL Cluster replication tables reside in the `mysql` system database.
>
> Information about how this change affects upgrades from MySQL Cluster 5.1.13 and earlier to 5.1.14 and later versions can be found in http://dev.mysql.com/doc/relnotes/mysql/5.1/en/news-5-1-14.html.

Beginning with MySQL Cluster NDB 6.3.2, this table has been changed to facilitate 3-way replication recovery. Two columns `orig_server_id` and `orig_epoch` have been added to this table; when `mysqld` is started with the `--ndb-log-orig` option, these columns store, respectively, the ID of the server on which the event originated and the epoch in which the event took place on the originating server. In addition, the table's primary key now includes these two columns. The modified table definition is shown here:

```
CREATE TABLE `ndb_binlog_index` (
    `Position` BIGINT(20) UNSIGNED NOT NULL,
    `File` VARCHAR(255) NOT NULL,
    `epoch` BIGINT(20) UNSIGNED NOT NULL,
    `inserts` INT(10) UNSIGNED NOT NULL,
    `updates` INT(10) UNSIGNED NOT NULL,
    `deletes` INT(10) UNSIGNED NOT NULL,
    `schemaops` INT(10) UNSIGNED NOT NULL,
    `orig_server_id` INT(10) UNSIGNED NOT NULL,
    `orig_epoch` BIGINT(20) UNSIGNED NOT NULL,
    `gci` INT(10) UNSIGNED NOT NULL,
    `next_position` bigint(20) unsigned NOT NULL,
    `next_file` varchar(255) NOT NULL,
    PRIMARY KEY (`epoch`,`orig_server_id`,`orig_epoch`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1;
```

The `gci` column was added in MySQL Cluster NDB 6.2.6 and MySQL Cluster NDB 6.3.2.

The `next_position` and `next_file` columns were added in MySQL Cluster NDB 7.0.33 and MySQL Cluster NDB 7.1.22; see Section 17.6.8, "Implementing Failover with MySQL Cluster Replication", for more information about using these columns.

The following figure shows the relationship of the MySQL Cluster replication master server, its binlog injector thread, and the `mysql.ndb_binlog_index` table.

Figure 17.17 The Replication Master Cluster
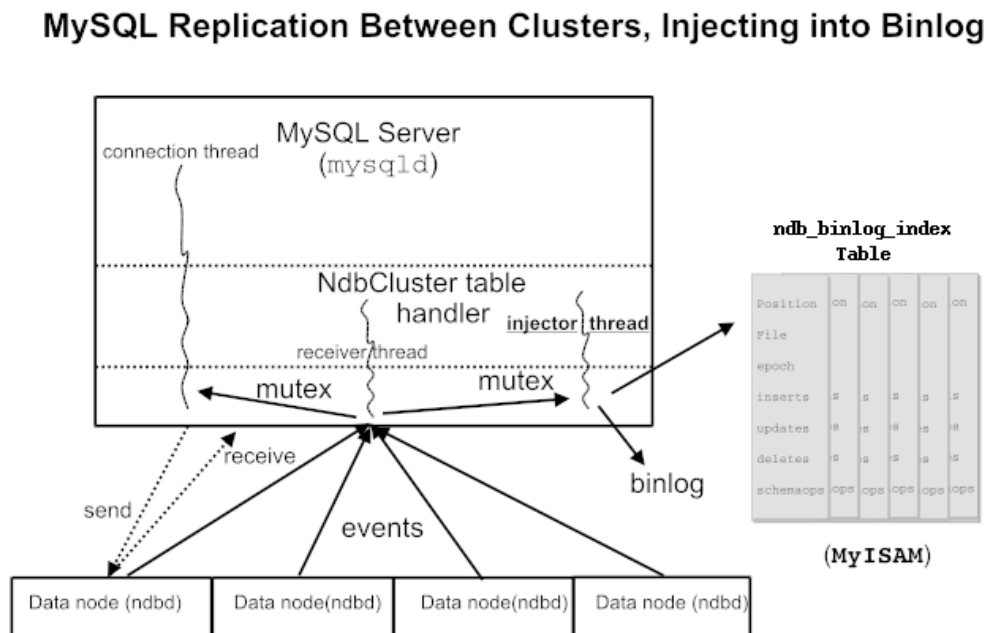
An additional table, named `ndb_apply_status`, is used to keep a record of the operations that have been replicated from the master to the slave. Unlike the case with `ndb_binlog_index`, the data in this table is not specific to any one SQL node in the (slave) cluster, and so `ndb_apply_status` can use the `NDBCLUSTER` storage engine, as shown here:

```
CREATE TABLE `ndb_apply_status` (
    `server_id`    INT(10) UNSIGNED NOT NULL,
    `epoch`        BIGINT(20) UNSIGNED NOT NULL,
    `log_name`     VARCHAR(255) CHARACTER SET latin1 COLLATE latin1_bin NOT NULL,
    `start_pos`    BIGINT(20) UNSIGNED NOT NULL,
    `end_pos`      BIGINT(20) UNSIGNED NOT NULL,
    PRIMARY KEY (`server_id`) USING HASH
) ENGINE=NDBCLUSTER   DEFAULT CHARSET=latin1;
```

The `ndb_apply_status` table is populated only on slaves, which means that, on the master, this table never contains any rows; thus, there is no need to allow for `DataMemory` or `IndexMemory` to be allotted to `ndb_apply_status` there.

Because this table is populated from data originating on the master, it should be allowed to replicate; any replication filtering or binary log filtering rules that inadvertently prevent the slave from updating `ndb_apply_status` or the master from writing into the binary log may prevent replication between clusters from operating properly. For more information about potential problems arising from such filtering rules, see Replication and binary log filtering rules with replication between MySQL Clusters.

The `log_name`, `start_pos`, and `end_pos` columns were added in MySQL 5.1.18.

> **Important**
>
> If you are using MySQL Cluster replication, see Section 17.2.7.3, "Upgrade and downgrade compatibility: MySQL 5.1" before upgrading to MySQL 5.1.18 or later from an earlier version.

The `ndb_binlog_index` and `ndb_apply_status` tables are created in the `mysql` database because they should not be explicitly replicated by the user. User intervention is normally not required to create or maintain either of these tables, since both `ndb_binlog_index` and the `ndb_apply_status` are maintained by the `NDB` binary log (binlog) injector thread. This keeps the master `mysqld` process updated to changes performed by the `NDB` storage engine. The `NDB` *binlog injector thread* receives events directly from the `NDB` storage engine. The `NDB` injector is responsible for capturing all the data events within the cluster, and ensures that all events which change, insert, or delete data are recorded in the `ndb_binlog_index` table. The slave I/O thread transfers the events from the master's binary log to the slave's relay log.

However, it is advisable to check for the existence and integrity of these tables as an initial step in preparing a MySQL Cluster for replication. It is possible to view event data recorded in the binary log by querying the `mysql.ndb_binlog_index` table directly on the master. This can be also be accomplished using the `SHOW BINLOG EVENTS` statement on either the replication master or slave MySQL servers. (See Section 13.7.5.3, "SHOW BINLOG EVENTS Syntax".)

You can also obtain useful information from the output of `SHOW ENGINE NDB STATUS`.

The `ndb_schema` table is used to track schema changes made to `NDB` tables. It is defined as shown here:

```
CREATE TABLE ndb_schema (
    `db` VARBINARY(63) NOT NULL,
```

```
    `name` VARBINARY(63) NOT NULL,
    `slock` BINARY(32) NOT NULL,
    `query` BLOB NOT NULL,
    `node_id` INT UNSIGNED NOT NULL,
    `epoch` BIGINT UNSIGNED NOT NULL,
    `id` INT UNSIGNED NOT NULL,
    `version` INT UNSIGNED NOT NULL,
    `type` INT UNSIGNED NOT NULL,
    PRIMARY KEY USING HASH (db,name)
) ENGINE=NDB   DEFAULT CHARSET=latin1;
```

Unlike the two tables previously mentioned in this section, the `ndb_schema` table is not visible either to MySQL `SHOW` statements, or in any `INFORMATION_SCHEMA` tables; however, it can be seen in the output of `ndb_show_tables`, as shown here:

```
shell> ndb_show_tables -t 2
id    type                state    logging database    schema    name
4     UserTable           Online   Yes     mysql        def       ndb_apply_status
5     UserTable           Online   Yes     ndbworld     def       city
6     UserTable           Online   Yes     ndbworld     def       country
3     UserTable           Online   Yes     mysql        def       NDB$BLOB_2_3
7     UserTable           Online   Yes     ndbworld     def       countrylanguage
2     UserTable           Online   Yes     mysql        def       ndb_schema

NDBT_ProgramExit: 0 - OK
```

It is also possible to `SELECT` from this table in `mysql` and other MySQL client applications, as shown here:

```
mysql> SELECT * FROM mysql.ndb_schema WHERE name='city' \G
*************************** 1. row ***************************
     db: ndbworld
   name: city
  slock:
  query: alter table city engine=ndb
node_id: 4
  epoch: 0
     id: 0
version: 0
   type: 7
1 row in set (0.00 sec)
```

This can sometimes be useful when debugging applications.

> **Note**
>
> When performing schema changes on `NDB` tables, applications should wait until the `ALTER TABLE` statement has returned in the MySQL client connection that issued the statement before attempting to use the updated definition of the table.

The `ndb_schema` table was added in MySQL 5.1.8.

Beginning with MySQL 5.1.14, if the `ndb_apply_status` table or the `ndb_schema` table does not exist on the slave, `ndb_restore` re-creates the missing table or tables (Bug #14612).

Conflict resolution for MySQL Cluster Replication requires the presence of an additional `mysql.ndb_replication` table. Currently, this table must be created manually. For information about how to do this, see Section 17.6.11, "MySQL Cluster Replication Conflict Resolution".

17.6.5 Preparing the MySQL Cluster for Replication

Preparing the MySQL Cluster for replication consists of the following steps:

1. Check all MySQL servers for version compatibility (see Section 17.6.2, "General Requirements for MySQL Cluster Replication").

2. Create a slave account on the master Cluster with the appropriate privileges:

```
mysqlM> GRANT REPLICATION SLAVE
    -> ON *.* TO 'slave_user'@'slave_host'
    -> IDENTIFIED BY 'slave_password';
```

In the previous statement, `slave_user` is the slave account user name, `slave_host` is the host name or IP address of the replication slave, and `slave_password` is the password to assign to this account.

For example, to create a slave user account with the name "`myslave`," logging in from the host named "`rep-slave`," and using the password "`53cr37`," use the following `GRANT` statement:

```
mysqlM> GRANT REPLICATION SLAVE
    -> ON *.* TO 'myslave'@'rep-slave'
    -> IDENTIFIED BY '53cr37';
```

For security reasons, it is preferable to use a unique user account—not employed for any other purpose—for the replication slave account.

3. Configure the slave to use the master. Using the MySQL Monitor, this can be accomplished with the `CHANGE MASTER TO` statement:

```
mysqlS> CHANGE MASTER TO
    -> MASTER_HOST='master_host',
    -> MASTER_PORT=master_port,
    -> MASTER_USER='slave_user',
    -> MASTER_PASSWORD='slave_password';
```

In the previous statement, `master_host` is the host name or IP address of the replication master, `master_port` is the port for the slave to use for connecting to the master, `slave_user` is the user name set up for the slave on the master, and `slave_password` is the password set for that user account in the previous step.

For example, to tell the slave to replicate from the MySQL server whose host name is "`rep-master`," using the replication slave account created in the previous step, use the following statement:

```
mysqlS> CHANGE MASTER TO
    -> MASTER_HOST='rep-master',
    -> MASTER_PORT=3306,
    -> MASTER_USER='myslave',
    -> MASTER_PASSWORD='53cr37';
```

For a complete list of options that can be used with this statement, see Section 13.4.2.1, "CHANGE MASTER TO Syntax".

To provide replication backup capability, you also need to add an `--ndb-connectstring` option to the slave's `my.cnf` file prior to starting the replication process. See Section 17.6.9, "MySQL Cluster Backups With MySQL Cluster Replication", for details.

For additional options that can be set in `my.cnf` for replication slaves, see Section 16.1.3, "Replication and Binary Logging Options and Variables".

4. If the master cluster is already in use, you can create a backup of the master and load this onto the slave to cut down on the amount of time required for the slave to synchronize itself with the master. If the slave is also running MySQL Cluster, this can be accomplished using the backup and restore procedure described in Section 17.6.9, "MySQL Cluster Backups With MySQL Cluster Replication".

```
ndb-connectstring=management_host[:port]
```

In the event that you are *not* using MySQL Cluster on the replication slave, you can create a backup with this command on the replication master:

```
shellM> mysqldump --master-data=1
```

Then import the resulting data dump onto the slave by copying the dump file over to the slave. After this, you can use the `mysql` client to import the data from the dumpfile into the slave database as shown here, where *dump_file* is the name of the file that was generated using `mysqldump` on the master, and *db_name* is the name of the database to be replicated:

```
shellS> mysql -u root -p db_name < dump_file
```

For a complete list of options to use with `mysqldump`, see Section 4.5.4, "`mysqldump` — A Database Backup Program".

> **Note**
>
> If you copy the data to the slave in this fashion, you should make sure that the slave is started with the `--skip-slave-start` option on the command line, or else include `skip-slave-start` in the slave's `my.cnf` file to keep it from trying to connect to the master to begin replicating before all the data has been loaded. Once the data loading has completed, follow the additional steps outlined in the next two sections.

5. Ensure that each MySQL server acting as a replication master is configured with a unique server ID, and with binary logging enabled, using the row format. (See Section 16.1.2, "Replication Formats".) These options can be set either in the master server's `my.cnf` file, or on the command line when starting the master `mysqld` process. See Section 17.6.6, "Starting MySQL Cluster Replication (Single Replication Channel)", for information regarding the latter option.

17.6.6 Starting MySQL Cluster Replication (Single Replication Channel)

This section outlines the procedure for starting MySQL Cluster replication using a single replication channel.

1. Start the MySQL replication master server by issuing this command:

```
shellM> mysqld --ndbcluster --server-id=id \
        --log-bin --binlog-format=ROW &
```

In the previous statement, *id* is this server's unique ID (see Section 17.6.2, "General Requirements for MySQL Cluster Replication"). This starts the server's `mysqld` process with binary logging enabled using the proper logging format.

> **Note**
>
> You can also start the master with `--binlog-format=MIXED`, in which case row-based replication is used automatically when replicating between clusters. `STATEMENT` based binary logging is not supported for MySQL Cluster Replication (see Section 17.6.2, "General Requirements for MySQL Cluster Replication").

2. Start the MySQL replication slave server as shown here:

```
shellS> mysqld --ndbcluster --server-id=id &
```

In the command just shown, `id` is the slave server's unique ID. It is not necessary to enable logging on the replication slave.

> **Note**
>
> You should use the `--skip-slave-start` option with this command or else you should include `skip-slave-start` in the slave server's `my.cnf` file, unless you want replication to begin immediately. With the use of this option, the start of replication is delayed until the appropriate `START SLAVE` statement has been issued, as explained in Step 4 below.

3. It is necessary to synchronize the slave server with the master server's replication binary log. If binary logging has not previously been running on the master, run the following statement on the slave:

```
mysqlS> CHANGE MASTER TO
     -> MASTER_LOG_FILE='',
     -> MASTER_LOG_POS=4;
```

This instructs the slave to begin reading the master's binary log from the log's starting point. Otherwise—that is, if you are loading data from the master using a backup—see Section 17.6.8, "Implementing Failover with MySQL Cluster Replication", for information on how to obtain the correct values to use for `MASTER_LOG_FILE` and `MASTER_LOG_POS` in such cases.

4. Finally, you must instruct the slave to begin applying replication by issuing this command from the `mysql` client on the replication slave:

```
mysqlS> START SLAVE;
```

This also initiates the transmission of replication data from the master to the slave.

It is also possible to use two replication channels, in a manner similar to the procedure described in the next section; the differences between this and using a single replication channel are covered in Section 17.6.7, "Using Two Replication Channels for MySQL Cluster Replication".

Beginning with MySQL Cluster NDB 6.2.3, it is possible to improve cluster replication performance by enabling *batched updates*. This can be accomplished by setting the `slave_allow_batching` system variable on the slave `mysqld` processes. Normally, updates are applied as soon as they are received. However, the use of batching causes updates to be applied in 32 KB batches, which can result in higher throughput and less CPU usage, particularly where individual updates are relatively small.

> **Note**
>
> Slave batching works on a per-epoch basis; updates belonging to more than one transaction can be sent as part of the same batch.
>
> All outstanding updates are applied when the end of an epoch is reached, even if the updates total less than 32 KB.

Batching can be turned on and off at runtime. To activate it at runtime, you can use either of these two statements:

```
SET GLOBAL slave_allow_batching = 1;
SET GLOBAL slave_allow_batching = ON;
```

If a particular batch causes problems (such as a statement whose effects do not appear to be replicated correctly), slave batching can be deactivated using either of the following statements:

```
SET GLOBAL slave_allow_batching = 0;
SET GLOBAL slave_allow_batching = OFF;
```

You can check whether slave batching is currently being used by means of an appropriate SHOW VARIABLES statement, like this one:

```
mysql> SHOW VARIABLES LIKE 'slave%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| slave_allow_batching     | ON    |
| slave_compressed_protocol | OFF  |
| slave_load_tmpdir        | /tmp  |
| slave_net_timeout        | 3600  |
| slave_skip_errors        | OFF   |
| slave_transaction_retries | 10   |
+--------------------------+-------+
6 rows in set (0.00 sec)
```

17.6.7 Using Two Replication Channels for MySQL Cluster Replication

In a more complete example scenario, we envision two replication channels to provide redundancy and thereby guard against possible failure of a single replication channel. This requires a total of four replication servers, two masters for the master cluster and two slave servers for the slave cluster. For purposes of the discussion that follows, we assume that unique identifiers are assigned as shown here:

Server ID	Description
1	Master - primary replication channel (*M*)
2	Master - secondary replication channel (*M'*)
3	Slave - primary replication channel (*S*)
4	Slave - secondary replication channel (*S'*)

Setting up replication with two channels is not radically different from setting up a single replication channel. First, the mysqld processes for the primary and secondary replication masters must be started, followed by those for the primary and secondary slaves. Then the replication processes may be initiated by issuing the START SLAVE statement on each of the slaves. The commands and the order in which they need to be issued are shown here:

1. Start the primary replication master:

```
shellM> mysqld --ndbcluster --server-id=1 \
               --log-bin --binlog-format=ROW &
```

2. Start the secondary replication master:

```
shellM'> mysqld --ndbcluster --server-id=2 \
                --log-bin --binlog-format=ROW &
```

3. Start the primary replication slave server:

```
shellS> mysqld --ndbcluster --server-id=3 \
               --skip-slave-start &
```

4. Start the secondary replication slave:

```
shellS'> mysqld --ndbcluster --server-id=4 \
                --skip-slave-start &
```

5. Finally, initiate replication on the primary channel by executing the START SLAVE statement on the primary slave as shown here:

```
mysqlS> START SLAVE;
```

> **Warning**
>
> Only the primary channel is to be started at this point. The secondary replication channel is to be started only in the event that the primary replication channel fails, as described in Section 17.6.8, "Implementing Failover with MySQL Cluster Replication". Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replication slaves.

As mentioned previously, it is not necessary to enable binary logging on replication slaves.

17.6.8 Implementing Failover with MySQL Cluster Replication

In the event that the primary Cluster replication process fails, it is possible to switch over to the secondary replication channel. The following procedure describes the steps required to accomplish this.

1. Obtain the time of the most recent global checkpoint (GCP). That is, you need to determine the most recent epoch from the ndb_apply_status table on the slave cluster, which can be found using the following query:

```
mysqlS'> SELECT @latest:=MAX(epoch)
      ->        FROM mysql.ndb_apply_status;
```

2. Using the information obtained from the query shown in Step 1, obtain the corresponding records from the ndb_binlog_index table on the master cluster.

Prior to MySQL Cluster NDB 7.0.33 and MySQL Cluster 7.1.22, you should use the following query to accomplish this task:

```
mysqlM'> SELECT
```

```
        ->      @file:=SUBSTRING_INDEX(File, '/', -1),
        ->      @pos:=Position
        -> FROM mysql.ndb_binlog_index
        -> WHERE epoch > @latest
        -> ORDER BY epoch ASC LIMIT 1;
```

Beginning with MySQL Cluster NDB 7.0.33 and MySQL Cluster NDB 7.1.22, you can take advantage of the improved binary logging of DDL statements implemented in those and later versions by using the following query to obtain the needed records from the master's `ndb_binlog_index` table:

```
mysqlM'> SELECT
        ->      @file:=SUBSTRING_INDEX(next_file, '/', -1),
        ->      @pos:=next_position
        -> FROM mysql.ndb_binlog_index
        -> WHERE epoch = @latest
        -> ORDER BY epoch ASC LIMIT 1;
```

In either case, these are the records saved on the master since the failure of the primary replication channel. We have employed a user variable `@latest` here to represent the value obtained in Step 1. Of course, it is not possible for one `mysqld` instance to access user variables set on another server instance directly. These values must be "plugged in" to the second query manually or in application code.

> ⚠️ **Important**
>
> If (and only if) you use the second of the two queries just shown against `ndb_binlog_index` (that is, the query that employs the `next_position` and `next_file` columns), you must ensure that the slave `mysqld` is started with `--slave-skip-errors=ddl_exist_errors` before executing `START SLAVE`. Otherwise, replication may stop with duplicate DDL errors.

3. Now it is possible to synchronize the secondary channel by running the following query on the secondary slave server:

```
mysqlS'> CHANGE MASTER TO
        ->      MASTER_LOG_FILE='@file',
        ->      MASTER_LOG_POS=@pos;
```

Again we have employed user variables (in this case `@file` and `@pos`) to represent the values obtained in Step 2 and applied in Step 3; in practice these values must be inserted manually or using application code that can access both of the servers involved.

> 📝 **Note**
>
> `@file` is a string value such as `'/var/log/mysql/replication-master-bin.00001'`, and so must be quoted when used in SQL or application code. However, the value represented by `@pos` must *not* be quoted. Although MySQL normally attempts to convert strings to numbers, this case is an exception.

4. You can now initiate replication on the secondary channel by issuing the appropriate command on the secondary slave `mysqld`:

```
mysqlS'> START SLAVE;
```

Once the secondary replication channel is active, you can investigate the failure of the primary and effect repairs. The precise actions required to do this will depend upon the reasons for which the primary channel failed.

Warning

The secondary replication channel is to be started only if and when the primary replication channel has failed. Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replication slaves.

If the failure is limited to a single server, it should (in theory) be possible to replicate from M to S', or from M' to S; however, this has not yet been tested.

17.6.9 MySQL Cluster Backups With MySQL Cluster Replication

This section discusses making backups and restoring from them using MySQL Cluster replication. We assume that the replication servers have already been configured as covered previously (see Section 17.6.5, "Preparing the MySQL Cluster for Replication", and the sections immediately following). This having been done, the procedure for making a backup and then restoring from it is as follows:

1. There are two different methods by which the backup may be started.

   - **Method A.** This method requires that the cluster backup process was previously enabled on the master server, prior to starting the replication process. This can be done by including the following line in a `[mysql_cluster]` section in the `my.cnf file`, where *management_host* is the IP address or host name of the `NDB` management server for the master cluster, and *port* is the management server's port number:

   ```
   ndb-connectstring=management_host[:port]
   ```


   Note

   The port number needs to be specified only if the default port (1186) is not being used. See Section 17.2.3, "Initial Configuration of MySQL Cluster", for more information about ports and port allocation in MySQL Cluster.

   In this case, the backup can be started by executing this statement on the replication master:

   ```
   shellM> ndb_mgm -e "START BACKUP"
   ```

   - **Method B.** If the `my.cnf` file does not specify where to find the management host, you can start the backup process by passing this information to the `NDB` management client as part of the `START BACKUP` command. This can be done as shown here, where *management_host* and *port* are the host name and port number of the management server:

   ```
   shellM> ndb_mgm management_host:port -e "START BACKUP"
   ```

   In our scenario as outlined earlier (see Section 17.6.5, "Preparing the MySQL Cluster for Replication"), this would be executed as follows:

   ```
   shellM> ndb_mgm rep-master:1186 -e "START BACKUP"
   ```

2. Copy the cluster backup files to the slave that is being brought on line. Each system running an `ndbd` process for the master cluster will have cluster backup files located on it, and *all* of these files must be copied to the slave to ensure a successful restore. The backup files can be copied into any directory on the computer where the slave management host resides, so long as the MySQL and NDB binaries have read permissions in that directory. In this case, we will assume that these files have been copied into the directory `/var/BACKUPS/BACKUP-1`.

It is not necessary that the slave cluster have the same number of `ndbd` processes (data nodes) as the master; however, it is highly recommended this number be the same. It *is* necessary that the slave be started with the `--skip-slave-start` option, to prevent premature startup of the replication process.

3. Create any databases on the slave cluster that are present on the master cluster that are to be replicated to the slave.

   > **Important**
   >
   > A `CREATE DATABASE` (or `CREATE SCHEMA`) statement corresponding to each database to be replicated must be executed on each SQL node in the slave cluster.

4. Reset the slave cluster using this statement in the MySQL Monitor:

   ```
   mysqlS> RESET SLAVE;
   ```

5. You can now start the cluster restoration process on the replication slave using the `ndb_restore` command for each backup file in turn. For the first of these, it is necessary to include the `-m` option to restore the cluster metadata:

   ```
   shellS> ndb_restore -c slave_host:port -n node-id \
           -b backup-id -m -r dir
   ```

   `dir` is the path to the directory where the backup files have been placed on the replication slave. For the `ndb_restore` commands corresponding to the remaining backup files, the `-m` option should *not* be used.

   For restoring from a master cluster with four data nodes (as shown in the figure in Section 17.6, "MySQL Cluster Replication") where the backup files have been copied to the directory `/var/BACKUPS/BACKUP-1`, the proper sequence of commands to be executed on the slave might look like this:

   ```
   shellS> ndb_restore -c rep-slave:1186 -n 2 -b 1 -m \
           -r ./var/BACKUPS/BACKUP-1
   shellS> ndb_restore -c rep-slave:1186 -n 3 -b 1 \
           -r ./var/BACKUPS/BACKUP-1
   shellS> ndb_restore -c rep-slave:1186 -n 4 -b 1 \
           -r ./var/BACKUPS/BACKUP-1
   shellS> ndb_restore -c rep-slave:1186 -n 5 -b 1 -e \
           -r ./var/BACKUPS/BACKUP-1
   ```

   > **Important**
   >
   > The `-e` (or `--restore_epoch`) option in the final invocation of `ndb_restore` in this example is required in order that the epoch is written to the slave `mysql.ndb_apply_status`. Without this information, the slave will not be able to synchronize properly with the master. (See Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup".)

6. Now you need to obtain the most recent epoch from the `ndb_apply_status` table on the slave (as discussed in Section 17.6.8, "Implementing Failover with MySQL Cluster Replication"):

   ```
   mysqlS> SELECT @latest:=MAX(epoch)
           FROM mysql.ndb_apply_status;
   ```

7. Using `@latest` as the epoch value obtained in the previous step, you can obtain the correct starting position `@pos` in the correct binary log file `@file` from the master's `mysql.ndb_binlog_index` table using the query shown here:

```
mysqlM> SELECT
    ->     @file:=SUBSTRING_INDEX(File, '/', -1),
    ->     @pos:=Position
    -> FROM mysql.ndb_binlog_index
    -> WHERE epoch > @latest
    -> ORDER BY epoch ASC LIMIT 1;
```

In the event that there is currently no replication traffic, you can get this information by running `SHOW MASTER STATUS` on the master and using the value in the `Position` column for the file whose name has the suffix with the greatest value for all files shown in the `File` column. However, in this case, you must determine this and supply it in the next step manually or by parsing the output with a script.

8. Using the values obtained in the previous step, you can now issue the appropriate `CHANGE MASTER TO` statement in the slave's `mysql` client:

```
mysqlS> CHANGE MASTER TO
    ->     MASTER_LOG_FILE='@file',
    ->     MASTER_LOG_POS=@pos;
```

9. Now that the slave "knows" from what point in which `binlog` file to start reading data from the master, you can cause the slave to begin replicating with this standard MySQL statement:

```
mysqlS> START SLAVE;
```

To perform a backup and restore on a second replication channel, it is necessary only to repeat these steps, substituting the host names and IDs of the secondary master and slave for those of the primary master and slave replication servers where appropriate, and running the preceding statements on them.

For additional information on performing Cluster backups and restoring Cluster from backups, see Section 17.5.3, "Online Backup of MySQL Cluster".

17.6.9.1 MySQL Cluster Replication: Automating Synchronization of the Replication Slave to the Master Binary Log

It is possible to automate much of the process described in the previous section (see Section 17.6.9, "MySQL Cluster Backups With MySQL Cluster Replication"). The following Perl script `reset-slave.pl` serves as an example of how you can do this.

```
#!/user/bin/perl -w

#  file: reset-slave.pl

#  Copyright ©2005 MySQL AB

#  This program is free software; you can redistribute it and/or modify
#  it under the terms of the GNU General Public License as published by
#  the Free Software Foundation; either version 2 of the License, or
#  (at your option) any later version.

#  This program is distributed in the hope that it will be useful,
#  but WITHOUT ANY WARRANTY; without even the implied warranty of
#  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
#  GNU General Public License for more details.
```

```
#  You should have received a copy of the GNU General Public License
#  along with this program; if not, write to:
#  Free Software Foundation, Inc.
#  59 Temple Place, Suite 330
#  Boston, MA 02111-1307 USA
#
#  Version 1.1


######################### Includes ###############################

use DBI;

######################### Globals ################################

my  $m_host='';
my  $m_port='';
my  $m_user='';
my  $m_pass='';
my  $s_host='';
my  $s_port='';
my  $s_user='';
my  $s_pass='';
my  $dbhM='';
my  $dbhS='';

######################### Sub Prototypes #########################

sub CollectCommandPromptInfo;
sub ConnectToDatabases;
sub DisconnectFromDatabases;
sub GetSlaveEpoch;
sub GetMasterInfo;
sub UpdateSlave;

######################### Program Main ###########################

CollectCommandPromptInfo;
ConnectToDatabases;
GetSlaveEpoch;
GetMasterInfo;
UpdateSlave;
DisconnectFromDatabases;

################## Collect Command Prompt Info ##################

sub CollectCommandPromptInfo
{
  ### Check that user has supplied correct number of command line args
  die "Usage:\n
       reset-slave >master MySQL host< >master MySQL port< \n
                   >master user< >master pass< >slave MySQL host< \n
                   >slave MySQL port< >slave user< >slave pass< \n
       All 8 arguments must be passed. Use BLANK for NULL passwords\n"
       unless @ARGV == 8;

  $m_host  =  $ARGV[0];
  $m_port  =  $ARGV[1];
  $m_user  =  $ARGV[2];
  $m_pass  =  $ARGV[3];
  $s_host  =  $ARGV[4];
  $s_port  =  $ARGV[5];
  $s_user  =  $ARGV[6];
  $s_pass  =  $ARGV[7];

  if ($m_pass eq "BLANK") { $m_pass = '';}
  if ($s_pass eq "BLANK") { $s_pass = '';}
```

```
}

###############  Make connections to both databases #############

sub ConnectToDatabases
{
  ### Connect to both master and slave cluster databases

  ### Connect to master
  $dbhM
    = DBI->connect(
    "dbi:mysql:database=mysql;host=$m_host;port=$m_port",
    "$m_user", "$m_pass")
      or die "Can't connect to Master Cluster MySQL process!
               Error: $DBI::errstr\n";

  ### Connect to slave
  $dbhS
    = DBI->connect(
          "dbi:mysql:database=mysql;host=$s_host",
          "$s_user", "$s_pass")
    or die "Can't connect to Slave Cluster MySQL process!
             Error: $DBI::errstr\n";
}

###############  Disconnect from both databases ###############

sub DisconnectFromDatabases
{
  ### Disconnect from master

  $dbhM->disconnect
  or warn " Disconnection failed: $DBI::errstr\n";

  ### Disconnect from slave

  $dbhS->disconnect
  or warn " Disconnection failed: $DBI::errstr\n";
}

#####################  Find the last good GCI #################

sub GetSlaveEpoch
{
  $sth = $dbhS->prepare("SELECT MAX(epoch)
                         FROM mysql.ndb_apply_status;")
      or die "Error while preparing to select epoch from slave: ",
             $dbhS->errstr;

  $sth->execute
      or die "Selecting epoch from slave error: ", $sth->errstr;

  $sth->bind_col (1, \$epoch);
  $sth->fetch;
  print "\tSlave Epoch =  $epoch\n";
  $sth->finish;
}

#######  Find the position of the last GCI in the binary log ########

sub GetMasterInfo
{
  $sth = $dbhM->prepare("SELECT
                            SUBSTRING_INDEX(File, '/', -1), Position
                          FROM mysql.ndb_binlog_index
                          WHERE epoch > $epoch
                          ORDER BY epoch ASC LIMIT 1;")
```

```
      or die "Prepare to select from master error: ", $dbhM->errstr;

  $sth->execute
      or die "Selecting from master error: ", $sth->errstr;

  $sth->bind_col (1, \$binlog);
  $sth->bind_col (2, \$binpos);
  $sth->fetch;
  print "\tMaster binary log =  $binlog\n";
  print "\tMaster binary log position =  $binpos\n";
  $sth->finish;
}

##########  Set the slave to process from that location #########

sub UpdateSlave
{
  $sth = $dbhS->prepare("CHANGE MASTER TO
                          MASTER_LOG_FILE='$binlog',
                          MASTER_LOG_POS=$binpos;")
      or die "Prepare to CHANGE MASTER error: ", $dbhS->errstr;

  $sth->execute
       or die "CHANGE MASTER on slave error: ", $sth->errstr;
  $sth->finish;
  print "\tSlave has been updated. You may now start the slave.\n";
}

# end reset-slave.pl
```

17.6.9.2 Point-In-Time Recovery Using MySQL Cluster Replication

Point-in-time recovery—that is, recovery of data changes made since a given point in time—is performed after restoring a full backup that returns the server to its state when the backup was made. Performing point-in-time recovery of MySQL Cluster tables with MySQL Cluster and MySQL Cluster Replication can be accomplished using a native `NDB` data backup (taken by issuing `CREATE BACKUP` in the `ndb_mgm` client) and restoring the `ndb_binlog_index` table (from a dump made using `mysqldump`).

To perform point-in-time recovery of MySQL Cluster, it is necessary to follow the steps shown here:

1. Back up all `NDB` databases in the cluster, using the `START BACKUP` command in the `ndb_mgm` client (see Section 17.5.3, "Online Backup of MySQL Cluster").

2. At some later point, prior to restoring the cluster, make a backup of the `mysql.ndb_binlog_index` table. It is probably simplest to use `mysqldump` for this task. Also back up the binary log files at this time.

   This backup should be updated regularly—perhaps even hourly—depending on your needs.

3. (*Catastrophic failure or error occurs.*)

4. Locate the last known good backup.

5. Clear the data node file systems (using `ndbd --initial` or, in MySQL Cluster NDB 7.0 and later, `ndbmtd --initial`).

   > **Note**
   >
   > MySQL Cluster Disk Data tablespace and log files are not removed by `--initial`. You must delete these manually.

6. Use `DROP TABLE` or `TRUNCATE TABLE` with the `mysql.ndb_binlog_index` table.

7. Execute `ndb_restore`, restoring all data. You must include the `--restore_epoch` option when you run `ndb_restore`, so that the `ndb_apply_status` table is populated correctly. (See Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup", for more information.)

8. Restore the `ndb_binlog_index` table from the output of `mysqldump` and restore the binary log files from backup, if necessary.

9. Find the epoch applied most recently—that is, the maximum `epoch` column value in the `ndb_apply_status` table—as the user variable `@LATEST_EPOCH` (emphasized):

```
SELECT @LATEST_EPOCH:=MAX(epoch)
    FROM mysql.ndb_apply_status;
```

10. Find the latest binary log file (`@FIRST_FILE`) and position (`Position` column value) within this file that correspond to `@LATEST_EPOCH` in the `ndb_binlog_index` table:

```
SELECT Position, @FIRST_FILE:=File
    FROM mysql.ndb_binlog_index
    WHERE epoch > @LATEST_EPOCH ORDER BY epoch ASC LIMIT 1;
```

11. Using `mysqlbinlog`, replay the binary log events from the given file and position up to the point of the failure. (See Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files".)

See also Section 7.5, "Point-in-Time (Incremental) Recovery Using the Binary Log", for more information about the binary log, replication, and incremental recovery.

17.6.10 MySQL Cluster Replication: Multi-Master and Circular Replication

Beginning with MySQL 5.1.18, it is possible to use MySQL Cluster in multi-master replication, including circular replication between a number of MySQL Clusters.

> **Note**
>
> Prior to MySQL 5.1.18, multi-master replication including circular replication was not supported with MySQL Cluster replication. This was because log events created in a particular MySQL Cluster were wrongly tagged with the server ID of the master rather than the server ID of the originating server.

Circular replication example.   In the next few paragraphs we consider the example of a replication setup involving three MySQL Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication master for Cluster 2, Cluster 2 acts as the master for Cluster 3, and Cluster 3 acts as the master for Cluster 1. Each cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

Circular replication using these clusters is supported as long as the following conditions are met:

- The SQL nodes on all masters and slaves are the same

- All SQL nodes acting as replication masters and slaves are started using the `--log-slave-updates` option

This type of circular replication setup is shown in the following diagram:

Figure 17.18 MySQL Cluster Circular Replication with All Masters As Slaves
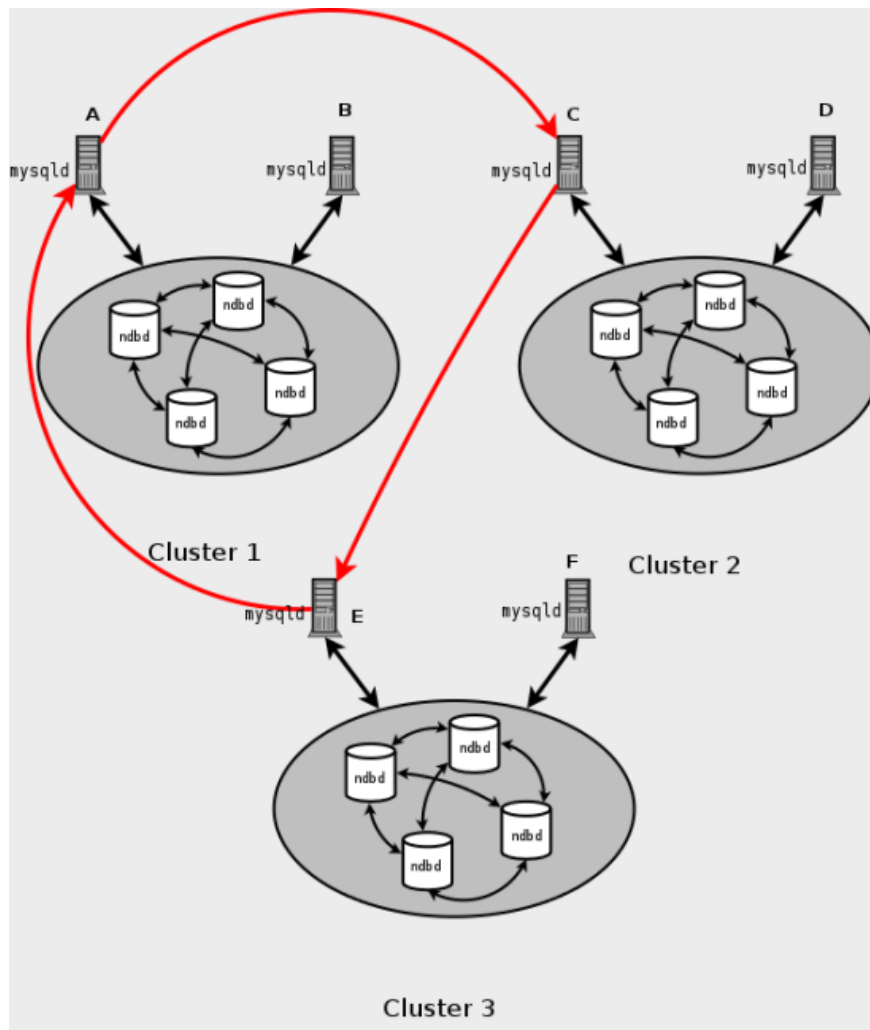
In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the red arrows in the diagram) directly connects all SQL nodes used as replication masters and slaves.

It is also possible to set up circular replication in such a way that not all master SQL nodes are also slaves, as shown here:

Figure 17.19 MySQL Cluster Circular Replication Where Not All Masters Are Slaves
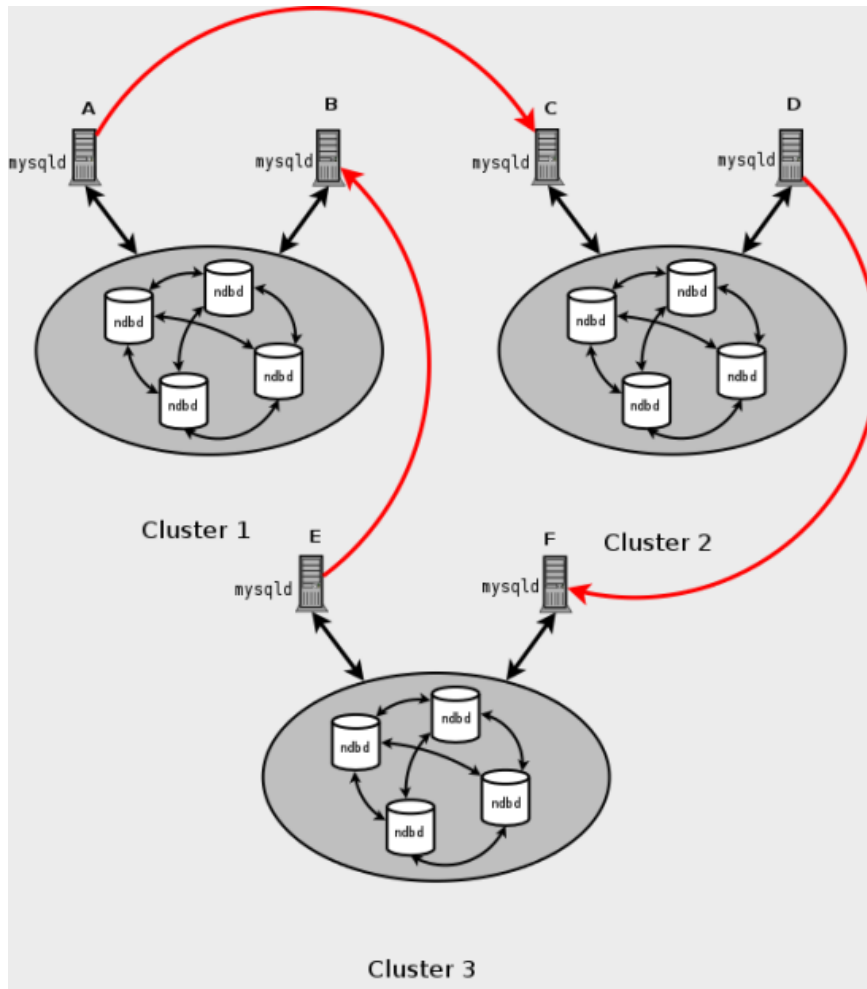
In this case, different SQL nodes in each cluster are used as replication masters and slaves. However, you must *not* start any of the SQL nodes using `--log-slave-updates`. This type of circular replication scheme for MySQL Cluster, in which the line of replication (again indicated by the red arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

Using NDB-native backup and restore to initialize a slave MySQL Cluster.   When setting up circular replication, it is possible to initialize the slave cluster by using the management client `BACKUP` command on one MySQL Cluster to create a backup and then applying this backup on another MySQL Cluster using `ndb_restore`. However, this does not automatically create binary logs on the second MySQL Cluster's SQL node acting as the replication slave. In order to cause the binary logs to be created, you must issue a `SHOW TABLES` statement on that SQL node; this should be done prior to running `START SLAVE`.

This is a known issue which we intend to address in a future release.

Multi-master failover example.   In this section, we discuss failover in a multi-master MySQL Cluster replication setup with three MySQL Clusters having server IDs 1, 2, and 3. In this scenario, Cluster 1 replicates to Clusters 2 and 3; Cluster 2 also replicates to Cluster 3. This relationship is shown here:

Figure 17.20 MySQL Cluster Multi-Master Replication With 3 Masters
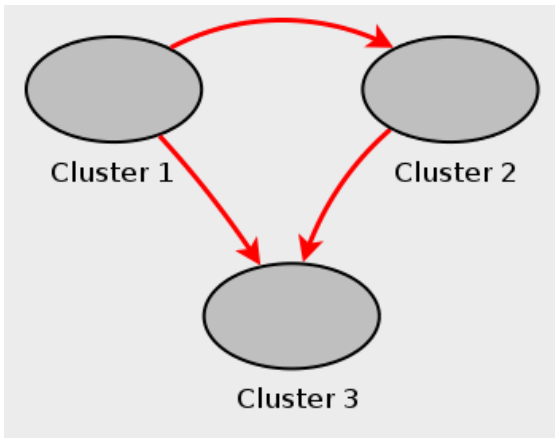
In other words, data replicates from Cluster 1 to Cluster 3 through 2 different routes: directly, and by way of Cluster 2.

Not all MySQL servers taking part in multi-master replication must act as both master and slave, and a given MySQL Cluster might use different SQL nodes for different replication channels. Such a case is shown here:

Figure 17.21 MySQL Cluster Multi-Master Replication, With MySQL Servers
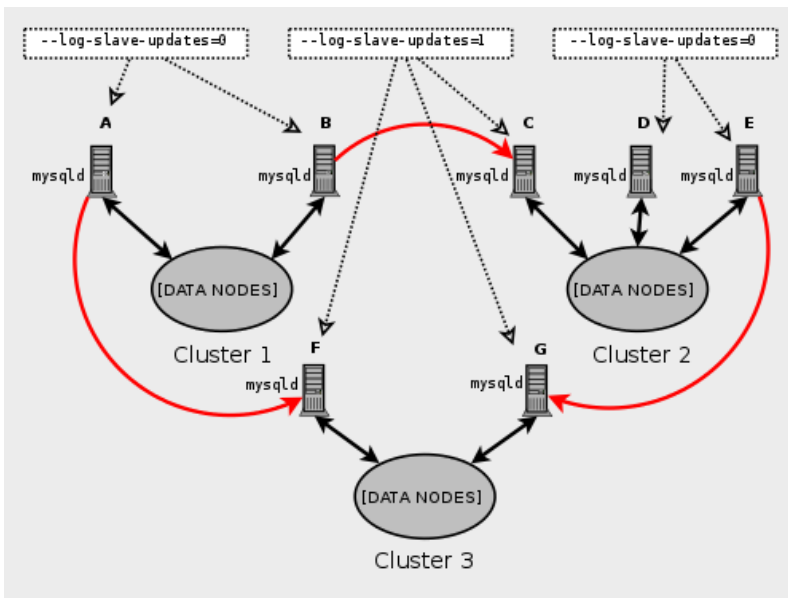
MySQL servers acting as replication slaves must be run with the `--log-slave-updates` option. Which `mysqld` processes require this option is also shown in the preceding diagram.

> **Note**
>
> Using the `--log-slave-updates` option has no effect on servers not being run as replication slaves.

The need for failover arises when one of the replicating clusters goes down. In this example, we consider the case where Cluster 1 is lost to service, and so Cluster 3 loses 2 sources of updates from Cluster 1.

Because replication between MySQL Clusters is asynchronous, there is no guarantee that Cluster 3's updates originating directly from Cluster 1 are more recent than those received through Cluster 2. You can handle this by ensuring that Cluster 3 catches up to Cluster 2 with regard to updates from Cluster 1. In terms of MySQL servers, this means that you need to replicate any outstanding updates from MySQL server C to server F.

On server C, perform the following queries:

```
mysqlC> SELECT @latest:=MAX(epoch)
     ->      FROM mysql.ndb_apply_status
     ->      WHERE server_id=1;

mysqlC> SELECT
     ->      @file:=SUBSTRING_INDEX(File, '/', -1),
     ->      @pos:=Position
     ->      FROM mysql.ndb_binlog_index
     ->      WHERE orig_epoch >= @latest
     ->      AND orig_server_id = 1
     ->      ORDER BY epoch ASC LIMIT 1;
```

> **Note**
>
> You can improve the performance of this query, and thus likely speed up failover times significantly, by adding the appropriate index to the `ndb_binlog_index` table. See Section 17.6.4, "MySQL Cluster Replication Schema and Tables", for more information.

Copy over the values for `@file` and `@pos` manually from server C to server F (or have your application perform the equivalent). Then, on server F, execute the following `CHANGE MASTER TO` statement:

```
mysqlF> CHANGE MASTER TO
     ->      MASTER_HOST = 'serverC'
     ->      MASTER_LOG_FILE='@file',
     ->      MASTER_LOG_POS=@pos;
```

Once this has been done, you can issue a `START SLAVE` statement on MySQL server F, and any missing updates originating from server B will be replicated to server F.

Beginning with MySQL Cluster MySQL Cluster NDB 6.1.29, MySQL Cluster NDB 6.3.31, MySQL Cluster NDB 7.0.11, and MySQL Cluster NDB 7.1.0, the `CHANGE MASTER TO` statement also supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. For more information, see Section 13.4.2.1, "CHANGE MASTER TO Syntax", and Section 13.7.5.36, "SHOW SLAVE STATUS Syntax".

17.6.11 MySQL Cluster Replication Conflict Resolution

When using a replication setup involving multiple masters (including circular replication), it is possible that different masters may try to update the same row on the slave with different data. Conflict resolution in MySQL Cluster Replication provides a means of resolving such conflicts by permitting a user-defined resolution column to be used to determine whether or not an update on a given master should be applied on the slave.

Some types of conflict resolution supported by MySQL Cluster (`NDB$OLD()`, `NDB$MAX()`, `NDB$MAX_DELETE_WIN()`) implement this user-defined column as a "timestamp" column (although its type cannot be `TIMESTAMP`, as explained later in this section). These types of conflict resolution are always applied a row-by-row basis rather than a transactional basis. The epoch-based conflict resolution functions introduced in MySQL Cluster NDB 7.1.16 (`NDB$EPOCH()` and `NDB$EPOCH_TRANS()`) compare the order

in which epochs are replicated (and thus these functions are transactional). Different methods can be used to compare resolution column values on the slave when conflicts occur, as explained later in this section; the method used can be set on a per-table basis.

You should also keep in mind that it is the application's responsibility to ensure that the resolution column is correctly populated with relevant values, so that the resolution function can make the appropriate choice when determining whether to apply an update.

Requirements. Preparations for conflict resolution must be made on both the master and the slave. These tasks are described in the following list:

- On the master writing the binary logs, you must determine which columns are sent (all columns or only those that have been updated). This is done for the MySQL Server as a whole by applying the `mysqld` startup option `--ndb-log-updated-only` (described later in this section) or on a per-table basis by entries in the `mysql.ndb_replication` table (see The ndb_replication system table).

  > **Note**
  >
  > If you are replicating tables with very large columns (such as `TEXT` or `BLOB` columns), `--ndb-log-updated-only` can also be useful for reducing the size of the master and slave binary logs and avoiding possible replication failures due to exceeding `max_allowed_packet`.
  >
  > See Section 16.4.1.21, "Replication and max_allowed_packet", for more information about this issue.

- On the slave, you must determine which type of conflict resolution to apply ("latest timestamp wins", "same timestamp wins", or none). This is done using the `mysql.ndb_replication` system table, on a per-table basis (see The ndb_replication system table).

- Prior to MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, conflict detection and resolution did not always work properly unless set up for `NDB` tables created on the same server only (Bug #13578660).

When using the functions `NDB$OLD()`, `NDB$MAX()`, and `NDB$MAX_DELETE_WIN()` for timestamp-based conflict resolution, we often refer to the column used for determining updates as a "timestamp" column, but the data type of this column is never `TIMESTAMP`; rather, its data type should be `INT` (`INTEGER`) or `BIGINT`. The "timestamp" column should also be `UNSIGNED` and `NOT NULL`.

Master column control. We can see update operations in terms of "before" and "after" images—that is, the states of the table before and after the update is applied. Normally, when updating a table with a primary key, the "before" image is not of great interest; however, when we need to determine on a per-update basis whether or not to use the updated values on a replication slave, we need to make sure that both images are written to the master's binary log. This is done with the `--ndb-log-update-as-write` option for `mysqld`, as described later in this section.

> **Important**
>
> Whether logging of complete rows or of updated columns only is done is decided when the MySQL server is started, and cannot be changed online; you must either restart `mysqld`, or start a new `mysqld` instance with different logging options.

Logging Full or Partial Rows (--ndb-log-updated-only Option)

Introduced	5.1.19-ndb-6.3.0

Command-Line Format	--ndb-log-updated-only	
System Variable	**Name**	`ndb_log_updated_only`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`ON`

For purposes of conflict resolution, there are two basic methods of logging rows, as determined by the setting of the `--ndb-log-updated-only` option for `mysqld`:

- Log complete rows

- Log only column data that has been updated—that is, column data whose value has been set, regardless of whether or not this value was actually changed. This is the default behavior.

It is usually sufficient—and more efficient—to log updated columns only; however, if you need to log full rows, you can do so by setting `--ndb-log-updated-only` to `0` or `OFF`.

--ndb-log-update-as-write Option: Logging Changed Data as Updates

Introduced	5.1.22-ndb-6.2.5	
Command-Line Format	--ndb-log-update-as-write	
System Variable	**Name**	`ndb_log_update_as_write`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`ON`

The setting of the MySQL Server's `--ndb-log-update-as-write` option determines whether logging is performed with or without the "before" image. Because conflict resolution is done in the MySQL Server's update handler, it is necessary to control logging on the master such that updates are updates and not writes; that is, such that updates are treated as changes in existing rows rather than the writing of new rows (even though these replace existing rows). This option is turned on by default; in other words, updates are treated as writes. (That is, updates are by default written as `write_row` events in the binary log, rather than as `update_row` events.)

To turn off the option, start the master `mysqld` with `--ndb-log-update-as-write=0` or `--ndb-log-update-as-write=OFF`. You must do this when replicating from NDB tables to tables using a different storage engine; see Replication from NDB to other storage engines.

Conflict resolution control.   Conflict resolution is usually enabled on the server where conflicts can occur. Like logging method selection, it is enabled by entries in the `mysql.ndb_replication` table.

The ndb_replication system table.   To enable conflict resolution, it is necessary to create an `ndb_replication` table in the `mysql` system database on the master, the slave, or both, depending on the conflict resolution type and method to be employed. This table is used to control logging and conflict resolution functions on a per-table basis, and has one row per table involved in replication.

`ndb_replication` is created and filled with control information on the server where the conflict is to be resolved. In a simple master-slave setup where data can also be changed locally on the slave this will typically be the slave. In a more complex master-master (2-way) replication schema this will usually be all of the masters involved. Each row in `mysql.ndb_replication` corresponds to a table being replicated, and specifies how to log and resolve conflicts (that is, which conflict resolution function, if any, to use) for that table. The definition of the `mysql.ndb_replication` table is shown here:

```
CREATE TABLE mysql.ndb_replication  (
    db VARBINARY(63),
    table_name VARBINARY(63),
    server_id INT UNSIGNED,
    binlog_type INT UNSIGNED,
    conflict_fn VARBINARY(128),
    PRIMARY KEY USING HASH (db, table_name, server_id)
)   ENGINE=NDB
PARTITION BY KEY(db,table_name);
```

The columns in this table are described in the next few paragraphs.

db.   The name of the database containing the table to be replicated.

Beginning with MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, you may employ either or both of the wildcards _ and % as part of the database name. Matching is similar to what is implemented for the `LIKE` operator.

table_name.   The name of the table to be replicated.

Beginning with MySQL Cluster NDB 7.0.31 and MySQL Cluster NDB 7.1.20, the table name may include either or both of the wildcards _ and %. Matching is similar to what is implemented for the `LIKE` operator.

server_id.   The unique server ID of the MySQL instance (SQL node) where the table resides.

binlog_type.   The type of binary logging to be employed. This is determined as shown in the following table:

Value	Internal Value	Description
0	`NBT_DEFAULT`	Use server default
1	`NBT_NO_LOGGING`	Do not log this table in the binary log
2	`NBT_UPDATED_ONLY`	Only updated attributes are logged
3	`NBT_FULL`	Log full row, even if not updated (MySQL server default behavior)
4	`NBT_USE_UPDATE`	(For generating `NBT_UPDATED_ONLY_USE_UPDATE` and `NBT_FULL_USE_UPDATE` values only—not intended for separate use)
5	[*Not used*]	---
6	`NBT_UPDATED_ONLY_USE_UPDATE` (equal to `NBT_UPDATED_ONLY` | `NBT_USE_UPDATE`)	Use updated attributes, even if values are unchanged
7	`NBT_FULL_USE_UPDATE` (equal to `NBT_FULL` | `NBT_USE_UPDATE`)	Use full row, even if values are unchanged

conflict_fn.   The conflict resolution function to be applied. This function must be specified as one of those shown in the following list:

- NDB$OLD(column_name)

- NDB$MAX(column_name)

- NDB$MAX_DELETE_WIN(column_name)

- NDB$EPOCH() and NDB$EPOCH_TRANS() (MySQL Cluster NDB 7.1.16 and later)

- NDB$EPOCH_TRANS() (MySQL Cluster NDB 7.1.16 and later)

- `NULL`: Indicates that conflict resolution is not to be used for the corresponding table.

These functions are described in the next few paragraphs.

NDB$OLD(column_name). If the value of `column_name` is the same on both the master and the slave, then the update is applied; otherwise, the update is not applied on the slave and an exception is written to the log. This is illustrated by the following pseudocode:

```
if (master_old_column_value == slave_current_column_value)
  apply_update();
else
  log_exception();
```

 This function can be used for "same value wins" conflict resolution. This type of conflict resolution ensures that updates are not applied on the slave from the wrong master.

> **Important**
>
> The column value from the master's "before" image is used by this function.

NDB$MAX(column_name). If the "timestamp" column value for a given row coming from the master is higher than that on the slave, it is applied; otherwise it is not applied on the slave. This is illustrated by the following pseudocode:

```
if (master_new_column_value > slave_current_column_value)
  apply_update();
```

 This function can be used for "greatest timestamp wins" conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was most recently updated is the version that persists.

> **Important**
>
> The column value from the master's "after" image is used by this function.

NDB$MAX_DELETE_WIN(column_name). This is a variation on `NDB$MAX()`. Due to the fact that no timestamp is available for a delete operation, a delete using `NDB$MAX()` is in fact processed as `NDB$OLD`. However, for some use cases, this is not optimal. For `NDB$MAX_DELETE_WIN()`, if the "timestamp" column value for a given row adding or updating an existing row coming from the master is higher than that on the slave, it is applied. However, delete operations are treated as always having the higher value. This is illustrated in the following pseudocode:

```
if ( (master_new_column_value > slave_current_column_value)
        ||
      operation.type == "delete")
  apply_update();
```

This function can be used for "greatest timestamp, delete wins" conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was deleted or (otherwise) most recently updated is the version that persists.

Note

As with `NDB$MAX()`, the column value from the master's "after" image is the value used by this function.

NDB$EPOCH() and NDB$EPOCH_TRANS().   The `NDB$EPOCH()` function, available beginning with MySQL Cluster NDB 7.1.16, tracks the order in which replicated epochs are applied on a slave MySQL Cluster relative to changes originating on the slave. This relative ordering is used to determine whether changes originating on the slave are concurrent with any changes that originate locally, and are therefore potentially in conflict.

Most of what follows in the description of `NDB$EPOCH()` also applies to `NDB$EPOCH_TRANS()`. Any exceptions are noted in the text.

`NDB$EPOCH()` is asymmetric, operating on one MySQL Cluster in a two-cluster circular replication configuration (sometimes referred to as "active-active" replication). We refer here to cluster on which it operates as the primary, and the other as the secondary. The slave on the primary is responsible for detecting and handling conflicts, while the slave on the secondary is not involved in any conflict detection or handling.

When the slave on the primary detects conflicts, it injects events into its own binary log to compensate for these; this ensures that the secondary MySQL Cluster eventually realigns itself with the primary and so keeps the primary and secondary from diverging. This compensation and realignment mechanism requires that the primary MySQL Cluster always wins any conflicts with the secondary—that is, that the primary's changes are always used rather than those from the secondary in event of a conflict. This "primary always wins" rule has the following implications:

- Operations that change data, once committed on the primary, are fully persistent and will not be undone or rolled back by conflict detection and resolution.

- Data read from the primary is fully consistent. Any changes committed on the Primary (locally or from the slave) will not be reverted later.

- Operations that change data on the secondary may later be reverted if the primary determines that they are in conflict.

- Individual rows read on the secondary are self-consistent at all times, each row always reflecting either a state committed by the secondary, or one committed by the primary.

- Sets of rows read on the secondary may not necessarily be consistent at a given single point in time. For `NDB$EPOCH_TRANS()`, this is a transient state; for `NDB$EPOCH()`, it can be a persistent state.

- Assuming a period of sufficient length without any conflicts, all data on the secondary MySQL Cluster (eventually) becomes consistent with the primary's data.

`NDB$EPOCH()` and `NDB$EPOCH_TRANS()` do not require any user schema modifications, or application changes to provide conflict detection. However, careful thought must be given to the schema used, and the access patterns used, to verify that the complete system behaves within specified limits.

Each of the `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions can take an optional parameter; this is the number of bits to use to represent the lower 32 bits of the epoch, and should be set to no less than

```
CEIL( LOG2( TimeBetweenGlobalCheckpoints / TimeBetweenEpochs ), 1)
```

For the default values of these configuration parameters (2000 and 100 milliseconds, respectively), this gives a value of 5 bits, so the default value (6) should be sufficient, unless other values are used for `TimeBetweenGlobalCheckpoints`, `TimeBetweenEpochs`, or both. A value that is too small can result in false positives, while one that is too large could lead to excessive wasted space in the database.

Both `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` insert entries for conflicting rows into the relevant exceptions tables, provided that these tables have been defined according to the same exception table schema rules as described elsewhere in this section (see NDB$OLD(column_name)). Note that you need to create any exception table before creating the table with which it is to be used.

As with the other conflict detection functions discussed in this section, `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` are activated by including relevant entries in the `mysql.ndb_replication` table (see The ndb_replication system table). The roles of the primary and secondary MySQL Clusters in this scenario are fully determined by `mysql.ndb_replication` table entries.

Because the conflict detection algorithms employed by `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` are asymmetric, you must use different values for the primary slave's and secondary slave's `server_id` entries.

Prior to MySQL Cluster NDB 7.1.32, conflict between `DELETE` operations were handled like those for `UPDATE` operations, and within the same epoch were considered in conflict. In MySQL Cluster NDB 7.1.32 and later, a conflict between `DELETE` operations alone is not sufficient to trigger a conflict using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()`, and the relative placement within epochs does not matter. (Bug "18454499)

NDB$EPOCH() and NDB$EPOCH_TRANS() status variables.   MySQL Cluster NDB 7.1.16 introduces several status variables that can be used to monitor `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` conflict detection. You can see how many rows have been found in conflict by `NDB$EPOCH()` since this slave was last restarted from the current value of the `Ndb_conflict_fn_epoch` system status variable.

`Ndb_conflict_fn_epoch_trans` provides the number of rows that have been found directly in conflict by `NDB$EPOCH_TRANS()`; the number of rows actually realigned, including those affected due to their membership in or dependency on the same transactions as other conflicting rows, is given by `Ndb_conflict_trans_row_reject_count`.

For more information, see MySQL Cluster Status Variables.

Limitations on NDB$EPOCH().   The following limitations currently apply when using `NDB$EPOCH()` to perform conflict detection:

- Conflicts are detected using MySQL Cluster epoch boundaries, with granularity proportional to `TimeBetweenEpochs` (default: 100 milliseconds). The minimum conflict window is the minimum time during which concurrent updates to the same data on both clusters always report a conflict. This is always a nonzero length of time, and is roughly proportional to `2 * (latency + queueing + TimeBetweenEpochs)`. This implies that—assuming the default for `TimeBetweenEpochs` and ignoring any latency between clusters (as well as any queuing delays)—the minimum conflict window size is approximately 200 milliseconds. This minimum window should be considered when looking at expected application "race" patterns.

- Additional storage is required for tables using the `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions; from 1 to 32 bits extra space per row is required, depending on the value passed to the function.

- Conflicts between delete operations may result in divergence between the primary and secondary. When a row is deleted on both clusters concurrently, the conflict can be detected, but is not recorded, since the row is deleted. This means that further conflicts during the propagation of any subsequent realignment operations will not be detected, which can lead to divergence.

Deletes should be externally serialized, or routed to one cluster only. Alternatively, a separate row should be updated transactionally with such deletes and any inserts that follow them, so that conflicts can be tracked across row deletes. This may require changes in applications.

- Only two MySQL Clusters in a circular "active-active" configuration are currently supported when using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()` for conflict detection.

- Tables having `BLOB` or `TEXT` columns are not currently supported with `NDB$EPOCH()` or `NDB$EPOCH_TRANS()`.

NDB$EPOCH_TRANS().   `NDB$EPOCH_TRANS()` extends the `NDB$EPOCH()` function, and, like `NDB$EPOCH()`, is available beginning with MySQL Cluster NDB 7.1.16. Conflicts are detected and handled in the same way using the "primary wins all" rule (see NDB$EPOCH() and NDB$EPOCH_TRANS()) but with the extra condition that any other rows updated in the same transaction in which the conflict occurred are also regarded as being in conflict. In other words, where `NDB$EPOCH()` realigns individual conflicting rows on the secondary, `NDB$EPOCH_TRANS()` realigns conflicting transactions.

In addition, any transactions which are detectably dependent on a conflicting transaction are also regarded as being in conflict, these dependencies being determined by the contents of the secondary cluster's binary log. Since the binary log contains only data modification operations (inserts, updates, and deletes), only overlapping data modifications are used to determine dependencies between transactions.

`NDB$EPOCH_TRANS()` is subject to the same conditions and limitations as `NDB$EPOCH()`, and in addition requires that Version 2 binary log row events are used (`--log-bin-use-v1-row-events` equal to 0), which adds a storage overhead of 2 bytes per event in the binary log. In addition, all transaction IDs must be recorded in the secondary's binary log (`--ndb-log-transaction-id` option), which adds a further variable overhead (up to 13 bytes per row).

See NDB$EPOCH() and NDB$EPOCH_TRANS().

Status information.   Beginning with MySQL Cluster NDB 6.3.3, a server status variable `Ndb_conflict_fn_max` provides a count of the number of times that a row was not applied on the current SQL node due to "greatest timestamp wins" conflict resolution since the last time that `mysqld` was started.

Beginning with MySQL Cluster NDB 6.3.4, the number of times that a row was not applied as the result of "same timestamp wins" conflict resolution on a given `mysqld` since the last time it was restarted is given by the global status variable `Ndb_conflict_fn_old`. In addition to incrementing `Ndb_conflict_fn_old`, the primary key of the row that was not used is inserted into an *exceptions table*, as explained later in this section.

Exceptions table.   To use the `NDB$OLD()` conflict resolution function, it is also necessary to create an exceptions table corresponding to each `NDB` table for which this type of conflict resolution is to be employed. This is also true when using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()` in MySQL Cluster NDB 7.1.16 and later. The name of this table is that of the table for which conflict resolution is to be applied, with the string `$EX` appended. (For example, if the name of the original table is `mytable`, the name of the corresponding exception table name should be `mytable$EX`.) This table is created as follows:

```
CREATE TABLE original_table$EX  (
    server_id INT UNSIGNED,
    master_server_id INT UNSIGNED,
    master_epoch BIGINT UNSIGNED,
    count INT UNSIGNED,
    original_table_pk_columns,
    [additional_columns,]
    PRIMARY KEY(server_id, master_server_id, master_epoch, count)
```

```
) ENGINE=NDB;
```

The first four columns are required. Following these columns, the columns making up the original table's primary key should be copied in the order in which they are used to define the primary key of the original table.

Note

The names of the first four columns and the columns matching the original table's primary key columns are not critical; however, we suggest for reasons of clarity and consistency, that you use the names shown here for the `server_id`, `master_server_id`, `master_epoch`, and `count` columns, and that you use the same names as in the original table for the columns matching those in the original table's primary key.

The data types for the columns duplicating the primary key columns of the original table should be the same as for (or larger than) the original columns.

Additional columns may optionally be defined following these columns, but not before any of them; any such extra columns cannot be `NOT NULL`. The exception table's primary key must be defined as shown. The exception table must use the `NDB` storage engine. An example that uses `NDB$OLD()` with an exceptions table is shown later in this section.

Important

The `mysql.ndb_replication` table is read when a data table is set up for replication, so the row corresponding to a table to be replicated must be inserted into `mysql.ndb_replication` *before* the table to be replicated is created.

Examples

The following examples assume that you have already a working MySQL Cluster replication setup, as described in Section 17.6.5, "Preparing the MySQL Cluster for Replication", and Section 17.6.6, "Starting MySQL Cluster Replication (Single Replication Channel)".

NDB$MAX() example.   Suppose you wish to enable "greatest timestamp wins" conflict resolution on table `test.t1`, using column `mycol` as the "timestamp". This can be done using the following steps:

1. Make sure that you have started the master `mysqld` with `--ndb-log-update-as-write=OFF`.

2. On the master, perform this `INSERT` statement:

   ```
   INSERT INTO mysql.ndb_replication
       VALUES ('test', 't1', 0, NULL, 'NDB$MAX(mycol)');
   ```

   Inserting a 0 into the `server_id` indicates that all SQL nodes accessing this table should use conflict resolution. If you want to use conflict resolution on a specific `mysqld` only, use the actual server ID.

   Inserting `NULL` into the `binlog_type` column has the same effect as inserting 0 (`NBT_DEFAULT`); the server default is used.

3. Create the `test.t1` table:

   ```
   CREATE TABLE test.t1 (
       columns
       mycol INT UNSIGNED,
       columns
   ```

```
)    ENGINE=NDB;
```

Now, when updates are done on this table, conflict resolution is applied, and the version of the row having the greatest value for `mycol` is written to the slave.

> **Note**
>
> Other `binlog_type` options—such as `NBT_UPDATED_ONLY_USE_UPDATE` should be used to control logging on the master using the `ndb_replication` table rather than by using command-line options.

NDB$OLD() example.   Suppose an `NDB` table such as the one defined here is being replicated, and you wish to enable "same timestamp wins" conflict resolution for updates to this table:

```
CREATE TABLE test.t2  (
    a INT UNSIGNED NOT NULL,
    b CHAR(25) NOT NULL,
    columns,
    mycol INT UNSIGNED NOT NULL,
    columns,
    PRIMARY KEY pk (a, b)
)    ENGINE=NDB;
```

The following steps are required, in the order shown:

1. First—and *prior* to creating `test.t2`—you must insert a row into the `mysql.ndb_replication` table, as shown here:

   ```
   INSERT INTO mysql.ndb_replication
       VALUES ('test', 't2', 0, NULL, 'NDB$OLD(mycol)');
   ```

   Possible values for the `binlog_type` column are shown earlier in this section. The value `'NDB$OLD(mycol)'` should be inserted into the `conflict_fn` column.

2. Create an appropriate exceptions table for `test.t2`. The table creation statement shown here includes all required columns; any additional columns must be declared following these columns, and before the definition of the table's primary key.

   ```
   CREATE TABLE test.t2$EX  (
       server_id SMALLINT UNSIGNED,
       master_server_id INT UNSIGNED,
       master_epoch BIGINT UNSIGNED,
       count BIGINT UNSIGNED,
       a INT UNSIGNED NOT NULL,
       b CHAR(25) NOT NULL,
       [additional_columns,]
       PRIMARY KEY(server_id, master_server_id, master_epoch, count)
   )    ENGINE=NDB;
   ```

3. Create the table `test.t2` as shown previously.

These steps must be followed for every table for which you wish to perform conflict resolution using `NDB$OLD()`. For each such table, there must be a corresponding row in `mysql.ndb_replication`, and there must be an exceptions table in the same database as the table being replicated.

17.7 MySQL Cluster NDB 6.1 - 7.1 Release Notes

MySQL Cluster release notes are no longer published in the MySQL Reference Manual.

Release notes for the changes in each release of MySQL Cluster are located at MySQL Cluster 7.1 Release Notes.

Table of Contents

This chapter discusses MySQL's implementation of *user-defined partitioning*. You can determine whether your MySQL Server supports partitioning by means of a SHOW VARIABLES statement such as this one:

> **Note**
>
> The have_partitioning variable is deprecated, and removed in MySQL 5.6.1.

```
mysql> SHOW VARIABLES LIKE '%partition%';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| have_partitioning | YES   |
+-------------------+-------+
1 row in set (0.00 sec)
```

> **Note**
>
> Prior to MySQL 5.1.6, this variable was named have_partition_engine. (Bug #16718)

You can also check the output of the SHOW PLUGINS statement, like this:

```
mysql> SHOW PLUGINS;
+------------+----------+----------------+---------+---------+
| Name       | Status   | Type           | Library | License |
+------------+----------+----------------+---------+---------+
```

```
| binlog      | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| partition   | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| ARCHIVE     | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| BLACKHOLE   | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| CSV         | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| FEDERATED   | DISABLED | STORAGE ENGINE | NULL     | GPL     |
| MEMORY      | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| InnoDB      | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| MRG_MYISAM  | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| MyISAM      | ACTIVE   | STORAGE ENGINE | NULL     | GPL     |
| ndbcluster  | DISABLED | STORAGE ENGINE | NULL     | GPL     |
+-----------+---------+----------------+---------+---------+
11 rows in set (0.00 sec)
```

In MySQL 5.1.5 and later, you can also check the `INFORMATION_SCHEMA.PLUGINS` table with a query similar to this one:

```
mysql> SELECT
    ->      PLUGIN_NAME as Name,
    ->      PLUGIN_VERSION as Version,
    ->      PLUGIN_STATUS as Status
    -> FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_TYPE='STORAGE ENGINE';
+--------------------+---------+--------+
| Name               | Version | Status |
+--------------------+---------+--------+
| binlog             | 1.0     | ACTIVE |
| CSV                | 1.0     | ACTIVE |
| MEMORY             | 1.0     | ACTIVE |
| MRG_MYISAM         | 1.0     | ACTIVE |
| MyISAM             | 1.0     | ACTIVE |
| PERFORMANCE_SCHEMA | 0.1     | ACTIVE |
| BLACKHOLE          | 1.0     | ACTIVE |
| ARCHIVE            | 3.0     | ACTIVE |
| InnoDB             | 5.6     | ACTIVE |
| partition          | 1.0     | ACTIVE |
+--------------------+---------+--------+
10 rows in set (0.00 sec)
```

Whichever of the preceding statements you employ, if you do not see the `partition` plugin listed with the value `ACTIVE` for the `Status` column in the output (shown in bold text in each of the examples just given), then your version of MySQL was not built with partitioning support.

MySQL 5.1 Community binaries provided by Oracle include partitioning support. For information about partitioning support offered in MySQL Enterprise Edition binaries, see Chapter 23, *MySQL Enterprise Edition*.

If you are compiling MySQL 5.1 from source, the build must be configured using `--with-partition` to enable partitioning. Using `--with-plugins=max` to configure the build includes this option automatically. For more information, see Section 2.11, "Installing MySQL from Source".

If your MySQL binary is built with partitioning support, nothing further needs to be done to enable it (for example, no special entries are required in your `my.cnf` file).

If you want to disable partitioning support, you can start the MySQL Server with the `--skip-partition` option, in which case the value of `have_partitioning` is `DISABLED`. When partitioning support is disabled, you can see any existing partitioned tables and drop them (although doing this is not advised), but you cannot otherwise manipulate them or access their data.

See Section 18.1, "Overview of Partitioning in MySQL", for an introduction to partitioning and partitioning concepts.

MySQL supports several types of partitioning as well as subpartitioning; see Section 18.2, "Partitioning Types", and Section 18.2.5, "Subpartitioning".

Section 18.3, "Partition Management", covers methods of adding, removing, and altering partitions in existing partitioned tables.

Section 18.3.3, "Maintenance of Partitions", discusses table maintenance commands for use with partitioned tables.

Beginning with MySQL 5.1.6, the `PARTITIONS` table in the `INFORMATION_SCHEMA` database provides information about partitions and partitioned tables. See Section 20.11, "The INFORMATION_SCHEMA PARTITIONS Table", for more information; for some examples of queries against this table, see Section 18.2.6, "How MySQL Partitioning Handles NULL".

> **Important**
>
> Partitioned tables created with MySQL versions prior to 5.1.6 cannot be read by a 5.1.6 or later MySQL Server. In addition, the `INFORMATION_SCHEMA.TABLES` table cannot be used if such tables are present on a 5.1.6 server. Beginning with MySQL 5.1.7, a suitable warning message is generated instead, to alert the user that incompatible partitioned tables have been found by the server.
>
> If you are using partitioned tables which were created in MySQL 5.1.5 or earlier, be sure to see the Release Notes for MySQL 5.1.6 for more information and suggested workarounds *before* upgrading to MySQL 5.1.6 or later.

For known issues with partitioning in MySQL 5.1, see Section 18.5, "Restrictions and Limitations on Partitioning".

You may also find the following resources to be useful when working with partitioned tables.

Additional Resources.   Other sources of information about user-defined partitioning in MySQL include the following:

- MySQL Partitioning Forum

  This is the official discussion forum for those interested in or experimenting with MySQL Partitioning technology. It features announcements and updates from MySQL developers and others. It is monitored by members of the Partitioning Development and Documentation Teams.

- Mikael Ronström's Blog

  MySQL Partitioning Architect and Lead Developer Mikael Ronström frequently posts articles here concerning his work with MySQL Partitioning and MySQL Cluster.

- PlanetMySQL

  A MySQL news site featuring MySQL-related blogs, which should be of interest to anyone using my MySQL. We encourage you to check here for links to blogs kept by those working with MySQL Partitioning, or to have your own blog added to those covered.

MySQL 5.1 binaries are available from http://dev.mysql.com/downloads/mysql/5.1.html. However, for the latest partitioning bugfixes and feature additions, you can obtain the source from our Bazaar repository. To enable partitioning, you need to compile the server using the `--with-partition` option. For more information about building MySQL, see Section 2.11, "Installing MySQL from Source". If you have problems compiling a partitioning-enabled MySQL 5.1 build, check the MySQL Partitioning Forum and ask for assistance there if you do not find a solution to your problem already posted.

18.1 Overview of Partitioning in MySQL

This section provides a conceptual overview of partitioning in MySQL 5.1.

For information on partitioning restrictions and feature limitations, see Section 18.5, "Restrictions and Limitations on Partitioning".

The SQL standard does not provide much in the way of guidance regarding the physical aspects of data storage. The SQL language itself is intended to work independently of any data structures or media underlying the schemas, tables, rows, or columns with which it works. Nonetheless, most advanced database management systems have evolved some means of determining the physical location to be used for storing specific pieces of data in terms of the file system, hardware or even both. In MySQL, the `InnoDB` storage engine has long supported the notion of a tablespace, and the MySQL Server, even prior to the introduction of partitioning, could be configured to employ different physical directories for storing different databases (see Section 8.12.4, "Using Symbolic Links", for an explanation of how this is done).

Partitioning takes this notion a step further, by enabling you to distribute portions of individual tables across a file system according to rules which you can set largely as needed. In effect, different portions of a table are stored as separate tables in different locations. The user-selected rule by which the division of data is accomplished is known as a *partitioning function*, which in MySQL can be the modulus, simple matching against a set of ranges or value lists, an internal hashing function, or a linear hashing function. The function is selected according to the partitioning type specified by the user, and takes as its parameter the value of a user-supplied expression. This expression can be a column value, a function acting on one or more column values, or a set of one or more column values, depending on the type of partitioning that is used.

In the case of `RANGE`, `LIST`, and [`LINEAR`] `HASH` partitioning, the value of the partitioning column is passed to the partitioning function, which returns an integer value representing the number of the partition in which that particular record should be stored. This function must be nonconstant and nonrandom. It may not contain any queries, but may use an SQL expression that is valid in MySQL, as long as that expression returns either `NULL` or an integer *intval* such that

```
-MAXVALUE <= intval <= MAXVALUE
```

(`MAXVALUE` is used to represent the least upper bound for the type of integer in question. `-MAXVALUE` represents the greatest lower bound.)

For [`LINEAR`] `KEY`, the partitioning expression consists of a list of one or more columns, and the partitioning function is supplied by MySQL.

For more information about permitted partitioning column types and partitioning functions, see Section 18.2, "Partitioning Types", as well as Section 13.1.17, "CREATE TABLE Syntax", which provides partitioning syntax descriptions and additional examples. For information about restrictions on partitioning functions, see Section 18.5.3, "Partitioning Limitations Relating to Functions".

This is known as *horizontal partitioning*—that is, different rows of a table may be assigned to different physical partitions. MySQL 5.1 does not support *vertical partitioning*, in which different columns of a table are assigned to different physical partitions. There are no plans at this time to introduce vertical partitioning into MySQL.

For information about determining whether your MySQL Server binary supports user-defined partitioning, see Chapter 18, *Partitioning*.

For creating partitioned tables, you can use most storage engines that are supported by your MySQL server; the MySQL partitioning engine runs in a separate layer and can interact with any of these. In MySQL 5.1, all partitions of the same partitioned table must use the same storage engine; for example, you

cannot use `MyISAM` for one partition and `InnoDB` for another. However, there is nothing preventing you from using different storage engines for different partitioned tables on the same MySQL server or even in the same database.

MySQL partitioning cannot be used with the `MERGE` or `CSV` storage engines. Beginning with MySQL 5.1.15, `FEDERATED` tables also cannot be partitioned (Bug #22451). Prior to MySQL 5.1.6, it was also not feasible to create a partitioned table using the `BLACKHOLE` storage engine (Bug #14524). See Section 18.5.2, "Partitioning Limitations Relating to Storage Engines".

Partitioning by `KEY` or `LINEAR KEY` is possible with `NDBCLUSTER`, but other types of user-defined partitioning are not supported for tables using this storage engine. In addition, an `NDBCLUSTER` table that employs user-defined partitioning must have an explicit primary key, and any columns referenced in the table's partitioning expression must be part of the primary key. However, if no columns are listed in the `PARTITION BY KEY` or `PARTITION BY LINEAR KEY` clause of the `CREATE TABLE` or `ALTER TABLE` statement used to create or modify a user-partitioned `NDBCLUSTER` table, then the table is not required to have an explicit primary key. For more information, see Section 17.1.6.1, "Noncompliance with SQL Syntax in MySQL Cluster".

To employ a particular storage engine for a partitioned table, it is necessary only to use the `[STORAGE] ENGINE` option just as you would for a nonpartitioned table. However, you should keep in mind that `[STORAGE] ENGINE` (and other table options) need to be listed *before* any partitioning options are used in a `CREATE TABLE` statement. This example shows how to create a table that is partitioned by hash into 6 partitions and which uses the `InnoDB` storage engine:

```
CREATE TABLE ti (id INT, amount DECIMAL(7,2), tr_date DATE)
    ENGINE=INNODB
    PARTITION BY HASH( MONTH(tr_date) )
    PARTITIONS 6;
```

Each `PARTITION` clause can include a `[STORAGE] ENGINE` option, but in MySQL 5.1 this has no effect.

> ⚠️ **Important**
>
> Partitioning applies to all data and indexes of a table; you cannot partition only the data and not the indexes, or vice versa, nor can you partition only a portion of the table.

Data and indexes for each partition can be assigned to a specific directory using the `DATA DIRECTORY` and `INDEX DIRECTORY` options for the `PARTITION` clause of the `CREATE TABLE` statement used to create the partitioned table.

Prior to MySQL 5.1.18, these options were permitted even when the `NO_DIR_IN_CREATE` server SQL mode was in effect (Bug #24633).

The `DATA DIRECTORY` and `INDEX DIRECTORY` options have no effect when defining partitions for tables using the `InnoDB` storage engine.

`DATA DIRECTORY` and `INDEX DIRECTORY` are not supported for individual partitions or subpartitions on Windows. Beginning with MySQL 5.1.24, these options are ignored on Windows, except that a warning is generated (Bug #30459)-

All columns used in the table's partitioning expression must be part of every unique key that the table may have, including any primary key. This means that a table such as this one, created by the following SQL statement, cannot be partitioned:

```
CREATE TABLE tnp (
    id INT NOT NULL AUTO_INCREMENT,
    ref BIGINT NOT NULL,
    name VARCHAR(255),
    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
);
```

Because the keys `pk` and `uk` have no columns in common, there are no columns available for use in a partitioning expression. Possible workarounds in this situation include adding the `name` column to the table's primary key, adding the `id` column to `uk`, or simply removing the unique key altogether. See Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys", for more information.

In addition, `MAX_ROWS` and `MIN_ROWS` can be used to determine the maximum and minimum numbers of rows, respectively, that can be stored in each partition. The `MAX_ROWS` option can be useful for causing MySQL Cluster tables to be created with extra partitions, thus allowing for greater storage of hash indexes. See the documentation for the `DataMemory` data node configuration parameter, as well as Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions", for more information.

Some advantages of partitioning are listed here:

- Partitioning makes it possible to store more data in one table than can be held on a single disk or file system partition.

- Data that loses its usefulness can often be easily removed from a partitioned table by dropping the partition (or partitions) containing only that data. Conversely, the process of adding new data can in some cases be greatly facilitated by adding one or more new partitions for storing specifically that data.

- Some queries can be greatly optimized in virtue of the fact that data satisfying a given `WHERE` clause can be stored only on one or more partitions, which automatically excludes any remaining partitions from the search. Because partitions can be altered after a partitioned table has been created, you can reorganize your data to enhance frequent queries that may not have been often used when the partitioning scheme was first set up. This ability to exclude non-matching partitions (and thus any rows they contain) is often referred to as *partition pruning*, and was implemented in MySQL 5.1.6. For more information, see Section 18.4, "Partition Pruning".

Other benefits usually associated with partitioning include those in the following list. These features are not currently implemented in MySQL Partitioning, but are high on our list of priorities.

- Queries involving aggregate functions such as `SUM()` and `COUNT()` can easily be parallelized. A simple example of such a query might be `SELECT salesperson_id, COUNT(orders) as order_total FROM sales GROUP BY salesperson_id;`. By "parallelized," we mean that the query can be run simultaneously on each partition, and the final result obtained merely by summing the results obtained for all partitions.

- Achieving greater query throughput in virtue of spreading data seeks over multiple disks.

Be sure to check this section and chapter frequently for updates as MySQL Partitioning development continues.

18.2 Partitioning Types

This section discusses the types of partitioning which are available in MySQL 5.1. These include the types listed here:

- **RANGE partitioning.**   This type of partitioning assigns rows to partitions based on column values falling within a given range. See Section 18.2.1, "RANGE Partitioning".

- **LIST partitioning.**   Similar to partitioning by `RANGE`, except that the partition is selected based on columns matching one of a set of discrete values. See Section 18.2.2, "LIST Partitioning".

- **HASH partitioning.**   With this type of partitioning, a partition is selected based on the value returned by a user-defined expression that operates on column values in rows to be inserted into the table. The function may consist of any expression valid in MySQL that yields a nonnegative integer value. An extension to this type, `LINEAR HASH`, is also available. See Section 18.2.3, "HASH Partitioning".

- **KEY partitioning.**   This type of partitioning is similar to partitioning by `HASH`, except that only one or more columns to be evaluated are supplied, and the MySQL server provides its own hashing function. These columns can contain other than integer values, since the hashing function supplied by MySQL guarantees an integer result regardless of the column data type. An extension to this type, `LINEAR KEY`, is also available. See Section 18.2.4, "KEY Partitioning".

A very common use of database partitioning is to segregate data by date. Some database systems support explicit date partitioning, which MySQL does not implement in 5.1. However, it is not difficult in MySQL to create partitioning schemes based on `DATE`, `TIME`, or `DATETIME` columns, or based on expressions making use of such columns.

When partitioning by `KEY` or `LINEAR KEY`, you can use a `DATE`, `TIME`, or `DATETIME` column as the partitioning column without performing any modification of the column value. For example, this table creation statement is perfectly valid in MySQL:

```
CREATE TABLE members (
    firstname VARCHAR(25) NOT NULL,
    lastname VARCHAR(25) NOT NULL,
    username VARCHAR(16) NOT NULL,
    email VARCHAR(35),
    joined DATE NOT NULL
)
PARTITION BY KEY(joined)
PARTITIONS 6;
```

MySQL's other partitioning types, however, require a partitioning expression that yields an integer value or `NULL`. If you wish to use date-based partitioning by `RANGE`, `LIST`, `HASH`, or `LINEAR HASH`, you can simply employ a function that operates on a `DATE`, `TIME`, or `DATETIME` column and returns such a value, as shown here:

```
CREATE TABLE members (
    firstname VARCHAR(25) NOT NULL,
    lastname VARCHAR(25) NOT NULL,
    username VARCHAR(16) NOT NULL,
    email VARCHAR(35),
    joined DATE NOT NULL
)
PARTITION BY RANGE( YEAR(joined) ) (
    PARTITION p0 VALUES LESS THAN (1960),
    PARTITION p1 VALUES LESS THAN (1970),
    PARTITION p2 VALUES LESS THAN (1980),
    PARTITION p3 VALUES LESS THAN (1990),
    PARTITION p4 VALUES LESS THAN MAXVALUE
);
```

Additional examples of partitioning using dates may be found in the following sections of this chapter:

- Section 18.2.1, "RANGE Partitioning"

- Section 18.2.3, "HASH Partitioning"

- Section 18.2.3.1, "LINEAR HASH Partitioning"

For more complex examples of date-based partitioning, see the following sections:

- Section 18.4, "Partition Pruning"

- Section 18.2.5, "Subpartitioning"

MySQL partitioning is optimized for use with the `TO_DAYS()` and `YEAR()` functions. However, you can use other date and time functions that return an integer or `NULL`, such as `WEEKDAY()`, `DAYOFYEAR()`, or `MONTH()`. See Section 12.7, "Date and Time Functions", for more information about such functions.

It is important to remember—regardless of the type of partitioning that you use—that partitions are always numbered automatically and in sequence when created, starting with `0`. When a new row is inserted into a partitioned table, it is these partition numbers that are used in identifying the correct partition. For example, if your table uses 4 partitions, these partitions are numbered `0`, `1`, `2`, and `3`. For the `RANGE` and `LIST` partitioning types, it is necessary to ensure that there is a partition defined for each partition number. For `HASH` partitioning, the user function employed must return an integer value greater than `0`. For `KEY` partitioning, this issue is taken care of automatically by the hashing function which the MySQL server employs internally.

Names of partitions generally follow the rules governing other MySQL identifiers, such as those for tables and databases. However, you should note that partition names are not case-sensitive. For example, the following `CREATE TABLE` statement fails as shown:

```
mysql> CREATE TABLE t2 (val INT)
    -> PARTITION BY LIST(val)(
    ->     PARTITION mypart VALUES IN (1,3,5),
    ->     PARTITION MyPart VALUES IN (2,4,6)
    -> );
ERROR 1488 (HY000): Duplicate partition name mypart
```

Failure occurs because MySQL sees no difference between the partition names `mypart` and `MyPart`.

When you specify the number of partitions for the table, this must be expressed as a positive, nonzero integer literal with no leading zeros, and may not be an expression such as `0.8E+01` or `6-2`, even if it evaluates to an integer value. (Beginning with MySQL 5.1.12, decimal fractions are no longer truncated, but instead are prohibited entirely.)

In the sections that follow, we do not necessarily provide all possible forms for the syntax that can be used for creating each partition type; this information may be found in Section 13.1.17, "CREATE TABLE Syntax".

18.2.1 RANGE Partitioning

A table that is partitioned by range is partitioned in such a way that each partition contains rows for which the partitioning expression value lies within a given range. Ranges should be contiguous but not overlapping, and are defined using the `VALUES LESS THAN` operator. For the next few examples, suppose that you are creating a table such as the following to hold personnel records for a chain of 20 video stores, numbered 1 through 20:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
```

```
    store_id INT NOT NULL
);
```

Note

The `employees` table used here has no primary or unique keys. While the examples work as shown for purposes of the present discussion, you should keep in mind that tables are extremely likely in practice to have primary keys, unique keys, or both, and that allowable choices for partitioning columns depend on the columns used for these keys, if any are present. For a discussion of these issues, see Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys".

This table can be partitioned by range in a number of ways, depending on your needs. One way would be to use the `store_id` column. For instance, you might decide to partition the table 4 ways by adding a `PARTITION BY RANGE` clause as shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (store_id) (
    PARTITION p0 VALUES LESS THAN (6),
    PARTITION p1 VALUES LESS THAN (11),
    PARTITION p2 VALUES LESS THAN (16),
    PARTITION p3 VALUES LESS THAN (21)
);
```

In this partitioning scheme, all rows corresponding to employees working at stores 1 through 5 are stored in partition `p0`, to those employed at stores 6 through 10 are stored in partition `p1`, and so on. Note that each partition is defined in order, from lowest to highest. This is a requirement of the `PARTITION BY RANGE` syntax; you can think of it as being analogous to a series of `if ... elseif ...` statements in C or Java in this regard.

It is easy to determine that a new row containing the data `(72, 'Mitchell', 'Wilson', '1998-06-25', NULL, 13)` is inserted into partition `p2`, but what happens when your chain adds a 21st store? Under this scheme, there is no rule that covers a row whose `store_id` is greater than 20, so an error results because the server does not know where to place it. You can keep this from occurring by using a "catchall" `VALUES LESS THAN` clause in the `CREATE TABLE` statement that provides for all values greater than the highest value explicitly named:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (store_id) (
    PARTITION p0 VALUES LESS THAN (6),
    PARTITION p1 VALUES LESS THAN (11),
    PARTITION p2 VALUES LESS THAN (16),
    PARTITION p3 VALUES LESS THAN MAXVALUE
);
```

> **Note**
>
> Another way to avoid an error when no matching value is found is to use the `IGNORE` keyword as part of the `INSERT` statement. For an example, see Section 18.2.2, "LIST Partitioning". Also see Section 13.2.5, "INSERT Syntax", for general information about `IGNORE`.

`MAXVALUE` represents an integer value that is always greater than the largest possible integer value (in mathematical language, it serves as a *least upper bound*). Now, any rows whose `store_id` column value is greater than or equal to 16 (the highest value defined) are stored in partition `p3`. At some point in the future—when the number of stores has increased to 25, 30, or more—you can use an `ALTER TABLE` statement to add new partitions for stores 21-25, 26-30, and so on (see Section 18.3, "Partition Management", for details of how to do this).

In much the same fashion, you could partition the table based on employee job codes—that is, based on ranges of `job_code` column values. For example—assuming that two-digit job codes are used for regular (in-store) workers, three-digit codes are used for office and support personnel, and four-digit codes are used for management positions—you could create the partitioned table using the following statement:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (job_code) (
    PARTITION p0 VALUES LESS THAN (100),
    PARTITION p1 VALUES LESS THAN (1000),
    PARTITION p2 VALUES LESS THAN (10000)
);
```

In this instance, all rows relating to in-store workers would be stored in partition `p0`, those relating to office and support staff in `p1`, and those relating to managers in partition `p2`.

It is also possible to use an expression in `VALUES LESS THAN` clauses. However, MySQL must be able to evaluate the expression's return value as part of a `LESS THAN` (<) comparison.

Rather than splitting up the table data according to store number, you can use an expression based on one of the two `DATE` columns instead. For example, let us suppose that you wish to partition based on the year that each employee left the company; that is, the value of `YEAR(separated)`. An example of a `CREATE TABLE` statement that implements such a partitioning scheme is shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY RANGE ( YEAR(separated) ) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1996),
    PARTITION p2 VALUES LESS THAN (2001),
    PARTITION p3 VALUES LESS THAN MAXVALUE
);
```

In this scheme, for all employees who left before 1991, the rows are stored in partition `p0`; for those who left in the years 1991 through 1995, in `p1`; for those who left in the years 1996 through 2000, in `p2`; and for any workers who left after the year 2000, in `p3`.

Beginning with MySQL 5.1.43, it is also possible to partition a table by `RANGE` based on the value of a `TIMESTAMP` column, using the `UNIX_TIMESTAMP()` function, as shown in this example:

```
CREATE TABLE quarterly_report_status (
    report_id INT NOT NULL,
    report_status VARCHAR(20) NOT NULL,
    report_updated TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
)
PARTITION BY RANGE ( UNIX_TIMESTAMP(report_updated) ) (
    PARTITION p0 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-01-01 00:00:00') ),
    PARTITION p1 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-04-01 00:00:00') ),
    PARTITION p2 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-07-01 00:00:00') ),
    PARTITION p3 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-10-01 00:00:00') ),
    PARTITION p4 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-01-01 00:00:00') ),
    PARTITION p5 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-04-01 00:00:00') ),
    PARTITION p6 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-07-01 00:00:00') ),
    PARTITION p7 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-10-01 00:00:00') ),
    PARTITION p8 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-01-01 00:00:00') ),
    PARTITION p9 VALUES LESS THAN (MAXVALUE)
);
```

Also beginning with MySQL 5.1.43, any other expressions involving `TIMESTAMP` values are not permitted. (See Bug #42849.)

> **Note**
>
> It is also possible in MySQL 5.1.43 and later to use `UNIX_TIMESTAMP(timestamp_column)` as a partitioning expression for tables that are partitioned by `LIST`. However, it is usually not practical to do so.

Range partitioning is particularly useful when one or more of the following conditions is true:

- You want or need to delete "old" data. If you are using the partitioning scheme shown previously for the `employees` table, you can simply use `ALTER TABLE employees DROP PARTITION p0;` to delete all rows relating to employees who stopped working for the firm prior to 1991. (See Section 13.1.7, "ALTER TABLE Syntax", and Section 18.3, "Partition Management", for more information.) For a table with a great many rows, this can be much more efficient than running a `DELETE` query such as `DELETE FROM employees WHERE YEAR(separated) <= 1990;`.

- You want to use a column containing date or time values, or containing values arising from some other series.

- You frequently run queries that depend directly on the column used for partitioning the table. For example, when executing a query such as `EXPLAIN PARTITIONS SELECT COUNT(*) FROM employees WHERE separated BETWEEN '2000-01-01' AND '2000-12-31' GROUP BY store_id;`, MySQL can quickly determine that only partition `p2` needs to be scanned because the remaining partitions cannot contain any records satisfying the `WHERE` clause. See Section 18.4, "Partition Pruning", for more information about how this is accomplished.

18.2.2 LIST Partitioning

List partitioning in MySQL is similar to range partitioning in many ways. As in partitioning by `RANGE`, each partition must be explicitly defined. The chief difference between the two types of partitioning is that, in list partitioning, each partition is defined and selected based on the membership of a column value in one of a set of value lists, rather than in one of a set of contiguous ranges of values. This is done

by using `PARTITION BY LIST(expr)` where `expr` is a column value or an expression based on a column value and returning an integer value, and then defining each partition by means of a `VALUES IN (value_list)`, where `value_list` is a comma-separated list of integers.

> **Note**
>
> In MySQL 5.1, it is possible to match against only a list of integers (and possibly `NULL`—see Section 18.2.6, "How MySQL Partitioning Handles NULL") when partitioning by `LIST`.

Unlike the case with partitions defined by range, list partitions do not need to be declared in any particular order. For more detailed syntactical information, see Section 13.1.17, "CREATE TABLE Syntax".

For the examples that follow, we assume that the basic definition of the table to be partitioned is provided by the `CREATE TABLE` statement shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
);
```

(This is the same table used as a basis for the examples in Section 18.2.1, "RANGE Partitioning".)

Suppose that there are 20 video stores distributed among 4 franchises as shown in the following table.

Region	Store ID Numbers
North	3, 5, 6, 9, 17
East	1, 2, 10, 11, 19, 20
West	4, 12, 13, 14, 18
Central	7, 8, 15, 16

To partition this table in such a way that rows for stores belonging to the same region are stored in the same partition, you could use the `CREATE TABLE` statement shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY LIST(store_id) (
    PARTITION pNorth VALUES IN (3,5,6,9,17),
    PARTITION pEast VALUES IN (1,2,10,11,19,20),
    PARTITION pWest VALUES IN (4,12,13,14,18),
    PARTITION pCentral VALUES IN (7,8,15,16)
);
```

This makes it easy to add or drop employee records relating to specific regions to or from the table. For instance, suppose that all stores in the West region are sold to another company. All rows relating to employees working at stores in that region can be deleted with an `ALTER TABLE employees DROP`

PARTITION pWest statement, which can be executed much more efficiently than the equivalent DELETE statement (DELETE FROM employees WHERE store_id IN (4,12,13,14,18)). However, the ALTER TABLE ... DROP PARTITION statement also removes the partition itself from the definition for the table, and you must execute an ALTER TABLE ... ADD PARTITION statement to restore the table's original partitioning scheme. (This problem is resolved in MySQL 5.5, which adds the ALTER TABLE ... TRUNCATE PARTITION statement for removing all rows from a given partition without affecting the table definition.)

As with RANGE partitioning, it is possible to combine LIST partitioning with partitioning by hash or key to produce a composite partitioning (subpartitioning). See Section 18.2.5, "Subpartitioning".

Unlike the case with RANGE partitioning, there is no "catch-all" such as MAXVALUE; all expected values for the partitioning expression should be covered in PARTITION ... VALUES IN (...) clauses. An INSERT statement containing an unmatched partitioning column value fails with an error, as shown in this example:

```
mysql> CREATE TABLE h2 (
    ->   c1 INT,
    ->   c2 INT
    -> )
    -> PARTITION BY LIST(c1) (
    ->   PARTITION p0 VALUES IN (1, 4, 7),
    ->   PARTITION p1 VALUES IN (2, 5, 8)
    -> );
Query OK, 0 rows affected (0.11 sec)

mysql> INSERT INTO h2 VALUES (3, 5);
ERROR 1525 (HY000): Table has no partition for value 3
```

When inserting multiple rows using a single INSERT statement the behavior depends on whether the table uses a transactional storage engine. For an InnoDB table, the statement is considered a single transaction, so the presence of any unmatched values causes the statement to fail completely, and no rows are inserted. For a table using a nontransactional storage engine such as MyISAM, any rows coming before the row containing the unmatched value are inserted, but any coming after it are not.

You can cause this type of error to be ignored by using the IGNORE keyword. If you do so, rows containing unmatched partitioning column values are not inserted, but any rows with matching values *are* inserted, and no errors are reported:

```
mysql> TRUNCATE h2;
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM h2;
Empty set (0.00 sec)

mysql> INSERT IGNORE INTO h2 VALUES (2, 5), (6, 10), (7, 5), (3, 1), (1, 9);
Query OK, 3 rows affected (0.00 sec)
Records: 5  Duplicates: 2  Warnings: 0

mysql> SELECT * FROM h2;
+------+------+
| c1   | c2   |
+------+------+
|    7 |    5 |
|    1 |    9 |
|    2 |    5 |
+------+------+
3 rows in set (0.00 sec)
```

18.2.3 HASH Partitioning

Partitioning by `HASH` is used primarily to ensure an even distribution of data among a predetermined number of partitions. With range or list partitioning, you must specify explicitly into which partition a given column value or set of column values is to be stored; with hash partitioning, MySQL takes care of this for you, and you need only specify a column value or expression based on a column value to be hashed and the number of partitions into which the partitioned table is to be divided.

To partition a table using `HASH` partitioning, it is necessary to append to the `CREATE TABLE` statement a `PARTITION BY HASH (expr)` clause, where `expr` is an expression that returns an integer. This can simply be the name of a column whose type is one of MySQL's integer types. In addition, you most likely want to follow this with `PARTITIONS num`, where `num` is a positive integer representing the number of partitions into which the table is to be divided.

> **Note**
>
> For simplicity, the tables in the examples that follow do not use any keys. You should be aware that, if a table has any unique keys, every column used in the partitioning expression for this table must be part of every unique key, including the primary key. See Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys", for more information.

The following statement creates a table that uses hashing on the `store_id` column and is divided into 4 partitions:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY HASH(store_id)
PARTITIONS 4;
```

If you do not include a `PARTITIONS` clause, the number of partitions defaults to `1`.

Using the `PARTITIONS` keyword without a number following it results in a syntax error.

You can also use an SQL expression that returns an integer for `expr`. For instance, you might want to partition based on the year in which an employee was hired. This can be done as shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY HASH( YEAR(hired) )
PARTITIONS 4;
```

`expr` must return a nonconstant, nonrandom integer value (in other words, it should be varying but deterministic), and must not contain any prohibited constructs as described in Section 18.5, "Restrictions and Limitations on Partitioning". You should also keep in mind that this expression is evaluated each time a row is inserted or updated (or possibly deleted); this means that very complex expressions may give rise

to performance issues, particularly when performing operations (such as batch inserts) that affect a great many rows at one time.

The most efficient hashing function is one which operates upon a single table column and whose value increases or decreases consistently with the column value, as this allows for "pruning" on ranges of partitions. That is, the more closely that the expression varies with the value of the column on which it is based, the more efficiently MySQL can use the expression for hash partitioning.

For example, where `date_col` is a column of type `DATE`, then the expression `TO_DAYS(date_col)` is said to vary directly with the value of `date_col`, because for every change in the value of `date_col`, the value of the expression changes in a consistent manner. The variance of the expression `YEAR(date_col)` with respect to `date_col` is not quite as direct as that of `TO_DAYS(date_col)`, because not every possible change in `date_col` produces an equivalent change in `YEAR(date_col)`. Even so, `YEAR(date_col)` is a good candidate for a hashing function, because it varies directly with a portion of `date_col` and there is no possible change in `date_col` that produces a disproportionate change in `YEAR(date_col)`.

By way of contrast, suppose that you have a column named `int_col` whose type is `INT`. Now consider the expression `POW(5-int_col,3) + 6`. This would be a poor choice for a hashing function because a change in the value of `int_col` is not guaranteed to produce a proportional change in the value of the expression. Changing the value of `int_col` by a given amount can produce by widely different changes in the value of the expression. For example, changing `int_col` from `5` to `6` produces a change of `-1` in the value of the expression, but changing the value of `int_col` from `6` to `7` produces a change of `-7` in the expression value.

In other words, the more closely the graph of the column value versus the value of the expression follows a straight line as traced by the equation $y=cx$ where c is some nonzero constant, the better the expression is suited to hashing. This has to do with the fact that the more nonlinear an expression is, the more uneven the distribution of data among the partitions it tends to produce.

In theory, pruning is also possible for expressions involving more than one column value, but determining which of such expressions are suitable can be quite difficult and time-consuming. For this reason, the use of hashing expressions involving multiple columns is not particularly recommended.

When `PARTITION BY HASH` is used, MySQL determines which partition of *num* partitions to use based on the modulus of the result of the user function. In other words, for an expression *expr*, the partition in which the record is stored is partition number *N*, where *N* = `MOD(`*expr*`, `*num*`)`. Suppose that table `t1` is defined as follows, so that it has 4 partitions:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY HASH( YEAR(col3) )
    PARTITIONS 4;
```

If you insert a record into `t1` whose `col3` value is `'2005-09-15'`, then the partition in which it is stored is determined as follows:

```
MOD(YEAR('2005-09-01'),4)
=  MOD(2005,4)
=  1
```

MySQL 5.1 also supports a variant of `HASH` partitioning known as *linear hashing* which employs a more complex algorithm for determining the placement of new rows inserted into the partitioned table. See Section 18.2.3.1, "LINEAR HASH Partitioning", for a description of this algorithm.

The user function is evaluated each time a record is inserted or updated. It may also—depending on the circumstances—be evaluated when records are deleted.

> **Note**
>
> If a table to be partitioned has a `UNIQUE` key, then any columns supplied as arguments to the `HASH` user function or to the `KEY`'s `column_list` must be part of that key.

18.2.3.1 LINEAR HASH Partitioning

MySQL also supports linear hashing, which differs from regular hashing in that linear hashing utilizes a linear powers-of-two algorithm whereas regular hashing employs the modulus of the hashing function's value.

Syntactically, the only difference between linear-hash partitioning and regular hashing is the addition of the `LINEAR` keyword in the `PARTITION BY` clause, as shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY LINEAR HASH( YEAR(hired) )
PARTITIONS 4;
```

Given an expression $expr$, the partition in which the record is stored when linear hashing is used is partition number N from among num partitions, where N is derived according to the following algorithm:

1. Find the next power of 2 greater than num. We call this value V; it can be calculated as:

   ```
   V = POWER(2, CEILING(LOG(2, num)))
   ```

   (Suppose that num is 13. Then `LOG(2,13)` is 3.7004397181411. `CEILING(3.7004397181411)` is 4, and V = `POWER(2,4)`, which is 16.)

2. Set N = F($column\_list$) & (V - 1).

3. While N >= num:

   - Set V = CEIL(V / 2)

   - Set N = N & (V - 1)

Suppose that the table `t1`, using linear hash partitioning and having 6 partitions, is created using this statement:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY LINEAR HASH( YEAR(col3) )
    PARTITIONS 6;
```

Now assume that you want to insert two records into `t1` having the `col3` column values `'2003-04-14'` and `'1998-10-19'`. The partition number for the first of these is determined as follows:

```
V = POWER(2, CEILING( LOG(2,6) )) = 8
N = YEAR('2003-04-14') & (8 - 1)
```

```
   = 2003 & 7
   = 3

(3 >= 6 is FALSE: record stored in partition #3)
```

The number of the partition where the second record is stored is calculated as shown here:

```
V = 8
N = YEAR('1998-10-19') & (8-1)
  = 1998 & 7
  = 6

(6 >= 6 is TRUE: additional step required)

N = 6 & CEILING(8 / 2)
  = 6 & 3
  = 2

(2 >= 6 is FALSE: record stored in partition #2)
```

The advantage in partitioning by linear hash is that the adding, dropping, merging, and splitting of partitions is made much faster, which can be beneficial when dealing with tables containing extremely large amounts (terabytes) of data. The disadvantage is that data is less likely to be evenly distributed between partitions as compared with the distribution obtained using regular hash partitioning.

18.2.4 KEY Partitioning

Partitioning by key is similar to partitioning by hash, except that where hash partitioning employs a user-defined expression, the hashing function for key partitioning is supplied by the MySQL server. MySQL Cluster uses `MD5()` for this purpose; for tables using other storage engines, the server employs its own internal hashing function which is based on the same algorithm as `PASSWORD()`.

The syntax rules for `CREATE TABLE ... PARTITION BY KEY` are similar to those for creating a table that is partitioned by hash. The major differences are listed here:

- `KEY` is used rather than `HASH`.

- `KEY` takes only a list of one or more column names. Beginning with MySQL 5.1.5, the column or columns used as the partitioning key must comprise part or all of the table's primary key, if the table has one.

  Beginning with MySQL 5.1.6, `KEY` takes a list of zero or more column names. Where no column name is specified as the partitioning key, the table's primary key is used, if there is one. For example, the following `CREATE TABLE` statement is valid in MySQL 5.1.6 or later:

```
CREATE TABLE k1 (
    id INT NOT NULL PRIMARY KEY,
    name VARCHAR(20)
)
PARTITION BY KEY()
PARTITIONS 2;
```

  If there is no primary key but there is a unique key, then the unique key is used for the partitioning key:

```
CREATE TABLE k1 (
    id INT NOT NULL,
    name VARCHAR(20),
    UNIQUE KEY (id)
)
PARTITION BY KEY()
```

```
PARTITIONS 2;
```

However, if the unique key column were not defined as NOT NULL, then the previous statement would fail.

In both of these cases, the partitioning key is the id column, even though it is not shown in the output of SHOW CREATE TABLE or in the PARTITION_EXPRESSION column of the INFORMATION_SCHEMA.PARTITIONS table.

Unlike the case with other partitioning types, columns used for partitioning by KEY are not restricted to integer or NULL values. For example, the following CREATE TABLE statement is valid:

```
CREATE TABLE tm1 (
    s1 CHAR(32) PRIMARY KEY
)
PARTITION BY KEY(s1)
PARTITIONS 10;
```

The preceding statement would *not* be valid, were a different partitioning type to be specified. (In this case, simply using PARTITION BY KEY() would also be valid and have the same effect as PARTITION BY KEY(s1), since s1 is the table's primary key.)

For additional information about this issue, see Section 18.5, "Restrictions and Limitations on Partitioning".

> **Note**
>
> Also beginning with MySQL 5.1.6, tables using the NDBCLUSTER storage engine are implicitly partitioned by KEY, again using the table's primary key as the partitioning key. In the event that the MySQL Cluster table has no explicit primary key, the "hidden" primary key generated by the NDBCLUSTER storage engine for each MySQL Cluster table is used as the partitioning key.
>
> Beginning with MySQL Cluster NDB 6.2.18, MySQL Cluster NDB 6.3.25, and MySQL Cluster NDB 7.0.6, if you define an explicit partitioning scheme for an NDBCLUSTER table, the table must have an explicit primary key, and any columns used in the partitioning expression must be part of this key. However, if the table uses an "empty" partitioning expression—that is, PARTITION BY KEY() with no column references—then no explicit primary key is required.
>
> You can observe this partitioning using the ndb_desc utility (with the -p option).

> **Important**
>
> For a key-partitioned table using any MySQL storage engine other than NDBCLUSTER, you cannot execute an ALTER TABLE DROP PRIMARY KEY, as doing so generates the error ERROR 1466 (HY000): Field in list of fields for partition function not found in table. This is not an issue for MySQL Cluster tables which are partitioned by KEY; in such cases, the table is reorganized using the "hidden" primary key as the table's new partitioning key. See Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*.

It is also possible to partition a table by linear key. Here is a simple example:

```
CREATE TABLE tk (
```

```
    col1 INT NOT NULL,
    col2 CHAR(5),
    col3 DATE
)
PARTITION BY LINEAR KEY (col1)
PARTITIONS 3;
```

Using `LINEAR` has the same effect on `KEY` partitioning as it does on `HASH` partitioning, with the partition number being derived using a powers-of-two algorithm rather than modulo arithmetic. See Section 18.2.3.1, "LINEAR HASH Partitioning", for a description of this algorithm and its implications.

18.2.5 Subpartitioning

Subpartitioning—also known as *composite partitioning*—is the further division of each partition in a partitioned table. Consider the following `CREATE TABLE` statement:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) )
    SUBPARTITIONS 2 (
        PARTITION p0 VALUES LESS THAN (1990),
        PARTITION p1 VALUES LESS THAN (2000),
        PARTITION p2 VALUES LESS THAN MAXVALUE
    );
```

Table `ts` has 3 `RANGE` partitions. Each of these partitions—`p0`, `p1`, and `p2`—is further divided into 2 subpartitions. In effect, the entire table is divided into `3 * 2 = 6` partitions. However, due to the action of the `PARTITION BY RANGE` clause, the first 2 of these store only those records with a value less than 1990 in the `purchased` column.

In MySQL 5.1, it is possible to subpartition tables that are partitioned by `RANGE` or `LIST`. Subpartitions may use either `HASH` or `KEY` partitioning. This is also known as *composite partitioning*.

> **Note**
>
> `SUBPARTITION BY HASH` and `SUBPARTITION BY KEY` generally follow the same syntax rules as `PARTITION BY HASH` and `PARTITION BY KEY`, respectively. An exception to this is that `SUBPARTITION BY KEY` (unlike `PARTITION BY KEY`) does not currently support a default column, so the column used for this purpose must be specified, even if the table has an explicit primary key. This is a known issue which we are working to address; see Issues with subpartitions, for more information and an example.

It is also possible to define subpartitions explicitly using `SUBPARTITION` clauses to specify options for individual subpartitions. For example, a more verbose fashion of creating the same table `ts` as shown in the previous example would be:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0,
            SUBPARTITION s1
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s2,
            SUBPARTITION s3
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
```

```
            SUBPARTITION s4,
            SUBPARTITION s5
        )
    );
```

Some syntactical items of note are listed here:

- Each partition must have the same number of subpartitions.

- If you explicitly define any subpartitions using `SUBPARTITION` on any partition of a partitioned table, you must define them all. In other words, the following statement will fail:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0,
            SUBPARTITION s1
        ),
        PARTITION p1 VALUES LESS THAN (2000),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s2,
            SUBPARTITION s3
        )
    );
```

  This statement would still fail even if it included a `SUBPARTITIONS 2` clause.

- Each `SUBPARTITION` clause must include (at a minimum) a name for the subpartition. Otherwise, you may set any desired option for the subpartition or allow it to assume its default setting for that option.

- In MySQL 5.1.7 and earlier, names of subpartitions were required to be unique within each partition, but did not have to be unique within the table as a whole. Beginning with MySQL 5.1.8, subpartition names must be unique across the entire table. For example, the following `CREATE TABLE` statement is valid in MySQL 5.1.8 and later:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0,
            SUBPARTITION s1
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s2,
            SUBPARTITION s3
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s4,
            SUBPARTITION s5
        )
    );
```

  (The previous statement is also valid for versions of MySQL prior to 5.1.8.)

Subpartitions can be used with especially large tables to distribute data and indexes across many disks. Suppose that you have 6 disks mounted as `/disk0`, `/disk1`, `/disk2`, and so on. Now consider the following example:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
```

```
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0
                DATA DIRECTORY = '/disk0/data'
                INDEX DIRECTORY = '/disk0/idx',
            SUBPARTITION s1
                DATA DIRECTORY = '/disk1/data'
                INDEX DIRECTORY = '/disk1/idx'
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s2
                DATA DIRECTORY = '/disk2/data'
                INDEX DIRECTORY = '/disk2/idx',
            SUBPARTITION s3
                DATA DIRECTORY = '/disk3/data'
                INDEX DIRECTORY = '/disk3/idx'
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s4
                DATA DIRECTORY = '/disk4/data'
                INDEX DIRECTORY = '/disk4/idx',
            SUBPARTITION s5
                DATA DIRECTORY = '/disk5/data'
                INDEX DIRECTORY = '/disk5/idx'
        )
    );
```

In this case, a separate disk is used for the data and for the indexes of each `RANGE`. Many other variations are possible; another example might be:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE(YEAR(purchased))
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0a
                DATA DIRECTORY = '/disk0'
                INDEX DIRECTORY = '/disk1',
            SUBPARTITION s0b
                DATA DIRECTORY = '/disk2'
                INDEX DIRECTORY = '/disk3'
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s1a
                DATA DIRECTORY = '/disk4/data'
                INDEX DIRECTORY = '/disk4/idx',
            SUBPARTITION s1b
                DATA DIRECTORY = '/disk5/data'
                INDEX DIRECTORY = '/disk5/idx'
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s2a,
            SUBPARTITION s2b
        )
    );
```

Here, the storage is as follows:

- Rows with `purchased` dates from before 1990 take up a vast amount of space, so are split up 4 ways, with a separate disk dedicated to the data and to the indexes for each of the two subpartitions (`s0a` and `s0b`) making up partition `p0`. In other words:

  - The data for subpartition `s0a` is stored on `/disk0`.

  - The indexes for subpartition `s0a` are stored on `/disk1`.

- The data for subpartition `s0b` is stored on `/disk2`.

- The indexes for subpartition `s0b` are stored on `/disk3`.

- Rows containing dates ranging from 1990 to 1999 (partition `p1`) do not require as much room as those from before 1990. These are split between 2 disks (`/disk4` and `/disk5`) rather than 4 disks as with the legacy records stored in `p0`:

    - Data and indexes belonging to `p1`'s first subpartition (`s1a`) are stored on `/disk4`—the data in `/disk4/data`, and the indexes in `/disk4/idx`.

    - Data and indexes belonging to `p1`'s second subpartition (`s1b`) are stored on `/disk5`—the data in `/disk5/data`, and the indexes in `/disk5/idx`.

- Rows reflecting dates from the year 2000 to the present (partition `p2`) do not take up as much space as required by either of the two previous ranges. Currently, it is sufficient to store all of these in the default location.

    In future, when the number of purchases for the decade beginning with the year 2000 grows to a point where the default location no longer provides sufficient space, the corresponding rows can be moved using an `ALTER TABLE ... REORGANIZE PARTITION` statement. See Section 18.3, "Partition Management", for an explanation of how this can be done.

Beginning with MySQL 5.1.18, the `DATA DIRECTORY` and `INDEX DIRECTORY` options are not permitted in partition definitions when the `NO_DIR_IN_CREATE` server SQL mode is in effect. However, this not true when defining subpartitions; this is a known issue which is fixed in MySQL 5.5 (Bug #42954).

18.2.6 How MySQL Partitioning Handles NULL

Partitioning in MySQL does nothing to disallow `NULL` as the value of a partitioning expression, whether it is a column value or the value of a user-supplied expression. Even though it is permitted to use `NULL` as the value of an expression that must otherwise yield an integer, it is important to keep in mind that `NULL` is not a number. Beginning with MySQL 5.1.8, the partitioning implementation treats `NULL` as being less than any non-`NULL` value, just as `ORDER BY` does.

This means that treatment of `NULL` varies between partitioning of different types, and may produce behavior which you do not expect if you are not prepared for it. This being the case, we discuss in this section how each MySQL partitioning type handles `NULL` values when determining the partition in which a row should be stored, and provide examples for each.

Handling of NULL with RANGE partitioning.   If you insert a row into a table partitioned by `RANGE` such that the column value used to determine the partition is `NULL`, the row is inserted into the lowest partition. Consider these two tables in a database named `p`, created as follows:

```
mysql> CREATE TABLE t1 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY RANGE(c1) (
    ->     PARTITION p0 VALUES LESS THAN (0),
    ->     PARTITION p1 VALUES LESS THAN (10),
    ->     PARTITION p2 VALUES LESS THAN MAXVALUE
    -> );
Query OK, 0 rows affected (0.09 sec)

mysql> CREATE TABLE t2 (
    ->     c1 INT,
```

```
    ->      c2 VARCHAR(20)
    -> )
    -> PARTITION BY RANGE(c1) (
    ->      PARTITION p0 VALUES LESS THAN (-5),
    ->      PARTITION p1 VALUES LESS THAN (0),
    ->      PARTITION p2 VALUES LESS THAN (10),
    ->      PARTITION p3 VALUES LESS THAN MAXVALUE
    -> );
Query OK, 0 rows affected (0.09 sec)
```

You can see the partitions created by these two CREATE TABLE statements using the following query against the PARTITIONS table in the INFORMATION_SCHEMA database:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
    >    FROM INFORMATION_SCHEMA.PARTITIONS
    >    WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 't_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| t1         | p0             |          0 |              0 |           0 |
| t1         | p1             |          0 |              0 |           0 |
| t1         | p2             |          0 |              0 |           0 |
| t2         | p0             |          0 |              0 |           0 |
| t2         | p1             |          0 |              0 |           0 |
| t2         | p2             |          0 |              0 |           0 |
| t2         | p3             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
7 rows in set (0.00 sec)
```

(For more information about this table, see Section 20.11, "The INFORMATION_SCHEMA PARTITIONS Table".) Now let us populate each of these tables with a single row containing a NULL in the column used as the partitioning key, and verify that the rows were inserted using a pair of SELECT statements:

```
mysql> INSERT INTO t1 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO t2 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM t1;
+------+--------+
| id   | name   |
+------+--------+
| NULL | mothra |
+------+--------+
1 row in set (0.00 sec)

mysql> SELECT * FROM t2;
+------+--------+
| id   | name   |
+------+--------+
| NULL | mothra |
+------+--------+
1 row in set (0.00 sec)
```

You can see which partitions are used to store the inserted rows by rerunning the previous query against INFORMATION_SCHEMA.PARTITIONS and inspecting the output:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
    >    FROM INFORMATION_SCHEMA.PARTITIONS
    >    WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 't_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
```

```
+-----------+----------------+-----------+----------------+-------------+
| t1        | p0             |         1 |             20 |          20 |
| t1        | p1             |         0 |              0 |           0 |
| t1        | p2             |         0 |              0 |           0 |
| t2        | p0             |         1 |             20 |          20 |
| t2        | p1             |         0 |              0 |           0 |
| t2        | p2             |         0 |              0 |           0 |
| t2        | p3             |         0 |              0 |           0 |
+-----------+----------------+-----------+----------------+-------------+
7 rows in set (0.01 sec)
```

You can also demonstrate that these rows were stored in the lowest partition of each table by dropping these partitions, and then re-running the SELECT statements:

```
mysql> ALTER TABLE t1 DROP PARTITION p0;
Query OK, 0 rows affected (0.16 sec)

mysql> ALTER TABLE t2 DROP PARTITION p0;
Query OK, 0 rows affected (0.16 sec)

mysql> SELECT * FROM t1;
Empty set (0.00 sec)

mysql> SELECT * FROM t2;
Empty set (0.00 sec)
```

> **Important**
>
> Prior to MySQL 5.1.8, RANGE partitioning treated a partitioning expression value of NULL as 0 with respect to determining placement. (The only way to circumvent this behavior was to design tables so as not to permit nulls, usually by declaring columns NOT NULL.) If you have a RANGE partitioning scheme that depends on this earlier behavior, you must re-implement it when upgrading to MySQL 5.1.8 or later. (Bug #15447)

NULL is also treated in this way for partitioning expressions that use SQL functions. Suppose that we define a table using a CREATE TABLE statement such as this one:

```
CREATE TABLE tndate (
    id INT,
    dt DATE
)
PARTITION BY RANGE( YEAR(dt) ) (
    PARTITION p0 VALUES LESS THAN (1990),
    PARTITION p1 VALUES LESS THAN (2000),
    PARTITION p2 VALUES LESS THAN MAXVALUE
);
```

As with other MySQL functions, YEAR(NULL) returns NULL. A row with a dt column value of NULL is treated as though the partitioning expression evaluated to a value less than any other value, and so is inserted into partition p0.

Handling of NULL with LIST partitioning. A table that is partitioned by LIST admits NULL values if and only if one of its partitions is defined using that value-list that contains NULL. The converse of this is that a table partitioned by LIST which does not explicitly use NULL in a value list rejects rows resulting in a NULL value for the partitioning expression, as shown in this example:

```
mysql> CREATE TABLE ts1 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
```

```
    -> )
    -> PARTITION BY LIST(c1) (
    ->     PARTITION p0 VALUES IN (0, 3, 6),
    ->     PARTITION p1 VALUES IN (1, 4, 7),
    ->     PARTITION p2 VALUES IN (2, 5, 8)
    -> );
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO ts1 VALUES (9, 'mothra');
ERROR 1504 (HY000): Table has no partition for value 9

mysql> INSERT INTO ts1 VALUES (NULL, 'mothra');
ERROR 1504 (HY000): Table has no partition for value NULL
```

Only rows having a `c1` value between `0` and `8` inclusive can be inserted into `ts1`. `NULL` falls outside this range, just like the number `9`. We can create tables `ts2` and `ts3` having value lists containing `NULL`, as shown here:

```
mysql> CREATE TABLE ts2 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY LIST(c1) (
    ->     PARTITION p0 VALUES IN (0, 3, 6),
    ->     PARTITION p1 VALUES IN (1, 4, 7),
    ->     PARTITION p2 VALUES IN (2, 5, 8),
    ->     PARTITION p3 VALUES IN (NULL)
    -> );
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE ts3 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY LIST(c1) (
    ->     PARTITION p0 VALUES IN (0, 3, 6),
    ->     PARTITION p1 VALUES IN (1, 4, 7, NULL),
    ->     PARTITION p2 VALUES IN (2, 5, 8)
    -> );
Query OK, 0 rows affected (0.01 sec)
```

When defining value lists for partitioning, you can (and should) treat `NULL` just as you would any other value. For example, both `VALUES IN (NULL)` and `VALUES IN (1, 4, 7, NULL)` are valid, as are `VALUES IN (1, NULL, 4, 7)`, `VALUES IN (NULL, 1, 4, 7)`, and so on. You can insert a row having `NULL` for column `c1` into each of the tables `ts2` and `ts3`:

```
mysql> INSERT INTO ts2 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO ts3 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)
```

By issuing the appropriate query against `INFORMATION_SCHEMA.PARTITIONS`, you can determine which partitions were used to store the rows just inserted (we assume, as in the previous examples, that the partitioned tables were created in the `p` database):

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
    >     FROM INFORMATION_SCHEMA.PARTITIONS
    >     WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 'ts_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
```

```
| ts2         | p0              |           0 |               0 |             0 |
| ts2         | p1              |           0 |               0 |             0 |
| ts2         | p2              |           0 |               0 |             0 |
| ts2         | p3              |           1 |              20 |            20 |
| ts3         | p0              |           0 |               0 |             0 |
| ts3         | p1              |           1 |              20 |            20 |
| ts3         | p2              |           0 |               0 |             0 |
+-------------+-----------------+-------------+-----------------+---------------+
7 rows in set (0.01 sec)
```

As shown earlier in this section, you can also verify which partitions were used for storing the rows by deleting these partitions and then performing a `SELECT`.

Handling of NULL with HASH and KEY partitioning.   `NULL` is handled somewhat differently for tables partitioned by `HASH` or `KEY`. In these cases, any partition expression that yields a `NULL` value is treated as though its return value were zero. We can verify this behavior by examining the effects on the file system of creating a table partitioned by `HASH` and populating it with a record containing appropriate values. Suppose that you have a table `th` (also in the `p` database) created using the following statement:

```
mysql> CREATE TABLE th (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY HASH(c1)
    -> PARTITIONS 2;
Query OK, 0 rows affected (0.00 sec)
```

The partitions belonging to this table can be viewed using the query shown here:

```
mysql> SELECT TABLE_NAME,PARTITION_NAME,TABLE_ROWS,AVG_ROW_LENGTH,DATA_LENGTH
    >     FROM INFORMATION_SCHEMA.PARTITIONS
    >     WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME ='th';
+------------+-----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME  | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+-----------------+------------+----------------+-------------+
| th         | p0              |          0 |              0 |           0 |
| th         | p1              |          0 |              0 |           0 |
+------------+-----------------+------------+----------------+-------------+
2 rows in set (0.00 sec)
```

Note that `TABLE_ROWS` for each partition is 0. Now insert two rows into `th` whose `c1` column values are `NULL` and 0, and verify that these rows were inserted, as shown here:

```
mysql> INSERT INTO th VALUES (NULL, 'mothra'), (0, 'gigan');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM th;
+------+---------+
| c1   | c2      |
+------+---------+
| NULL | mothra  |
+------+---------+
|    0 | gigan   |
+------+---------+
2 rows in set (0.01 sec)
```

Recall that for any integer N, the value of `NULL MOD` N is always `NULL`. For tables that are partitioned by `HASH` or `KEY`, this result is treated for determining the correct partition as `0`. Checking the `INFORMATION_SCHEMA.PARTITIONS` table once again, we can see that both rows were inserted into partition `p0`:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
    >    FROM INFORMATION_SCHEMA.PARTITIONS
    >    WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME ='th';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| th         | p0             |          2 |             20 |          20 |
| th         | p1             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
2 rows in set (0.00 sec)
```

If you repeat this example using `PARTITION BY KEY` in place of `PARTITION BY HASH` in the definition of the table, you can verify easily that `NULL` is also treated like 0 for this type of partitioning.

18.3 Partition Management

MySQL 5.1 provides a number of ways to modify partitioned tables. It is possible to add, drop, redefine, merge, or split existing partitions. All of these actions can be carried out using the partitioning extensions to the `ALTER TABLE` statement Section 13.1.7, "ALTER TABLE Syntax". There are also ways to obtain information about partitioned tables and partitions. We discuss these topics in the sections that follow.

- For information about partition management in tables partitioned by `RANGE` or `LIST`, see Section 18.3.1, "Management of RANGE and LIST Partitions".

- For a discussion of managing `HASH` and `KEY` partitions, see Section 18.3.2, "Management of HASH and KEY Partitions".

- See Section 18.3.4, "Obtaining Information About Partitions", for a discussion of mechanisms provided in MySQL 5.1 for obtaining information about partitioned tables and partitions.

- For a discussion of performing maintenance operations on partitions, see Section 18.3.3, "Maintenance of Partitions".

> **Note**
>
> In MySQL 5.1, all partitions of a partitioned table must have the same number of subpartitions, and it is not possible to change the subpartitioning once the table has been created.

The statement `ALTER TABLE ... PARTITION BY ...` is available and is functional beginning with MySQL 5.1.6; previously in MySQL 5.1, this was accepted as valid syntax, but the statement did nothing.

To change a table's partitioning scheme, it is necessary only to use the `ALTER TABLE` statement with a `partition_options` clause. This clause has the same syntax as that as used with `CREATE TABLE` for creating a partitioned table, and always begins with the keywords `PARTITION BY`. Suppose that you have a table partitioned by range using the following `CREATE TABLE` statement:

```
CREATE TABLE trb3 (id INT, name VARCHAR(50), purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990),
        PARTITION p1 VALUES LESS THAN (1995),
        PARTITION p2 VALUES LESS THAN (2000),
        PARTITION p3 VALUES LESS THAN (2005)
    );
```

To repartition this table so that it is partitioned by key into two partitions using the `id` column value as the basis for the key, you can use this statement:

```
ALTER TABLE trb3 PARTITION BY KEY(id) PARTITIONS 2;
```

This has the same effect on the structure of the table as dropping the table and re-creating it using `CREATE TABLE trb3 PARTITION BY KEY(id) PARTITIONS 2;`.

In MySQL 5.1.7 and earlier MySQL 5.1 releases, `ALTER TABLE ... ENGINE = ...` removed all partitioning from the affected table. Beginning with MySQL 5.1.8, this statement changes only the storage engine used by the table, and leaves the table's partitioning scheme intact. As of MySQL 5.1.8, use `ALTER TABLE ... REMOVE PARTITIONING` to remove a table's partitioning. See Section 13.1.7, "ALTER TABLE Syntax".

> ⚠️ **Important**
>
> Only a single `PARTITION BY`, `ADD PARTITION`, `DROP PARTITION`, `REORGANIZE PARTITION`, or `COALESCE PARTITION` clause can be used in a given `ALTER TABLE` statement. If you (for example) wish to drop a partition and reorganize a table's remaining partitions, you must do so in two separate `ALTER TABLE` statements (one using `DROP PARTITION` and then a second one using `REORGANIZE PARTITIONS`).

18.3.1 Management of RANGE and LIST Partitions

Range and list partitions are very similar with regard to how the adding and dropping of partitions are handled. For this reason we discuss the management of both sorts of partitioning in this section. For information about working with tables that are partitioned by hash or key, see Section 18.3.2, "Management of HASH and KEY Partitions". Dropping a `RANGE` or `LIST` partition is more straightforward than adding one, so we discuss this first.

Dropping a partition from a table that is partitioned by either `RANGE` or by `LIST` can be accomplished using the `ALTER TABLE` statement with a `DROP PARTITION` clause. Here is a very basic example, which supposes that you have already created a table which is partitioned by range and then populated with 10 records using the following `CREATE TABLE` and `INSERT` statements:

```
mysql> CREATE TABLE tr (id INT, name VARCHAR(50), purchased DATE)
    ->     PARTITION BY RANGE( YEAR(purchased) ) (
    ->         PARTITION p0 VALUES LESS THAN (1990),
    ->         PARTITION p1 VALUES LESS THAN (1995),
    ->         PARTITION p2 VALUES LESS THAN (2000),
    ->         PARTITION p3 VALUES LESS THAN (2005)
    ->     );
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO tr VALUES
    ->     (1, 'desk organiser', '2003-10-15'),
    ->     (2, 'CD player', '1993-11-05'),
    ->     (3, 'TV set', '1996-03-10'),
    ->     (4, 'bookcase', '1982-01-10'),
    ->     (5, 'exercise bike', '2004-05-09'),
    ->     (6, 'sofa', '1987-06-05'),
    ->     (7, 'popcorn maker', '2001-11-22'),
    ->     (8, 'aquarium', '1992-08-04'),
    ->     (9, 'study desk', '1984-09-16'),
    ->     (10, 'lava lamp', '1998-12-25');
Query OK, 10 rows affected (0.01 sec)
```

You can see which items should have been inserted into partition `p2` as shown here:

```
mysql> SELECT * FROM tr
    -> WHERE purchased BETWEEN '1995-01-01' AND '1999-12-31';
+------+-----------+------------+
| id   | name      | purchased  |
```

```
+------+-----------+------------+
|    3 | TV set    | 1996-03-10 |
|   10 | lava lamp | 1998-12-25 |
+------+-----------+------------+
2 rows in set (0.00 sec)
```

To drop the partition named `p2`, execute the following command:

```
mysql> ALTER TABLE tr DROP PARTITION p2;
Query OK, 0 rows affected (0.03 sec)
```

Note

The `NDBCLUSTER` storage engine does not support `ALTER TABLE ... DROP PARTITION`. It does, however, support the other partitioning-related extensions to `ALTER TABLE` that are described in this chapter.

It is very important to remember that, *when you drop a partition, you also delete all the data that was stored in that partition*. You can see that this is the case by re-running the previous `SELECT` query:

```
mysql> SELECT * FROM tr WHERE purchased
    -> BETWEEN '1995-01-01' AND '1999-12-31';
Empty set (0.00 sec)
```

Because of this, the requirement was added in MySQL 5.1.10 that you have the `DROP` privilege for a table before you can execute `ALTER TABLE ... DROP PARTITION` on that table.

If you wish to drop all data from all partitions while preserving the table definition and its partitioning scheme, use the `TRUNCATE TABLE` statement. (See Section 13.1.34, "TRUNCATE TABLE Syntax".)

If you intend to change the partitioning of a table *without* losing data, use `ALTER TABLE ... REORGANIZE PARTITION` instead. See below or in Section 13.1.7, "ALTER TABLE Syntax", for information about `REORGANIZE PARTITION`.

If you now execute a `SHOW CREATE TABLE` statement, you can see how the partitioning makeup of the table has been changed:

```
mysql> SHOW CREATE TABLE tr\G
*************************** 1. row ***************************
       Table: tr
Create Table: CREATE TABLE `tr` (
  `id` int(11) default NULL,
  `name` varchar(50) default NULL,
  `purchased` date default NULL
) ENGINE=MyISAM DEFAULT CHARSET=latin1
PARTITION BY RANGE ( YEAR(purchased) ) (
  PARTITION p0 VALUES LESS THAN (1990) ENGINE = MyISAM,
  PARTITION p1 VALUES LESS THAN (1995) ENGINE = MyISAM,
  PARTITION p3 VALUES LESS THAN (2005) ENGINE = MyISAM
)
1 row in set (0.01 sec)
```

When you insert new rows into the changed table with `purchased` column values between `'1995-01-01'` and `'2004-12-31'` inclusive, those rows will be stored in partition `p3`. You can verify this as follows:

```
mysql> INSERT INTO tr VALUES (11, 'pencil holder', '1995-07-12');
Query OK, 1 row affected (0.00 sec)
```

```
mysql> SELECT * FROM tr WHERE purchased
    -> BETWEEN '1995-01-01' AND '2004-12-31';
+------+----------------+------------+
| id   | name           | purchased  |
+------+----------------+------------+
|   11 | pencil holder  | 1995-07-12 |
|    1 | desk organiser | 2003-10-15 |
|    5 | exercise bike  | 2004-05-09 |
|    7 | popcorn maker  | 2001-11-22 |
+------+----------------+------------+
4 rows in set (0.00 sec)

mysql> ALTER TABLE tr DROP PARTITION p3;
Query OK, 0 rows affected (0.03 sec)

mysql> SELECT * FROM tr WHERE purchased
    -> BETWEEN '1995-01-01' AND '2004-12-31';
Empty set (0.00 sec)
```

Note that the number of rows dropped from the table as a result of ALTER TABLE ... DROP PARTITION is not reported by the server as it would be by the equivalent DELETE query.

Dropping LIST partitions uses exactly the same ALTER TABLE ... DROP PARTITION syntax as used for dropping RANGE partitions. However, there is one important difference in the effect this has on your use of the table afterward: You can no longer insert into the table any rows having any of the values that were included in the value list defining the deleted partition. (See Section 18.2.2, "LIST Partitioning", for an example.)

To add a new range or list partition to a previously partitioned table, use the ALTER TABLE ... ADD PARTITION statement. For tables which are partitioned by RANGE, this can be used to add a new range to the end of the list of existing partitions. Suppose that you have a partitioned table containing membership data for your organization, which is defined as follows:

```
CREATE TABLE members (
    id INT,
    fname VARCHAR(25),
    lname VARCHAR(25),
    dob DATE
)
PARTITION BY RANGE( YEAR(dob) ) (
    PARTITION p0 VALUES LESS THAN (1970),
    PARTITION p1 VALUES LESS THAN (1980),
    PARTITION p2 VALUES LESS THAN (1990)
);
```

Suppose further that the minimum age for members is 16. As the calendar approaches the end of 2005, you realize that you will soon be admitting members who were born in 1990 (and later in years to come). You can modify the members table to accommodate new members born in the years 1990 to 1999 as shown here:

```
ALTER TABLE members ADD PARTITION (PARTITION p3 VALUES LESS THAN (2000));
```

With tables that are partitioned by range, you can use ADD PARTITION to add new partitions to the high end of the partitions list only. Trying to add a new partition in this manner between or before existing partitions results in an error as shown here:

```
mysql> ALTER TABLE members
    >     ADD PARTITION (
    >     PARTITION n VALUES LESS THAN (1960));
ERROR 1463 (HY000): VALUES LESS THAN value must be strictly »
```

```
     increasing for each partition
```

You can work around this problem by reorganizing the first partition into two new ones that split the range between them, like this:

```
ALTER TABLE members
    REORGANIZE PARTITION p0 INTO (
        PARTITION n0 VALUES LESS THAN (1960),
        PARTITION n1 VALUES LESS THAN (1970)
);
```

Using SHOW CREATE TABLE you can see that the ALTER TABLE statement has had the desired effect:

```
mysql> SHOW CREATE TABLE members\G
*************************** 1. row ***************************
       Table: members
Create Table: CREATE TABLE `members` (
  `id` int(11) DEFAULT NULL,
  `fname` varchar(25) DEFAULT NULL,
  `lname` varchar(25) DEFAULT NULL,
  `dob` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY RANGE ( YEAR(dob))
(PARTITION n0 VALUES LESS THAN (1960) ENGINE = MyISAM,
 PARTITION n1 VALUES LESS THAN (1970) ENGINE = MyISAM,
 PARTITION p1 VALUES LESS THAN (1980) ENGINE = MyISAM,
 PARTITION p2 VALUES LESS THAN (1990) ENGINE = MyISAM,
 PARTITION p3 VALUES LESS THAN (2000) ENGINE = MyISAM) */
1 row in set (0.00 sec)
```

See also Section 13.1.7.1, "ALTER TABLE Partition Operations".

You can also use ALTER TABLE ... ADD PARTITION to add new partitions to a table that is partitioned by LIST. Suppose a table tt is defined using the following CREATE TABLE statement:

```
CREATE TABLE tt (
    id INT,
    data INT
)
PARTITION BY LIST(data) (
    PARTITION p0 VALUES IN (5, 10, 15),
    PARTITION p1 VALUES IN (6, 12, 18)
);
```

You can add a new partition in which to store rows having the data column values 7, 14, and 21 as shown:

```
ALTER TABLE tt ADD PARTITION (PARTITION p2 VALUES IN (7, 14, 21));
```

Note that you *cannot* add a new LIST partition encompassing any values that are already included in the value list of an existing partition. If you attempt to do so, an error will result:

```
mysql> ALTER TABLE tt ADD PARTITION
    >       (PARTITION np VALUES IN (4, 8, 12));
ERROR 1465 (HY000): Multiple definition of same constant »
                    in list partitioning
```

Because any rows with the data column value 12 have already been assigned to partition p1, you cannot create a new partition on table tt that includes 12 in its value list. To accomplish this, you could drop p1, and add np and then a new p1 with a modified definition. However, as discussed earlier, this would

result in the loss of all data stored in `p1`—and it is often the case that this is not what you really want to do. Another solution might appear to be to make a copy of the table with the new partitioning and to copy the data into it using `CREATE TABLE ... SELECT ...`, then drop the old table and rename the new one, but this could be very time-consuming when dealing with a large amounts of data. This also might not be feasible in situations where high availability is a requirement.

Beginning with MySQL 5.1.6, you can add multiple partitions in a single `ALTER TABLE ... ADD PARTITION` statement as shown here:

```
CREATE TABLE employees (
  id INT NOT NULL,
  fname VARCHAR(50) NOT NULL,
  lname VARCHAR(50) NOT NULL,
  hired DATE NOT NULL
)
PARTITION BY RANGE( YEAR(hired) ) (
  PARTITION p1 VALUES LESS THAN (1991),
  PARTITION p2 VALUES LESS THAN (1996),
  PARTITION p3 VALUES LESS THAN (2001),
  PARTITION p4 VALUES LESS THAN (2005)
);

ALTER TABLE employees ADD PARTITION (
    PARTITION p5 VALUES LESS THAN (2010),
    PARTITION p6 VALUES LESS THAN MAXVALUE
);
```

Fortunately, MySQL's partitioning implementation provides ways to redefine partitions without losing data. Let us look first at a couple of simple examples involving `RANGE` partitioning. Recall the `members` table which is now defined as shown here:

```
mysql> SHOW CREATE TABLE members\G
*************************** 1. row ***************************
       Table: members
Create Table: CREATE TABLE `members` (
  `id` int(11) default NULL,
  `fname` varchar(25) default NULL,
  `lname` varchar(25) default NULL,
  `dob` date default NULL
) ENGINE=MyISAM DEFAULT CHARSET=latin1
PARTITION BY RANGE ( YEAR(dob) ) (
  PARTITION p0 VALUES LESS THAN (1970) ENGINE = MyISAM,
  PARTITION p1 VALUES LESS THAN (1980) ENGINE = MyISAM,
  PARTITION p2 VALUES LESS THAN (1990) ENGINE = MyISAM.
  PARTITION p3 VALUES LESS THAN (2000) ENGINE = MyISAM
)
```

Suppose that you would like to move all rows representing members born before 1960 into a separate partition. As we have already seen, this cannot be done using `ALTER TABLE ... ADD PARTITION`. However, you can use another partition-related extension to `ALTER TABLE` to accomplish this:

```
ALTER TABLE members REORGANIZE PARTITION p0 INTO (
    PARTITION s0 VALUES LESS THAN (1960),
    PARTITION s1 VALUES LESS THAN (1970)
);
```

In effect, this command splits partition `p0` into two new partitions `s0` and `s1`. It also moves the data that was stored in `p0` into the new partitions according to the rules embodied in the two `PARTITION ... VALUES ...` clauses, so that `s0` contains only those records for which `YEAR(dob)` is less than 1960 and `s1` contains those rows in which `YEAR(dob)` is greater than or equal to 1960 but less than 1970.

A `REORGANIZE PARTITION` clause may also be used for merging adjacent partitions. You can return the `members` table to its previous partitioning as shown here:

```
ALTER TABLE members REORGANIZE PARTITION s0,s1 INTO (
    PARTITION p0 VALUES LESS THAN (1970)
);
```

No data is lost in splitting or merging partitions using `REORGANIZE PARTITION`. In executing the above statement, MySQL moves all of the records that were stored in partitions `s0` and `s1` into partition `p0`.

The general syntax for `REORGANIZE PARTITION` is shown here:

```
ALTER TABLE tbl_name
    REORGANIZE PARTITION partition_list
    INTO (partition_definitions);
```

Here, `tbl_name` is the name of the partitioned table, and `partition_list` is a comma-separated list of names of one or more existing partitions to be changed. `partition_definitions` is a comma-separated list of new partition definitions, which follow the same rules as for the `partition_definitions` list used in `CREATE TABLE` (see Section 13.1.17, "CREATE TABLE Syntax"). It should be noted that you are not limited to merging several partitions into one, or to splitting one partition into many, when using `REORGANIZE PARTITION`. For example, you can reorganize all four partitions of the `members` table into two, as follows:

```
ALTER TABLE members REORGANIZE PARTITION p0,p1,p2,p3 INTO (
    PARTITION m0 VALUES LESS THAN (1980),
    PARTITION m1 VALUES LESS THAN (2000)
);
```

You can also use `REORGANIZE PARTITION` with tables that are partitioned by `LIST`. Let us return to the problem of adding a new partition to the list-partitioned `tt` table and failing because the new partition had a value that was already present in the value-list of one of the existing partitions. We can handle this by adding a partition that contains only nonconflicting values, and then reorganizing the new partition and the existing one so that the value which was stored in the existing one is now moved to the new one:

```
ALTER TABLE tt ADD PARTITION (PARTITION np VALUES IN (4, 8));
ALTER TABLE tt REORGANIZE PARTITION p1,np INTO (
    PARTITION p1 VALUES IN (6, 18),
    PARTITION np VALUES in (4, 8, 12)
);
```

Here are some key points to keep in mind when using `ALTER TABLE ... REORGANIZE PARTITION` to repartition tables that are partitioned by `RANGE` or `LIST`:

• The `PARTITION` clauses used to determine the new partitioning scheme are subject to the same rules as those used with a `CREATE TABLE` statement.

  Most importantly, you should remember that the new partitioning scheme cannot have any overlapping ranges (applies to tables partitioned by `RANGE`) or sets of values (when reorganizing tables partitioned by `LIST`).

> **Note**
>
> Prior to MySQL 5.1.4, you could not reuse the names of existing partitions in the `INTO` clause, even when those partitions were being dropped or redefined. See the Release Notes for MySQL 5.1.4 for more information.

- The combination of partitions in the *partition_definitions* list should account for the same range or set of values overall as the combined partitions named in the *partition_list*.

  For instance, in the `members` table used as an example in this section, partitions `p1` and `p2` together cover the years 1980 through 1999. Therefore, any reorganization of these two partitions should cover the same range of years overall.

- For tables partitioned by `RANGE`, you can reorganize only adjacent partitions; you cannot skip over range partitions.

  For instance, you could not reorganize the `members` table used as an example in this section using a statement beginning with `ALTER TABLE members REORGANIZE PARTITION p0,p2 INTO ...` because `p0` covers the years prior to 1970 and `p2` the years from 1990 through 1999 inclusive, and thus the two are not adjacent partitions.

- You cannot use `REORGANIZE PARTITION` to change the table's partitioning type; that is, you cannot (for example) change `RANGE` partitions to `HASH` partitions or vice versa. You also cannot use this command to change the partitioning expression or column. To accomplish either of these tasks without dropping and re-creating the table, you can use `ALTER TABLE ... PARTITION BY ....` For example:

```
ALTER TABLE members
    PARTITION BY HASH( YEAR(dob) )
    PARTITIONS 8;
```

18.3.2 Management of HASH and KEY Partitions

Tables which are partitioned by hash or by key are very similar to one another with regard to making changes in a partitioning setup, and both differ in a number of ways from tables which have been partitioned by range or list. For that reason, this section addresses the modification of tables partitioned by hash or by key only. For a discussion of adding and dropping of partitions of tables that are partitioned by range or list, see Section 18.3.1, "Management of RANGE and LIST Partitions".

You cannot drop partitions from tables that are partitioned by `HASH` or `KEY` in the same way that you can from tables that are partitioned by `RANGE` or `LIST`. However, you can merge `HASH` or `KEY` partitions using the `ALTER TABLE ... COALESCE PARTITION` statement. Suppose that you have a table containing data about clients, which is divided into twelve partitions. The `clients` table is defined as shown here:

```
CREATE TABLE clients (
    id INT,
    fname VARCHAR(30),
    lname VARCHAR(30),
    signed DATE
)
PARTITION BY HASH( MONTH(signed) )
PARTITIONS 12;
```

To reduce the number of partitions from twelve to eight, execute the following `ALTER TABLE` command:

```
mysql> ALTER TABLE clients COALESCE PARTITION 4;
Query OK, 0 rows affected (0.02 sec)
```

`COALESCE` works equally well with tables that are partitioned by `HASH`, `KEY`, `LINEAR HASH`, or `LINEAR KEY`. Here is an example similar to the previous one, differing only in that the table is partitioned by `LINEAR KEY`:

```
mysql> CREATE TABLE clients_lk (
    ->      id INT,
    ->      fname VARCHAR(30),
    ->      lname VARCHAR(30),
    ->      signed DATE
    -> )
    -> PARTITION BY LINEAR KEY(signed)
    -> PARTITIONS 12;
Query OK, 0 rows affected (0.03 sec)

mysql> ALTER TABLE clients_lk COALESCE PARTITION 4;
Query OK, 0 rows affected (0.06 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

Note that the number following `COALESCE PARTITION` is the number of partitions to merge into the remainder—in other words, it is the number of partitions to remove from the table.

If you attempt to remove more partitions than the table has, the result is an error like the one shown:

```
mysql> ALTER TABLE clients COALESCE PARTITION 18;
ERROR 1478 (HY000): Cannot remove all partitions, use DROP TABLE instead
```

To increase the number of partitions for the `clients` table from 12 to 18. use `ALTER TABLE ... ADD PARTITION` as shown here:

```
ALTER TABLE clients ADD PARTITION PARTITIONS 6;
```

18.3.3 Maintenance of Partitions

A number of table and partition maintenance tasks can be carried out using SQL statements intended for such purposes on partitioned tables in MySQL 5.1.

Table maintenance of partitioned tables can be accomplished using the statements `CHECK TABLE`, `OPTIMIZE TABLE`, `ANALYZE TABLE`, and `REPAIR TABLE`, which are supported for partitioned tables as of MySQL 5.1.27.

Also beginning with MySQL 5.1.27, you can use a number of extensions to `ALTER TABLE` for performing operations of this type on one or more partitions directly, as described in the following list:

- **Rebuilding partitions.**   Rebuilds the partition; this has the same effect as dropping all records stored in the partition, then reinserting them. This can be useful for purposes of defragmentation.

  Example:

  ```
  ALTER TABLE t1 REBUILD PARTITION p0, p1;
  ```

- **Optimizing partitions.**   If you have deleted a large number of rows from a partition or if you have made many changes to a partitioned table with variable-length rows (that is, having `VARCHAR`, `BLOB`, or `TEXT` columns), you can use `ALTER TABLE ... OPTIMIZE PARTITION` to reclaim any unused space and to defragment the partition data file.

  Example:

  ```
  ALTER TABLE t1 OPTIMIZE PARTITION p0, p1;
  ```

  Using `OPTIMIZE PARTITION` on a given partition is equivalent to running `CHECK PARTITION`, `ANALYZE PARTITION`, and `REPAIR PARTITION` on that partition.

Some MySQL storage engines, including `InnoDB`, do not support per-partition optimization; in these cases, `ALTER TABLE ... OPTIMIZE PARTITION` rebuilds the entire table. In MySQL 5.1.68 and later, running this statement on such a table causes the entire table to rebuilt and analyzed, and an appropriate warning to be issued. (Bug #11751825, Bug #42822) Use `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION` instead, to avoid this issue.

- **Analyzing partitions.** This reads and stores the key distributions for partitions.

  Example:

  ```
  ALTER TABLE t1 ANALYZE PARTITION p3;
  ```

- **Repairing partitions.** This repairs corrupted partitions.

  Example:

  ```
  ALTER TABLE t1 REPAIR PARTITION p0,p1;
  ```

- **Checking partitions.** You can check partitions for errors in much the same way that you can use `CHECK TABLE` with nonpartitioned tables.

  Example:

  ```
  ALTER TABLE trb3 CHECK PARTITION p1;
  ```

  This command will tell you if the data or indexes in partition `p1` of table `t1` are corrupted. If this is the case, use `ALTER TABLE ... REPAIR PARTITION` to repair the partition.

Each of the statements in the list just shown also supports the keyword `ALL` in place of the list of partition names. Using `ALL` causes the statement to act on all partitions in the table.

> **Note**
>
> The statements `ALTER TABLE ... ANALYZE PARTITION`, `ALTER TABLE ... CHECK PARTITION`, `ALTER TABLE ... OPTIMIZE PARTITION`, and `ALTER TABLE ... REPAIR PARTITION` were originally introduced in MySQL 5.1.5, but did not work properly and were disabled in MySQL 5.1.24. They were re-introduced in MySQL 5.1.27. (Bug #20129) The use of these partitioning-specific `ALTER TABLE` statements with tables which are not partitioned is not supported; beginning with MySQL 5.1.31, it is expressly not permitted. (Bug #39434)
>
> `ALTER TABLE ... REBUILD PARTITION` was also introduced in MySQL 5.1.5.

The use of `mysqlcheck` and `myisamchk` is not supported with partitioned tables.

`ANALYZE`, `CHECK`, `OPTIMIZE`, `REBUILD`, `REPAIR`, and `TRUNCATE` operations are not supported for subpartitions.

18.3.4 Obtaining Information About Partitions

This section discusses obtaining information about existing partitions, which can be done in a number of ways. Methods of obtaining such information include the following:

- Using the `SHOW CREATE TABLE` statement to view the partitioning clauses used in creating a partitioned table.

- Using the `SHOW TABLE STATUS` statement to determine whether a table is partitioned.

- Querying the `INFORMATION_SCHEMA.PARTITIONS` table.

- Using the statement `EXPLAIN PARTITIONS SELECT` to see which partitions are used by a given `SELECT`.

As discussed elsewhere in this chapter, `SHOW CREATE TABLE` includes in its output the `PARTITION BY` clause used to create a partitioned table. For example:

```
mysql> SHOW CREATE TABLE trb3\G
*************************** 1. row ***************************
       Table: trb3
Create Table: CREATE TABLE `trb3` (
  `id` int(11) default NULL,
  `name` varchar(50) default NULL,
  `purchased` date default NULL
) ENGINE=MyISAM DEFAULT CHARSET=latin1
PARTITION BY RANGE (YEAR(purchased)) (
  PARTITION p0 VALUES LESS THAN (1990) ENGINE = MyISAM,
  PARTITION p1 VALUES LESS THAN (1995) ENGINE = MyISAM,
  PARTITION p2 VALUES LESS THAN (2000) ENGINE = MyISAM,
  PARTITION p3 VALUES LESS THAN (2005) ENGINE = MyISAM
)
1 row in set (0.00 sec)
```

Note

In early MySQL 5.1 releases, the `PARTITIONS` clause was not shown for tables partitioned by `HASH` or `KEY`. This issue was fixed in MySQL 5.1.6.

`SHOW TABLE STATUS` works with partitioned tables. Beginning with MySQL 5.1.9, its output is the same as that for nonpartitioned tables, except that the `Create_options` column contains the string `partitioned`. In MySQL 5.1.8 and earlier, the `Engine` column always contained the value `PARTITION`; beginning with MySQL 5.1.9, this column contains the name of the storage engine used by all partitions of the table. (See Section 13.7.5.38, "SHOW TABLE STATUS Syntax", for more information about this statement.)

You can also obtain information about partitions from `INFORMATION_SCHEMA`, which contains a `PARTITIONS` table. See Section 20.11, "The INFORMATION_SCHEMA PARTITIONS Table".

Beginning with MySQL 5.1.5, it is possible to determine which partitions of a partitioned table are involved in a given `SELECT` query using `EXPLAIN PARTITIONS`. The `PARTITIONS` keyword adds a `partitions` column to the output of `EXPLAIN` listing the partitions from which records would be matched by the query.

Suppose that you have a table `trb1` created and populated as follows:

```
CREATE TABLE trb1 (id INT, name VARCHAR(50), purchased DATE)
    PARTITION BY RANGE(id)
    (
        PARTITION p0 VALUES LESS THAN (3),
        PARTITION p1 VALUES LESS THAN (7),
        PARTITION p2 VALUES LESS THAN (9),
        PARTITION p3 VALUES LESS THAN (11)
    );

INSERT INTO trb1 VALUES
    (1, 'desk organiser', '2003-10-15'),
    (2, 'CD player', '1993-11-05'),
    (3, 'TV set', '1996-03-10'),
    (4, 'bookcase', '1982-01-10'),
```

```
    (5, 'exercise bike', '2004-05-09'),
    (6, 'sofa', '1987-06-05'),
    (7, 'popcorn maker', '2001-11-22'),
    (8, 'aquarium', '1992-08-04'),
    (9, 'study desk', '1984-09-16'),
    (10, 'lava lamp', '1998-12-25');
```

You can see which partitions are used in a query such as `SELECT * FROM trb1;`, as shown here:

```
mysql> EXPLAIN PARTITIONS SELECT * FROM trb1\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: trb1
   partitions: p0,p1,p2,p3
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 10
        Extra: Using filesort
```

In this case, all four partitions are searched. However, when a limiting condition making use of the partitioning key is added to the query, you can see that only those partitions containing matching values are scanned, as shown here:

```
mysql> EXPLAIN PARTITIONS SELECT * FROM trb1 WHERE id < 5\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: trb1
   partitions: p0,p1
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 10
        Extra: Using where
```

`EXPLAIN PARTITIONS` provides information about keys used and possible keys, just as with the standard `EXPLAIN SELECT` statement:

```
mysql> ALTER TABLE trb1 ADD PRIMARY KEY (id);
Query OK, 10 rows affected (0.03 sec)
Records: 10  Duplicates: 0  Warnings: 0

mysql> EXPLAIN PARTITIONS SELECT * FROM trb1 WHERE id < 5\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: trb1
   partitions: p0,p1
         type: range
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: NULL
         rows: 7
        Extra: Using where
```

You should take note of the following restrictions and limitations on `EXPLAIN PARTITIONS`:

- You cannot use the `PARTITIONS` and `EXTENDED` keywords together in the same `EXPLAIN ... SELECT` statement. Attempting to do so produces a syntax error.

- If `EXPLAIN PARTITIONS` is used to examine a query against a nonpartitioned table, no error is produced, but the value of the `partitions` column is always `NULL`.

As of MySQL 5.1.28, the `rows` column of `EXPLAIN PARTITIONS` output always displays the total number of rows in the table. Previously, this was the number of matching rows (see Bug #35745).

See also Section 13.8.2, "EXPLAIN Syntax".

18.4 Partition Pruning

This section discusses an optimization known as *partition pruning*, which was implemented for partitioned tables in MySQL 5.1.6. The core concept behind partition pruning is relatively simple, and can be described as "Do not scan partitions where there can be no matching values". Suppose that you have a partitioned table `t1` defined by this statement:

```
CREATE TABLE t1 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY RANGE( region_code ) (
    PARTITION p0 VALUES LESS THAN (64),
    PARTITION p1 VALUES LESS THAN (128),
    PARTITION p2 VALUES LESS THAN (192),
    PARTITION p3 VALUES LESS THAN MAXVALUE
);
```

Consider the case where you wish to obtain results from a query such as this one:

```
SELECT fname, lname, region_code, dob
    FROM t1
    WHERE region_code > 125 AND region_code < 130;
```

It is easy to see that none of the rows which ought to be returned will be in either of the partitions `p0` or `p3`; that is, we need to search only in partitions `p1` and `p2` to find matching rows. By doing so, it is possible to expend much less time and effort in finding matching rows than would be required to scan all partitions in the table. This "cutting away" of unneeded partitions is known as *pruning*. When the optimizer can make use of partition pruning in performing a query, execution of the query can be an order of magnitude faster than the same query against a nonpartitioned table containing the same column definitions and data.

> **Note**
>
> When pruning is performed on a partitioned `MyISAM` table, all partitions are opened, whether or not they are examined, due to the design of the `MyISAM` storage engine. This means that you must have a sufficient number of file descriptors available to cover all partitions of the table. See MyISAM and partition file descriptor usage.
>
> This limitation does not apply to partitioned tables using other MySQL storage engines such as `InnoDB`.

The query optimizer can perform pruning whenever a `WHERE` condition can be reduced to either one of the following two cases:

- *partition_column = constant*

- *partition_column* IN (*constant1, constant2, ..., constantN*)

In the first case, the optimizer simply evaluates the partitioning expression for the value given, determines which partition contains that value, and scans only this partition. In many cases, the equal sign can be replaced with another arithmetic comparison, including <, >, <=, >=, and <>. Some queries using BETWEEN in the WHERE clause can also take advantage of partition pruning. See the examples later in this section.

In the second case, the optimizer evaluates the partitioning expression for each value in the list, creates a list of matching partitions, and then scans only the partitions in this partition list.

Pruning can also be applied to short ranges, which the optimizer can convert into equivalent lists of values. For instance, in the previous example, the WHERE clause can be converted to WHERE region_code IN (126, 127, 128, 129). Then the optimizer can determine that the first two values in the list are found in partition p1, the remaining two values in partition p2, and that the other partitions contain no relevant values and so do not need to be searched for matching rows.

This type of optimization can be applied whenever the partitioning expression consists of an equality or a range which can be reduced to a set of equalities, or when the partitioning expression represents an increasing or decreasing relationship. Pruning can also be applied for tables partitioned on a DATE or DATETIME column when the partitioning expression uses the YEAR() or TO_DAYS() function.

Suppose that table t2, defined as shown here, is partitioned on a DATE column:

```
CREATE TABLE t2 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY RANGE( YEAR(dob) ) (
    PARTITION d0 VALUES LESS THAN (1970),
    PARTITION d1 VALUES LESS THAN (1975),
    PARTITION d2 VALUES LESS THAN (1980),
    PARTITION d3 VALUES LESS THAN (1985),
    PARTITION d4 VALUES LESS THAN (1990),
    PARTITION d5 VALUES LESS THAN (2000),
    PARTITION d6 VALUES LESS THAN (2005),
    PARTITION d7 VALUES LESS THAN MAXVALUE
);
```

The following queries on t2 can make of use partition pruning:

```
SELECT * FROM t2 WHERE dob = '1982-06-23';

SELECT * FROM t2 WHERE dob BETWEEN '1991-02-15' AND '1997-04-25';

SELECT * FROM t2 WHERE dob >= '1984-06-21' AND dob <= '1999-06-21'
```

In the case of the last query, the optimizer can also act as follows:

1. *Find the partition containing the low end of the range*.

   YEAR('1984-06-21') yields the value 1984, which is found in partition d3.

2. *Find the partition containing the high end of the range*.

   YEAR('1999-06-21') evaluates to 1999, which is found in partition d5.

3. *Scan only these two partitions and any partitions that may lie between them*.

In this case, this means that only partitions `d3`, `d4`, and `d5` are scanned. The remaining partitions may be safely ignored (and are ignored).

> **Important**
>
> Invalid `DATE` and `DATETIME` values referenced in the `WHERE` clause of a query on a partitioned table are treated as `NULL`. This means that a query such as `SELECT * FROM partitioned_table WHERE date_column < '2008-12-00'` does not return any values (see Bug #40972).

So far, we have looked only at examples using `RANGE` partitioning, but pruning can be applied with other partitioning types as well.

Consider a table that is partitioned by `LIST`, where the partitioning expression is increasing or decreasing, such as the table `t3` shown here. (In this example, we assume for the sake of brevity that the `region_code` column is limited to values between 1 and 10 inclusive.)

```
CREATE TABLE t3 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY LIST(region_code) (
    PARTITION r0 VALUES IN (1, 3),
    PARTITION r1 VALUES IN (2, 5, 8),
    PARTITION r2 VALUES IN (4, 9),
    PARTITION r3 VALUES IN (6, 7, 10)
);
```

For a query such as `SELECT * FROM t3 WHERE region_code BETWEEN 1 AND 3`, the optimizer determines in which partitions the values 1, 2, and 3 are found (`r0` and `r1`) and skips the remaining ones (`r2` and `r3`).

For tables that are partitioned by `HASH` or `[LINEAR] KEY`, partition pruning is also possible in cases in which the `WHERE` clause uses a simple `=` relation against a column used in the partitioning expression. Consider a table created like this:

```
CREATE TABLE t4 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY KEY(region_code)
PARTITIONS 8;
```

Any query, such as this one, that compares a column value with a constant can be pruned:

```
SELECT * FROM t4 WHERE region_code = 7;
```

Pruning can also be employed for short ranges, because the optimizer can turn such conditions into `IN` relations. For example, using the same table `t4` as defined previously, queries such as these can be pruned:

```
SELECT * FROM t4 WHERE region_code > 2 AND region_code < 6;
```

```
SELECT * FROM t4 WHERE region_code BETWEEN 3 AND 5;
```

In both these cases, the `WHERE` clause is transformed by the optimizer into `WHERE region_code IN (3, 4, 5)`.

> **Important**
>
> This optimization is used only if the range size is smaller than the number of partitions. Consider this query:
>
> ```
> SELECT * FROM t4 WHERE region_code BETWEEN 4 AND 12;
> ```
>
> The range in the `WHERE` clause covers 9 values (4, 5, 6, 7, 8, 9, 10, 11, 12), but `t4` has only 8 partitions. This means that the previous query cannot be pruned.

When a table is partitioned by `HASH` or `[LINEAR] KEY`, pruning can be used only on integer columns. For example, this query on table `t4` cannot use pruning because `dob` is a `DATE` column:

```
SELECT * FROM t4 WHERE dob >= '2001-04-14' AND dob <= '2005-10-15';
```

However, if the table stores year values in an `INT` column, then a query having `WHERE year_col >= 2001 AND year_col <= 2005` can be pruned.

For a table that is partitioned by `KEY`, has a composite primary key, and uses a composite partitioning key, it is possible to perform pruning for queries meeting the following two criteria:

- The query must have a `WHERE` clause of the form `pkcol1 = c1 AND pkcol2 = c2 AND ... pkcolN = cN`, where `pkcol1` ... `pkcolN` are the partitioning key columns and `c1` ... `cN` are constant values.

- All columns of the partitioning key must be referenced in the `WHERE` clause.

For example, suppose a table named `cities` is created as shown here:

```
CREATE TABLE cities (
    id INT NOT NULL AUTO_INCREMENT,
    name CHAR(35) NOT NULL DEFAULT '',
    country_code CHAR(3) NOT NULL DEFAULT '',
    district CHAR(20) NOT NULL DEFAULT '',
    population INT NOT NULL DEFAULT 0,
    PRIMARY KEY (ID, Population)
)
PARTITION BY KEY ()
PARTITIONS 8;
```

(Note that `PARTITION BY KEY()` is equivalent in this case to `PARTITION BY KEY(id, population)`.)

Only a query that references both the `id` and `population` columns of this table can be pruned, as shown here:

```
mysql> SELECT * FROM cities WHERE id = 101;
+-----+------------+--------------+----------+------------+
| id  | name       | country_code | district | population |
+-----+------------+--------------+----------+------------+
| 101 | Godoy Cruz | ARG          | Mendoza  |     206998 |
+-----+------------+--------------+----------+------------+
1 row in set (0.00 sec)
```

```
mysql> SELECT * FROM cities WHERE population = 206998;
+-----+------------+--------------+----------+------------+
| id  | name       | country_code | district | population |
+-----+------------+--------------+----------+------------+
| 101 | Godoy Cruz | ARG          | Mendoza  |     206998 |
+-----+------------+--------------+----------+------------+
1 row in set (0.00 sec)

mysql> EXPLAIN PARTITIONS SELECT * FROM cities WHERE id = 101\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: cities
   partitions: p0,p1,p2,p3,p4,p5,p6,p7
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: const
         rows: 6
        Extra:
1 row in set (0.00 sec)

mysql> EXPLAIN PARTITIONS SELECT * FROM cities WHERE population = 206998\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: cities
   partitions: p0,p1,p2,p3,p4,p5,p6,p7
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 1973
        Extra: Using where
1 row in set (0.00 sec)


mysql> EXPLAIN PARTITIONS SELECT * FROM cities WHERE id = 101 AND population = 206998\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: cities
   partitions: p2
         type: const
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 8
          ref: const,const
         rows: 1
        Extra:
1 row in set (0.00 sec)
```

This limitation on pruning with composite partitioning keys is removed in MySQL 5.5.

18.5 Restrictions and Limitations on Partitioning

This section discusses current restrictions and limitations on MySQL partitioning support.

Prohibited constructs.   Beginning with MySQL 5.1.12, the following constructs are not permitted in partitioning expressions:

• Stored procedures, stored functions, UDFs, or plugins.

- Declared variables or user variables.

For a list of SQL functions which are permitted in partitioning expressions, see Section 18.5.3, "Partitioning Limitations Relating to Functions".

Arithmetic and logical operators.   Use of the arithmetic operators `+`, `-`, and `*` is permitted in partitioning expressions. However, the result must be an integer value or `NULL` (except in the case of `[LINEAR] KEY` partitioning, as discussed elsewhere in this chapter; see Section 18.2, "Partitioning Types", for more information).

Beginning with MySQL 5.1.23, the `DIV` operator is also supported, and the `/` operator is not permitted. (Bug #30188, Bug #33182)

Beginning with MySQL 5.1.12, the bit operators `|`, `&`, `^`, `<<`, `>>`, and `~` are not permitted in partitioning expressions.

HANDLER statements.   In MySQL 5.1, the `HANDLER` statement is not supported with partitioned tables.

Server SQL mode.   Tables employing user-defined partitioning do not preserve the SQL mode in effect at the time that they were created. As discussed in Section 5.1.7, "Server SQL Modes", the results of many MySQL functions and operators may change according to the server SQL mode. Therefore, a change in the SQL mode at any time after the creation of partitioned tables may lead to major changes in the behavior of such tables, and could easily lead to corruption or loss of data. For these reasons, *it is strongly recommended that you never change the server SQL mode after creating partitioned tables*.

Examples.   The following examples illustrate some changes in behavior of partitioned tables due to a change in the server SQL mode:

1. **Error handling.**   Suppose that you create a partitioned table whose partitioning expression is one such as *column* `DIV 0` or *column* `MOD 0`, as shown here:

   ```
   mysql> CREATE TABLE tn (c1 INT)
       ->     PARTITION BY LIST(1 DIV c1) (
       ->         PARTITION p0 VALUES IN (NULL),
       ->         PARTITION p1 VALUES IN (1)
       -> );
   Query OK, 0 rows affected (0.05 sec)
   ```

   The default behavior for MySQL is to return `NULL` for the result of a division by zero, without producing any errors:

   ```
   mysql> SELECT @@sql_mode;
   +------------+
   | @@sql_mode |
   +------------+
   |            |
   +------------+
   1 row in set (0.00 sec)


   mysql> INSERT INTO tn VALUES (NULL), (0), (1);
   Query OK, 3 rows affected (0.00 sec)
   Records: 3  Duplicates: 0  Warnings: 0
   ```

   However, changing the server SQL mode to treat division by zero as an error and to enforce strict error handling causes the same `INSERT` statement to fail, as shown here:

```
mysql> SET sql_mode='STRICT_ALL_TABLES,ERROR_FOR_DIVISION_BY_ZERO';
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO tn VALUES (NULL), (0), (1);
ERROR 1365 (22012): Division by 0
```

2. **Table accessibility.** Sometimes a change in the server SQL mode can make partitioned tables unusable. The following CREATE TABLE statement can be executed successfully only if the NO_UNSIGNED_SUBTRACTION mode is in effect:

```
mysql> SELECT @@sql_mode;
+------------+
| @@sql_mode |
+------------+
|            |
+------------+
1 row in set (0.00 sec)

mysql> CREATE TABLE tu (c1 BIGINT UNSIGNED)
    ->   PARTITION BY RANGE(c1 - 10) (
    ->     PARTITION p0 VALUES LESS THAN (-5),
    ->     PARTITION p1 VALUES LESS THAN (0),
    ->     PARTITION p2 VALUES LESS THAN (5),
    ->     PARTITION p3 VALUES LESS THAN (10),
    ->     PARTITION p4 VALUES LESS THAN (MAXVALUE)
    -> );
ERROR 1563 (HY000): Partition constant is out of partition function domain

mysql> SET sql_mode='NO_UNSIGNED_SUBTRACTION';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@sql_mode;
+-------------------------+
| @@sql_mode              |
+-------------------------+
| NO_UNSIGNED_SUBTRACTION |
+-------------------------+
1 row in set (0.00 sec)

mysql> CREATE TABLE tu (c1 BIGINT UNSIGNED)
    ->   PARTITION BY RANGE(c1 - 10) (
    ->     PARTITION p0 VALUES LESS THAN (-5),
    ->     PARTITION p1 VALUES LESS THAN (0),
    ->     PARTITION p2 VALUES LESS THAN (5),
    ->     PARTITION p3 VALUES LESS THAN (10),
    ->     PARTITION p4 VALUES LESS THAN (MAXVALUE)
    -> );
Query OK, 0 rows affected (0.05 sec)
```

If you remove the NO_UNSIGNED_SUBTRACTION server SQL mode after creating tu, you may no longer be able to access this table:

```
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT * FROM tu;
ERROR 1563 (HY000): Partition constant is out of partition function domain
mysql> INSERT INTO tu VALUES (20);
ERROR 1563 (HY000): Partition constant is out of partition function domain
```

Server SQL modes also impact replication of partitioned tables. Differing SQL modes on master and slave can lead to partitioning expressions being evaluated differently; this can cause the distribution of data among partitions to be different in the master's and slave's copies of a given table, and may even cause

inserts into partitioned tables that succeed on the master to fail on the slave. For best results, you should always use the same server SQL mode on the master and on the slave.

Performance considerations. Some affects of partitioning operations on performance are given in the following list:

- **File system operations.** Partitioning and repartitioning operations (such as `ALTER TABLE` with `PARTITION BY ...`, `REORGANIZE PARTITIONS`, or `REMOVE PARTITIONING`) depend on file system operations for their implementation. This means that the speed of these operations is affected by such factors as file system type and characteristics, disk speed, swap space, file handling efficiency of the operating system, and MySQL server options and variables that relate to file handling. In particular, you should make sure that `large_files_support` is enabled and that `open_files_limit` is set properly. For partitioned tables using the `MyISAM` storage engine, increasing `myisam_max_sort_file_size` may improve performance; partitioning and repartitioning operations involving `InnoDB` tables may be made more efficient by enabling `innodb_file_per_table`.

  See also Maximum number of partitions.

- **MyISAM and partition file descriptor usage.** For a partitioned `MyISAM` table, MySQL uses 2 file descriptors for each partition, for each such table that is open. This means that you need many more file descriptors to perform operations on a partitioned `MyISAM` table than on a table which is identical to it except that the latter table is not partitioned, particularly when performing `ALTER TABLE` operations that change the table's partitioning scheme.

  Assume a `MyISAM` table `t` with 100 partitions, such as the table created by this SQL statement:

```
CREATE TABLE t (c1 VARCHAR(50))
PARTITION BY KEY (c1) PARTITIONS 100
ENGINE=MYISAM;
```

> **Note**
>
> For brevity, we use `KEY` partitioning for the table shown in this example, but file descriptor usage as described here applies to all partitioned `MyISAM` tables, regardless of the type of partitioning that is employed. Partitioned tables using other storage engines such as `InnoDB` are not affected by this issue.

  Now assume that you wish to repartition `t` so that it has 101 partitions, using the statement shown here:

```
ALTER TABLE t PARTITION BY KEY (c1) PARTITIONS 101;
```

  To process this `ALTER TABLE` statement, MySQL uses 402 file descriptors—that is, two for each of the 100 original partitions, plus two for each of the 101 new partitions. This is because all partitions (old and new) must be opened concurrently during the reorganization of the table data. It is recommended that, if you expect to perform such operations, you should make sure that `--open-files-limit` is not set too low to accommodate them.

- **Table locks.** The process executing a partitioning operation on a table takes a write lock on the table. Reads from such tables are relatively unaffected; pending `INSERT` and `UPDATE` operations are performed as soon as the partitioning operation has completed.

- **Storage engine.** Partitioning operations, queries, and update operations generally tend to be faster with `MyISAM` tables than with `InnoDB` or `NDB` tables.

- **Indexes; partition pruning.** As with nonpartitioned tables, proper use of indexes can speed up queries on partitioned tables significantly. In addition, designing partitioned tables and queries on these

tables to take advantage of *partition pruning* can improve performance dramatically. See Section 18.4, "Partition Pruning", for more information.

- **Performance with LOAD DATA.** Prior to MySQL 5.1.23, `LOAD DATA` performed very poorly when importing into partitioned tables. The statement now uses buffering to improve performance; however, the buffer uses 130 KB memory per partition to achieve this. (Bug #26527)

Maximum number of partitions.

The maximum possible number of partitions for a given table (that does not use the `NDB` storage engine) is 1024. This number includes subpartitions.

The maximum possible number of user-defined partitions for a table using the `NDBCLUSTER` storage engine is determined according to the version of the MySQL Cluster software being used, the number of data nodes, and other factors. See NDB and user-defined partitioning, for more information.

If, when creating tables with a large number of partitions (but less than the maximum), you encounter an error message such as `Got error ... from storage engine: Out of resources when opening file`, you may be able to address the issue by increasing the value of the `open_files_limit` system variable. However, this is dependent on the operating system, and may not be possible or advisable on all platforms; see Section B.5.2.18, "File Not Found and Similar Errors", for more information. In some cases, using large numbers (hundreds) of partitions may also not be advisable due to other concerns, so using more partitions does not automatically lead to better results.

See also File system operations.

Foreign keys not supported for partitioned InnoDB tables.

Partitioned tables using the `InnoDB` storage engine do not support foreign keys. More specifically, this means that the following two statements are true:

1. No definition of an `InnoDB` table employing user-defined partitioning may contain foreign key references; no `InnoDB` table whose definition contains foreign key references may be partitioned.

2. No `InnoDB` table definition may contain a foreign key reference to a user-partitioned table; no `InnoDB` table with user-defined partitioning may contain columns referenced by foreign keys.

The scope of the restrictions just listed includes all tables that use the `InnoDB` storage engine. `CREATE TABLE` and `ALTER TABLE` statements that would result in tables violating these restrictions are not allowed.

ALTER TABLE ... ORDER BY. An `ALTER TABLE ... ORDER BY column` statement run against a partitioned table causes ordering of rows only within each partition.

Effects on REPLACE statements by modification of primary keys. It can be desirable in some cases (see Section 18.5.1, "Partitioning Keys, Primary Keys, and Unique Keys") to modify a table's primary key. Be aware that, if your application uses `REPLACE` statements and you do this, the results of these statements can be drastically altered. See Section 13.2.7, "REPLACE Syntax", for more information and an example.

FULLTEXT indexes.

Partitioned tables do not support `FULLTEXT` indexes or searches. This includes partitioned tables employing the `MyISAM` storage engine.

Spatial columns. Columns with spatial data types such as `POINT` or `GEOMETRY` cannot be used in partitioned tables.

Temporary tables.

As of MySQL 5.1.8, temporary tables cannot be partitioned. (Bug #17497)

Log tables.   Beginning with MySQL 5.1.20, it is no longer possible to partition the log tables; beginning with that version, an `ALTER TABLE ... PARTITION BY ...` statement on such a table fails with an error. (Bug #27816)

Data type of partitioning key.
A partitioning key must be either an integer column or an expression that resolves to an integer. Expressions employing `ENUM` columns cannot be used. The column or expression value may also be `NULL`. (See Section 18.2.6, "How MySQL Partitioning Handles NULL".)

The lone exception to this restriction occurs when partitioning by `[LINEAR] KEY`, it is possible to use columns of any valid MySQL data type other than `TEXT` or `BLOB` as partitioning keys, because MySQL's internal key-hashing functions produce the correct data type from these types. For example, the following two `CREATE TABLE` statements are valid:

```
CREATE TABLE tkc (c1 CHAR)
PARTITION BY KEY(c1)
PARTITIONS 4;

CREATE TABLE tke
    ( c1 ENUM('red', 'orange', 'yellow', 'green', 'blue', 'indigo', 'violet') )
PARTITION BY LINEAR KEY(c1)
PARTITIONS 6;
```

Subqueries.
A partitioning key may not be a subquery, even if that subquery resolves to an integer value or `NULL`.

Issues with subpartitions.
Subpartitions must use `HASH` or `KEY` partitioning. Only `RANGE` and `LIST` partitions may be subpartitioned; `HASH` and `KEY` partitions cannot be subpartitioned.

 `SUBPARTITION BY KEY` requires that the subpartitioning column or columns be specified explicitly, unlike the case with `PARTITION BY KEY`, where it can be omitted (in which case the table's primary key column is used by default). Consider the table created by this statement:

```
CREATE TABLE ts (
    id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(30)
);
```

You can create a table having the same columns, partitioned by `KEY`, using a statement such as this one:

```
CREATE TABLE ts (
    id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(30)
)
PARTITION BY KEY()
PARTITIONS 4;
```

The previous statement is treated as though it had been written like this, with the table's primary key column used as the partitioning column:

```
CREATE TABLE ts (
    id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(30)
```

```
)
PARTITION BY KEY(id)
PARTITIONS 4;
```

However, the following statement that attempts to create a subpartitioned table using the default column as the subpartitioning column fails, and the column must be specified for the statement to succeed, as shown here:

```
mysql> CREATE TABLE ts (
    ->     id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->     name VARCHAR(30)
    -> )
    -> PARTITION BY RANGE(id)
    -> SUBPARTITION BY KEY()
    -> SUBPARTITIONS 4
    -> (
    ->     PARTITION p0 VALUES LESS THAN (100),
    ->     PARTITION p1 VALUES LESS THAN (MAXVALUE)
    -> );
ERROR 1064 (42000): You have an error in your SQL syntax; check the manual that
corresponds to your MySQL server version for the right syntax to use near ')

mysql> CREATE TABLE ts (
    ->     id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->     name VARCHAR(30)
    -> )
    -> PARTITION BY RANGE(id)
    -> SUBPARTITION BY KEY(id)
    -> SUBPARTITIONS 4
    -> (
    ->     PARTITION p0 VALUES LESS THAN (100),
    ->     PARTITION p1 VALUES LESS THAN (MAXVALUE)
    -> );
Query OK, 0 rows affected (0.07 sec)
```

This is a known issue (see Bug #51470).

Query cache not supported.
The query cache is not supported for partitioned tables. Beginning with MySQL 5.1.63, the query cache is automatically disabled for queries involving partitioned tables, and cannot be enabled for such queries. (Bug #53775)

Key cache not supported.
Caching is not supported for partitioned tables. The `CACHE INDEX` and `LOAD INDEX INTO CACHE` statements, when you attempt to use them on tables having user-defined partitioning, fail with the errors `The storage engine for the table doesn't support assign_to_keycache` and `The storage engine for the table doesn't support preload_keys`, respectively. This issue is fixed in MySQL 5.5.

DELAYED option not supported.   Use of `INSERT DELAYED` to insert rows into a partitioned table is not supported. Beginning with MySQL 5.1.23, attempting to do so fails with an error (see Bug #31210).

DATA DIRECTORY and INDEX DIRECTORY options.   `DATA DIRECTORY` and `INDEX DIRECTORY` are subject to the following restrictions when used with partitioned tables:

- Beginning with MySQL 5.1.23, table-level `DATA DIRECTORY` and `INDEX DIRECTORY` options are ignored (see Bug #32091).

- On Windows, the `DATA DIRECTORY` and `INDEX DIRECTORY` options are not supported for individual partitions or subpartitions (Bug #30459).

Repairing and rebuilding partitioned tables.   The statements `CHECK TABLE`, `OPTIMIZE TABLE`, `ANALYZE TABLE`, and `REPAIR TABLE` are supported for partitioned tables beginning with MySQL 5.1.27. (See Bug #20129.)

In addition, you can use `ALTER TABLE ... REBUILD PARTITION` to rebuild one or more partitions of a partitioned table; `ALTER TABLE ... REORGANIZE PARTITION` also causes partitions to be rebuilt. Both of these statements were added in MySQL 5.1.5. See Section 13.1.7, "ALTER TABLE Syntax", for more information about these two statements.

`mysqlcheck`, `myisamchk`, and `myisampack` are not supported with partitioned tables.

18.5.1 Partitioning Keys, Primary Keys, and Unique Keys

This section discusses the relationship of partitioning keys with primary keys and unique keys. The rule governing this relationship can be expressed as follows: All columns used in the partitioning expression for a partitioned table must be part of every unique key that the table may have.

In other words, *every unique key on the table must use every column in the table's partitioning expression*. (This also includes the table's primary key, since it is by definition a unique key. This particular case is discussed later in this section.) For example, each of the following table creation statements is invalid:

```
CREATE TABLE t1 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col2)
)
PARTITION BY HASH(col3)
PARTITIONS 4;

CREATE TABLE t2 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1),
    UNIQUE KEY (col3)
)
PARTITION BY HASH(col1 + col3)
PARTITIONS 4;
```

In each case, the proposed table would have at least one unique key that does not include all columns used in the partitioning expression.

Each of the following statements is valid, and represents one way in which the corresponding invalid table creation statement could be made to work:

```
CREATE TABLE t1 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col2, col3)
)
PARTITION BY HASH(col3)
PARTITIONS 4;

CREATE TABLE t2 (
    col1 INT NOT NULL,
```

```
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col3)
)
PARTITION BY HASH(col1 + col3)
PARTITIONS 4;
```

This example shows the error produced in such cases:

```
mysql> CREATE TABLE t3 (
    ->     col1 INT NOT NULL,
    ->     col2 DATE NOT NULL,
    ->     col3 INT NOT NULL,
    ->     col4 INT NOT NULL,
    ->     UNIQUE KEY (col1, col2),
    ->     UNIQUE KEY (col3)
    -> )
    -> PARTITION BY HASH(col1 + col3)
    -> PARTITIONS 4;
ERROR 1491 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

The `CREATE TABLE` statement fails because both `col1` and `col3` are included in the proposed partitioning key, but neither of these columns is part of both of unique keys on the table. This shows one possible fix for the invalid table definition:

```
mysql> CREATE TABLE t3 (
    ->     col1 INT NOT NULL,
    ->     col2 DATE NOT NULL,
    ->     col3 INT NOT NULL,
    ->     col4 INT NOT NULL,
    ->     UNIQUE KEY (col1, col2, col3),
    ->     UNIQUE KEY (col3)
    -> )
    -> PARTITION BY HASH(col3)
    -> PARTITIONS 4;
Query OK, 0 rows affected (0.05 sec)
```

In this case, the proposed partitioning key `col3` is part of both unique keys, and the table creation statement succeeds.

The following table cannot be partitioned at all, because there is no way to include in a partitioning key any columns that belong to both unique keys:

```
CREATE TABLE t4 (
    col1 INT NOT NULL,
    col2 INT NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col3),
    UNIQUE KEY (col2, col4)
);
```

Since every primary key is by definition a unique key, this restriction also includes the table's primary key, if it has one. For example, the next two statements are invalid:

```
CREATE TABLE t5 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
```

```
    PRIMARY KEY(col1, col2)
)
PARTITION BY HASH(col3)
PARTITIONS 4;

CREATE TABLE t6 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col3),
    UNIQUE KEY(col2)
)
PARTITION BY HASH( YEAR(col2) )
PARTITIONS 4;
```

In both cases, the primary key does not include all columns referenced in the partitioning expression. However, both of the next two statements are valid:

```
CREATE TABLE t7 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col2)
)
PARTITION BY HASH(col1 + YEAR(col2))
PARTITIONS 4;

CREATE TABLE t8 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col2, col4),
    UNIQUE KEY(col2, col1)
)
PARTITION BY HASH(col1 + YEAR(col2))
PARTITIONS 4;
```

If a table has no unique keys—this includes having no primary key—then this restriction does not apply, and you may use any column or columns in the partitioning expression as long as the column type is compatible with the partitioning type.

For the same reason, you cannot later add a unique key to a partitioned table unless the key includes all columns used by the table's partitioning expression. Consider the partitioned table created as shown here:

```
mysql> CREATE TABLE t_no_pk (c1 INT, c2 INT)
    ->     PARTITION BY RANGE(c1) (
    ->         PARTITION p0 VALUES LESS THAN (10),
    ->         PARTITION p1 VALUES LESS THAN (20),
    ->         PARTITION p2 VALUES LESS THAN (30),
    ->         PARTITION p3 VALUES LESS THAN (40)
    ->     );
Query OK, 0 rows affected (0.12 sec)
```

It is possible to add a primary key to `t_no_pk` using either of these `ALTER TABLE` statements:

```
#  possible PK
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c1);
Query OK, 0 rows affected (0.13 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

```
# drop this PK
mysql> ALTER TABLE t_no_pk DROP PRIMARY KEY;
Query OK, 0 rows affected (0.10 sec)
Records: 0  Duplicates: 0  Warnings: 0

#  use another possible PK
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c1, c2);
Query OK, 0 rows affected (0.12 sec)
Records: 0  Duplicates: 0  Warnings: 0

# drop this PK
mysql> ALTER TABLE t_no_pk DROP PRIMARY KEY;
Query OK, 0 rows affected (0.09 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

However, the next statement fails, because `c1` is part of the partitioning key, but is not part of the proposed primary key:

```
#  fails with error 1503
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c2);
ERROR 1503 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

Since `t_no_pk` has only `c1` in its partitioning expression, attempting to adding a unique key on `c2` alone fails. However, you can add a unique key that uses both `c1` and `c2`.

These rules also apply to existing nonpartitioned tables that you wish to partition using `ALTER TABLE ...
PARTITION BY`. Consider a table `np_pk` created as shown here:

```
mysql> CREATE TABLE np_pk (
    ->     id INT NOT NULL AUTO_INCREMENT,
    ->     name VARCHAR(50),
    ->     added DATE,
    ->     PRIMARY KEY (id)
    -> );
Query OK, 0 rows affected (0.08 sec)
```

The following `ALTER TABLE` statement fails with an error, because the `added` column is not part of any unique key in the table:

```
mysql> ALTER TABLE np_pk
    ->     PARTITION BY HASH( TO_DAYS(added) )
    ->     PARTITIONS 4;
ERROR 1503 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

However, this statement using the `id` column for the partitioning column is valid, as shown here:

```
mysql> ALTER TABLE np_pk
    ->     PARTITION BY HASH(id)
    ->     PARTITIONS 4;
Query OK, 0 rows affected (0.11 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

In the case of `np_pk`, the only column that may be used as part of a partitioning expression is `id`; if you wish to partition this table using any other column or columns in the partitioning expression, you must first modify the table, either by adding the desired column or columns to the primary key, or by dropping the primary key altogether.

18.5.2 Partitioning Limitations Relating to Storage Engines

The following limitations apply to the use of storage engines with user-defined partitioning of tables.

MERGE storage engine.   User-defined partitioning and the `MERGE` storage engine are not compatible. Tables using the `MERGE` storage engine cannot be partitioned. Partitioned tables cannot be merged.

FEDERATED storage engine.   Partitioning of `FEDERATED` tables is not supported. Beginning with MySQL 5.1.15, it is not possible to create partitioned `FEDERATED` tables at all.

CSV storage engine.   Partitioned tables using the `CSV` storage engine are not supported. Starting with MySQL 5.1.12, it is not possible to create partitioned `CSV` tables at all.

BLACKHOLE storage engine.   Prior to MySQL 5.1.6, tables using the `BLACKHOLE` storage engine also could not be partitioned.

InnoDB storage engine.   `InnoDB` foreign keys and MySQL partitioning are not compatible. Partitioned `InnoDB` tables cannot have foreign key references, nor can they have columns referenced by foreign keys. `InnoDB` tables which have or which are referenced by foreign keys cannot be partitioned.

In addition, `ALTER TABLE ... OPTIMIZE PARTITION` does not work correctly with partitioned tables that use the `InnoDB` storage engine. Use `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION`, instead, for such tables. For more information, see Section 13.1.7.1, "ALTER TABLE Partition Operations".

User-defined partitioning and the NDB storage engine (MySQL Cluster).   Partitioning by `KEY` (including `LINEAR KEY`) is the only type of partitioning supported for the `NDBCLUSTER` storage engine. Beginning with MySQL 5.1.12, it is not possible under normal circumstances to create a MySQL Cluster table using any partitioning type other than [`LINEAR`] `KEY`, and attempting to do so fails with an error.

Exception (not for production): It is possible to override this restriction by setting the `new` system variable on MySQL Cluster SQL nodes to `ON`. If you choose to do this, you should be aware that tables using partitioning types other than [`LINEAR`] `KEY` are not supported in production. *In such cases, you can create and use tables with partitioning types other than `KEY` or `LINEAR KEY`, but you do this entirely at your own risk*.

The maximum number of partitions that can be defined for an `NDBCLUSTER` table depends on the number of data nodes and node groups in the cluster, the version of the MySQL Cluster software in use, and other factors. See NDB and user-defined partitioning, for more information.

The maximum amount of fixed-size data that can be stored per partition in an `NDB` table is 16 GB.

Beginning with MySQL Cluster NDB 6.2.18, MySQL Cluster NDB 6.3.25, and MySQL Cluster NDB 7.0.6, `CREATE TABLE` and `ALTER TABLE` statements that would cause a user-partitioned `NDBCLUSTER` table not to meet either or both of the following two requirements are not permitted, and fail with an error (Bug #40709):

1. The table must have an explicit primary key.

2. All columns listed in the table's partitioning expression must be part of the primary key.

Exception.   If a user-partitioned `NDBCLUSTER` table is created using an empty column-list (that is, using `PARTITION BY KEY()` or `PARTITION BY LINEAR KEY()`), then no explicit primary key is required.

Upgrading partitioned tables.   When performing an upgrade, tables which are partitioned by `KEY` and which use any storage engine other than `NDBCLUSTER` must be dumped and reloaded.

Same storage engine for all partitions.   All partitions of a partitioned table must use the same storage engine and it must be the same storage engine used by the table as a whole. In addition, if one does not

specify an engine on the table level, then one must do either of the following when creating or altering a partitioned table:

- Do *not* specify any engine for *any* partition or subpartition

- Specify the engine for *all* partitions or subpartitions

18.5.3 Partitioning Limitations Relating to Functions

This section discusses limitations in MySQL Partitioning relating specifically to functions used in partitioning expressions.

Beginning with MySQL 5.1.12, only the MySQL functions allowed in the following table are allowed in partitioning expressions.

`ABS()`	`CEILING()` (see CEILING() and FLOOR())	`DAY()`
`DAYOFMONTH()`	`DAYOFWEEK()`	`DAYOFYEAR()`
`DATEDIFF()`	`EXTRACT()` (see EXTRACT() function with WEEK specifier)	`FLOOR()` (see CEILING() and FLOOR())
`HOUR()`	`MICROSECOND()`	`MINUTE()`
`MOD()`	`MONTH()`	`QUARTER()`
`SECOND()`	`TIME_TO_SEC()`	`TO_DAYS()`
`UNIX_TIMESTAMP()` (permitted in MySQL 5.1.43 and later, with `TIMESTAMP` columns)	`WEEKDAY()`	`YEAR()`
	`YEARWEEK()`	

In MySQL 5.1, range optimization can be used only for the `TO_DAYS()` and `YEAR()` functions. See Section 18.4, "Partition Pruning", for more information.

CEILING() and FLOOR().   Each of these functions returns an integer only if it is passed an argument of an exact numeric type, such as one of the `INT` types or `DECIMAL`. This means, for example, that the following `CREATE TABLE` statement fails with an error, as shown here:

```
mysql> CREATE TABLE t (c FLOAT) PARTITION BY LIST( FLOOR(c) )(
    ->      PARTITION p0 VALUES IN (1,3,5),
    ->      PARTITION p1 VALUES IN (2,4,6)
    -> );
ERROR 1490 (HY000): The PARTITION function returns the wrong type
```

EXTRACT() function with WEEK specifier.   The value returned by the `EXTRACT()` function, when used as `EXTRACT(WEEK FROM col)`, depends on the value of the `default_week_format` system variable. For this reason, beginning with MySQL 5.1.55, `EXTRACT()` is no longer permitted as a partitioning function when it specifies the unit as `WEEK`. (Bug #54483)

See Section 12.6.2, "Mathematical Functions", for more information about the return types of these functions, as well as Section 11.2, "Numeric Types".

18.5.4 Partitioning and Table-Level Locking

For storage engines such as `MyISAM` that actually execute table-level locks when executing DML or DDL statements, such a statement affecting a partitioned table imposes a lock on the table as a whole; that

is, all partitions are locked until the statement was finished. For example, a `SELECT` from a partitioned `MyISAM` table causes a lock on the entire table.

In practical terms, what this means is that the statements discussed later in this section tend to execute more slowly as the number of partitions increases. This limitation is greatly reduced in MySQL 5.6, with the introduction of *partition lock pruning* in MySQL 5.6.6.

This is not true for statements effecting partitioned tables using storage engines such as `InnoDB`, that employ row-level locking and do not actually perform (or need to perform) the locks prior to partition pruning.

The next few paragraphs discuss the effects of MySQL statements on partitioned tables using storage engines that employ table-level locks.

DML statements

`SELECT` statements lock the entire table. `SELECT` statements containing unions or joins lock all tables named in the union or join.

`UPDATE` also locks the entire table.

`REPLACE` and `INSERT` (including `INSERT ... ON DUPLICATE KEY UPDATE`) lock the entire table.

`INSERT ... SELECT` locks both the source table and the target table.

> **Note**
>
> `INSERT DELAYED` is not supported for partitioned tables.

A `LOAD DATA` statement on a partitioned table locks the entire table.

A trigger on a partitioned table, once activated, locks the entire table.

DDL statements

`CREATE VIEW` causes a lock on any partitioned table from which it reads.

`ALTER TABLE` locks the affected partitioned table.

Other statements

`LOCK TABLES` locks all partitions of a partioned table.

Evaluating the `expr` in a `CALL stored_procedure(expr)` statement locks all partitions of any partitioned table referenced by `expr`.

`ALTER TABLE` also takes a metadata lock on the table level.

Chapter 19 Stored Programs and Views

Table of Contents

This chapter discusses stored programs and views, which are database objects defined in terms of SQL code that is stored on the server for later execution.

Stored programs include these objects:

- Stored routines, that is, stored procedures and functions. A stored procedure is invoked using the `CALL` statement. A procedure does not have a return value but can modify its parameters for later inspection by the caller. It can also generate result sets to be returned to the client program. A stored function is used much like a built-in function. you invoke it in an expression and it returns a value during expression evaluation.

- Triggers. A trigger is a named database object that is associated with a table and that is activated when a particular event occurs for the table, such as an insert or update.

- Events. An event is a task that the server runs according to schedule.

Views are stored queries that when referenced produce a result set. A view acts as a virtual table.

This chapter describes how to use stored programs and views. The following sections provide additional information about SQL syntax for statements related to these objects:

- For each object type, there are `CREATE`, `ALTER`, and `DROP` statements that control which objects exist and how they are defined. See Section 13.1, "Data Definition Statements".

- The `CALL` statement is used to invoke stored procedures. See Section 13.2.1, "CALL Syntax".

- Stored program definitions include a body that may use compound statements, loops, conditionals, and declared variables. See Section 13.6, "MySQL Compound-Statement Syntax".

19.1 Defining Stored Programs

Each stored program contains a body that consists of an SQL statement. This statement may be a compound statement made up of several statements separated by semicolon (`;`) characters. For example, the following stored procedure has a body made up of a `BEGIN ... END` block that contains a `SET` statement and a `REPEAT` loop that itself contains another `SET` statement:

```
CREATE PROCEDURE dorepeat(p1 INT)
BEGIN
  SET @x = 0;
  REPEAT SET @x = @x + 1; UNTIL @x > p1 END REPEAT;
END;
```

If you use the `mysql` client program to define a stored program containing semicolon characters, a problem arises. By default, `mysql` itself recognizes the semicolon as a statement delimiter, so you must redefine the delimiter temporarily to cause `mysql` to pass the entire stored program definition to the server.

To redefine the `mysql` delimiter, use the `delimiter` command. The following example shows how to do this for the `dorepeat()` procedure just shown. The delimiter is changed to `//` to enable the entire definition to be passed to the server as a single statement, and then restored to `;` before invoking the procedure. This enables the `;` delimiter used in the procedure body to be passed through to the server rather than being interpreted by `mysql` itself.

```
mysql> delimiter //

mysql> CREATE PROCEDURE dorepeat(p1 INT)
    -> BEGIN
    ->   SET @x = 0;
    ->   REPEAT SET @x = @x + 1; UNTIL @x > p1 END REPEAT;
    -> END
    -> //
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter ;

mysql> CALL dorepeat(1000);
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @x;
+------+
| @x   |
+------+
| 1001 |
+------+
1 row in set (0.00 sec)
```

You can redefine the delimiter to a string other than `//`, and the delimiter can consist of a single character or multiple characters. You should avoid the use of the backslash ("\") character because that is the escape character for MySQL.

The following is an example of a function that takes a parameter, performs an operation using an SQL function, and returns the result. In this case, it is unnecessary to use `delimiter` because the function definition contains no internal `;` statement delimiters:

```
mysql> CREATE FUNCTION hello (s CHAR(20))
mysql> RETURNS CHAR(50) DETERMINISTIC
```

```
    -> RETURN CONCAT('Hello, ',s,'!');
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT hello('world');
+----------------+
| hello('world') |
+----------------+
| Hello, world!  |
+----------------+
1 row in set (0.00 sec)
```

19.2 Using Stored Routines (Procedures and Functions)

Stored routines (procedures and functions) are supported in MySQL 5.1. A stored routine is a set of SQL statements that can be stored in the server. Once this has been done, clients don't need to keep reissuing the individual statements but can refer to the stored routine instead.

Stored routines require the `proc` table in the `mysql` database. This table is created during the MySQL 5.1 installation procedure. If you are upgrading to MySQL 5.1 from an earlier version, be sure to update your grant tables to make sure that the `proc` table exists. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

Stored routines can be particularly useful in certain situations:

- When multiple client applications are written in different languages or work on different platforms, but need to perform the same database operations.

- When security is paramount. Banks, for example, use stored procedures and functions for all common operations. This provides a consistent and secure environment, and routines can ensure that each operation is properly logged. In such a setup, applications and users would have no access to the database tables directly, but can only execute specific stored routines.

Stored routines can provide improved performance because less information needs to be sent between the server and the client. The tradeoff is that this does increase the load on the database server because more of the work is done on the server side and less is done on the client (application) side. Consider this if many client machines (such as Web servers) are serviced by only one or a few database servers.

Stored routines also enable you to have libraries of functions in the database server. This is a feature shared by modern application languages that enable such design internally (for example, by using classes). Using these client application language features is beneficial for the programmer even outside the scope of database use.

MySQL follows the SQL:2003 syntax for stored routines, which is also used by IBM's DB2. All syntax described here is supported and any limitations and extensions are documented where appropriate.

Additional Resources

- You may find the Stored Procedures User Forum of use when working with stored procedures and functions.

- For answers to some commonly asked questions regarding stored routines in MySQL, see Section A.4, "MySQL 5.1 FAQ: Stored Procedures and Functions".

- There are some restrictions on the use of stored routines. See Section C.1, "Restrictions on Stored Programs".

- Binary logging for stored routines takes place as described in Section 19.7, "Binary Logging of Stored Programs".

19.2.1 Stored Routine Syntax

A stored routine is either a procedure or a function. Stored routines are created with the `CREATE PROCEDURE` and `CREATE FUNCTION` statements (see Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax"). A procedure is invoked using a `CALL` statement (see Section 13.2.1, "CALL Syntax"), and can only pass back values using output variables. A function can be called from inside a statement just like any other function (that is, by invoking the function's name), and can return a scalar value. The body of a stored routine can use compound statements (see Section 13.6, "MySQL Compound-Statement Syntax").

Stored routines can be dropped with the `DROP PROCEDURE` and `DROP FUNCTION` statements (see Section 13.1.26, "DROP PROCEDURE and DROP FUNCTION Syntax"), and altered with the `ALTER PROCEDURE` and `ALTER FUNCTION` statements (see Section 13.1.5, "ALTER PROCEDURE Syntax").

A stored procedure or function is associated with a particular database. This has several implications:

- When the routine is invoked, an implicit `USE` *db_name* is performed (and undone when the routine terminates). `USE` statements within stored routines are not permitted.

- You can qualify routine names with the database name. This can be used to refer to a routine that is not in the current database. For example, to invoke a stored procedure `p` or function `f` that is associated with the `test` database, you can say `CALL test.p()` or `test.f()`.

- When a database is dropped, all stored routines associated with it are dropped as well.

Stored functions cannot be recursive.

Recursion in stored procedures is permitted but disabled by default. To enable recursion, set the `max_sp_recursion_depth` server system variable to a value greater than zero. Stored procedure recursion increases the demand on thread stack space. If you increase the value of `max_sp_recursion_depth`, it may be necessary to increase thread stack size by increasing the value of `thread_stack` at server startup. See Section 5.1.4, "Server System Variables", for more information.

MySQL supports a very useful extension that enables the use of regular `SELECT` statements (that is, without using cursors or local variables) inside a stored procedure. The result set of such a query is simply sent directly to the client. Multiple `SELECT` statements generate multiple result sets, so the client must use a MySQL client library that supports multiple result sets. This means the client must use a client library from a version of MySQL at least as recent as 4.1. The client should also specify the `CLIENT_MULTI_RESULTS` option when it connects. For C programs, this can be done with the `mysql_real_connect()` C API function. See Section 21.8.7.52, "mysql_real_connect()", and Section 21.8.16, "C API Support for Multiple Statement Execution".

19.2.2 Stored Routines and MySQL Privileges

The MySQL grant system takes stored routines into account as follows:

- The `CREATE ROUTINE` privilege is needed to create stored routines.

- The `ALTER ROUTINE` privilege is needed to alter or drop stored routines. This privilege is granted automatically to the creator of a routine if necessary, and dropped from the creator when the routine is dropped.

- The `EXECUTE` privilege is required to execute stored routines. However, this privilege is granted automatically to the creator of a routine if necessary (and dropped from the creator when the routine is dropped). Also, the default `SQL SECURITY` characteristic for a routine is `DEFINER`, which enables users who have access to the database with which the routine is associated to execute the routine.

- If the `automatic_sp_privileges` system variable is 0, the `EXECUTE` and `ALTER ROUTINE` privileges are not automatically granted to and dropped from the routine creator.

- The creator of a routine is the account used to execute the `CREATE` statement for it. This might not be the same as the account named as the `DEFINER` in the routine definition.

The server manipulates the `mysql.proc` table in response to statements that create, alter, or drop stored routines. It is not supported that the server will notice manual manipulation of this table.

19.2.3 Stored Routine Metadata

Metadata about stored routines can be obtained as follows:

- Query the `ROUTINES` table of the `INFORMATION_SCHEMA` database. See Section 20.16, "The INFORMATION_SCHEMA ROUTINES Table".

- Use the `SHOW CREATE PROCEDURE` and `SHOW CREATE FUNCTION` statements to see routine definitions. See Section 13.7.5.11, "SHOW CREATE PROCEDURE Syntax".

- Use the `SHOW PROCEDURE STATUS` and `SHOW FUNCTION STATUS` statements to see routine characteristics. See Section 13.7.5.30, "SHOW PROCEDURE STATUS Syntax".

- `INFORMATION_SCHEMA` does not have a `PARAMETERS` table until MySQL 5.5, so applications that need to acquire routine parameter information at runtime must use workarounds such as parsing the output of `SHOW CREATE` statements or the `param_list` column of the `mysql.proc` table. `param_list` contents can be processed from within a stored routine, unlike the output from `SHOW`.

19.2.4 Stored Procedures, Functions, Triggers, and LAST_INSERT_ID()

Within the body of a stored routine (procedure or function) or a trigger, the value of `LAST_INSERT_ID()` changes the same way as for statements executed outside the body of these kinds of objects (see Section 12.14, "Information Functions"). The effect of a stored routine or trigger upon the value of `LAST_INSERT_ID()` that is seen by following statements depends on the kind of routine:

- If a stored procedure executes statements that change the value of `LAST_INSERT_ID()`, the changed value is seen by statements that follow the procedure call.

- For stored functions and triggers that change the value, the value is restored when the function or trigger ends, so following statements do not see a changed value.

19.3 Using Triggers

A trigger is a named database object that is associated with a table, and that activates when a particular event occurs for the table. Some uses for triggers are to perform checks of values to be inserted into a table or to perform calculations on values involved in an update.

A trigger is defined to activate when a statement inserts, updates, or deletes rows in the associated table. These row operations are trigger events. For example, rows can be inserted by `INSERT` or `LOAD DATA` statements, and an insert trigger activates for each inserted row. A trigger can be set to activate either before or after the trigger event. For example, you can have a trigger activate before each row that is inserted into a table or after each row that is updated.

> **Important**
>
> MySQL triggers activate only for changes made to tables by SQL statements. They do not activate for changes in views, nor by changes to tables made by APIs that do not transmit SQL statements to the MySQL Server. This means that:

- Triggers are not activated by changes in `INFORMATION_SCHEMA` tables, because these tables are actually views.

- Triggers are not activated by updates made using the `NDB` API.

To use triggers if you have upgraded to MySQL 5.1 from an older release that did not support triggers, you should upgrade your grant tables so that they contain the trigger-related privileges. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

The following sections describe the syntax for creating and dropping triggers, show some examples of how to use them, and indicate how to obtain trigger metadata.

Additional Resources

- You may find the Triggers User Forum of use when working with triggers.

- For answers to commonly asked questions regarding triggers in MySQL, see Section A.5, "MySQL 5.1 FAQ: Triggers".

- There are some restrictions on the use of triggers; see Section C.1, "Restrictions on Stored Programs".

- Binary logging for triggers takes place as described in Section 19.7, "Binary Logging of Stored Programs".

19.3.1 Trigger Syntax and Examples

To create a trigger or drop a trigger, use the `CREATE TRIGGER` or `DROP TRIGGER` statement, described in Section 13.1.19, "CREATE TRIGGER Syntax", and Section 13.1.30, "DROP TRIGGER Syntax".

Here is a simple example that associates a trigger with a table, to activate for `INSERT` operations. The trigger acts as an accumulator, summing the values inserted into one of the columns of the table.

```
mysql> CREATE TABLE account (acct_num INT, amount DECIMAL(10,2));
Query OK, 0 rows affected (0.03 sec)

mysql> CREATE TRIGGER ins_sum BEFORE INSERT ON account
    -> FOR EACH ROW SET @sum = @sum + NEW.amount;
Query OK, 0 rows affected (0.06 sec)
```

The `CREATE TRIGGER` statement creates a trigger named `ins_sum` that is associated with the `account` table. It also includes clauses that specify the trigger action time, the triggering event, and what to do when the trigger activates:

- The keyword `BEFORE` indicates the trigger action time. In this case, the trigger activates before each row inserted into the table. The other permitted keyword here is `AFTER`.

- The keyword `INSERT` indicates the trigger event; that is, the type of operation that activates the trigger. In the example, `INSERT` operations cause trigger activation. You can also create triggers for `DELETE` and `UPDATE` operations.

- The statement following `FOR EACH ROW` defines the trigger body; that is, the statement to execute each time the trigger activates, which occurs once for each row affected by the triggering event. In the example, the trigger body is a simple `SET` that accumulates into a user variable the values inserted into the `amount` column. The statement refers to the column as `NEW.amount` which means "the value of the `amount` column to be inserted into the new row."

To use the trigger, set the accumulator variable to zero, execute an `INSERT` statement, and then see what value the variable has afterward:

```
mysql> SET @sum = 0;
mysql> INSERT INTO account VALUES(137,14.98),(141,1937.50),(97,-100.00);
mysql> SELECT @sum AS 'Total amount inserted';
+-----------------------+
| Total amount inserted |
+-----------------------+
| 1852.48               |
+-----------------------+
```

In this case, the value of `@sum` after the `INSERT` statement has executed is `14.98 + 1937.50 - 100`, or `1852.48`.

To destroy the trigger, use a `DROP TRIGGER` statement. You must specify the schema name if the trigger is not in the default schema:

```
mysql> DROP TRIGGER test.ins_sum;
```

If you drop a table, any triggers for the table are also dropped.

Trigger names exist in the schema namespace, meaning that all triggers must have unique names within a schema. Triggers in different schemas can have the same name.

In addition to the requirement that trigger names be unique for a schema, there are other limitations on the types of triggers you can create. In particular, there cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. To work around this, you can define a trigger that executes multiple statements by using the `BEGIN ... END` compound statement construct after `FOR EACH ROW`. (An example appears later in this section.)

Within the trigger body, the `OLD` and `NEW` keywords enable you to access columns in the rows affected by a trigger. `OLD` and `NEW` are MySQL extensions to triggers; they are not case sensitive.

In an `INSERT` trigger, only `NEW.col_name` can be used; there is no old row. In a `DELETE` trigger, only `OLD.col_name` can be used; there is no new row. In an `UPDATE` trigger, you can use `OLD.col_name` to refer to the columns of a row before it is updated and `NEW.col_name` to refer to the columns of the row after it is updated.

A column named with `OLD` is read only. You can refer to it (if you have the `SELECT` privilege), but not modify it. You can refer to a column named with `NEW` if you have the `SELECT` privilege for it. In a `BEFORE` trigger, you can also change its value with `SET NEW.col_name = value` if you have the `UPDATE` privilege for it. This means you can use a trigger to modify the values to be inserted into a new row or used to update a row. (Such a `SET` statement has no effect in an `AFTER` trigger because the row change will have already occurred.)

In a `BEFORE` trigger, the `NEW` value for an `AUTO_INCREMENT` column is 0, not the sequence number that is generated automatically when the new row actually is inserted.

By using the `BEGIN ... END` construct, you can define a trigger that executes multiple statements. Within the `BEGIN` block, you also can use other syntax that is permitted within stored routines such as conditionals and loops. However, just as for stored routines, if you use the `mysql` program to define a trigger that executes multiple statements, it is necessary to redefine the `mysql` statement delimiter so that you can use the `;` statement delimiter within the trigger definition. The following example illustrates these points. It defines an `UPDATE` trigger that checks the new value to be used for updating each row, and modifies the value to be within the range from 0 to 100. This must be a `BEFORE` trigger because the value must be checked before it is used to update the row:

```
mysql> delimiter //
mysql> CREATE TRIGGER upd_check BEFORE UPDATE ON account
    -> FOR EACH ROW
    -> BEGIN
    ->     IF NEW.amount < 0 THEN
    ->         SET NEW.amount = 0;
    ->     ELSEIF NEW.amount > 100 THEN
    ->         SET NEW.amount = 100;
    ->     END IF;
    -> END;//
mysql> delimiter ;
```

It can be easier to define a stored procedure separately and then invoke it from the trigger using a simple `CALL` statement. This is also advantageous if you want to execute the same code from within several triggers.

There are limitations on what can appear in statements that a trigger executes when activated:

- The trigger cannot use the `CALL` statement to invoke stored procedures that return data to the client or that use dynamic SQL. (Stored procedures are permitted to return data to the trigger through `OUT` or `INOUT` parameters.)

- The trigger cannot use statements that explicitly or implicitly begin or end a transaction, such as `START TRANSACTION`, `COMMIT`, or `ROLLBACK`. (`ROLLBACK to SAVEPOINT` is permitted because it does not end a transaction.).

See also Section C.1, "Restrictions on Stored Programs".

MySQL handles errors during trigger execution as follows:

- If a `BEFORE` trigger fails, the operation on the corresponding row is not performed.

- A `BEFORE` trigger is activated by the *attempt* to insert or modify the row, regardless of whether the attempt subsequently succeeds.

- An `AFTER` trigger is executed only if any `BEFORE` triggers and the row operation execute successfully.

- An error during either a `BEFORE` or `AFTER` trigger results in failure of the entire statement that caused trigger invocation.

- For transactional tables, failure of a statement should cause rollback of all changes performed by the statement. Failure of a trigger causes the statement to fail, so trigger failure also causes rollback. For nontransactional tables, such rollback cannot be done, so although the statement fails, any changes performed prior to the point of the error remain in effect.

In MySQL 5.1, triggers can contain direct references to tables by name, such as the trigger named `testref` shown in this example:

```
CREATE TABLE test1(a1 INT);
CREATE TABLE test2(a2 INT);
CREATE TABLE test3(a3 INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
CREATE TABLE test4(
  a4 INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
  b4 INT DEFAULT 0
);

delimiter |

CREATE TRIGGER testref BEFORE INSERT ON test1
  FOR EACH ROW
```

```
  BEGIN
    INSERT INTO test2 SET a2 = NEW.a1;
    DELETE FROM test3 WHERE a3 = NEW.a1;
    UPDATE test4 SET b4 = b4 + 1 WHERE a4 = NEW.a1;
  END;
|

delimiter ;

INSERT INTO test3 (a3) VALUES
  (NULL), (NULL), (NULL), (NULL), (NULL),
  (NULL), (NULL), (NULL), (NULL), (NULL);

INSERT INTO test4 (a4) VALUES
  (0), (0), (0), (0), (0), (0), (0), (0), (0), (0);
```

Suppose that you insert the following values into table `test1` as shown here:

```
mysql> INSERT INTO test1 VALUES
    -> (1), (3), (1), (7), (1), (8), (4), (4);
Query OK, 8 rows affected (0.01 sec)
Records: 8  Duplicates: 0  Warnings: 0
```

As a result, the four tables contain the following data:

```
mysql> SELECT * FROM test1;
+------+
| a1   |
+------+
|    1 |
|    3 |
|    1 |
|    7 |
|    1 |
|    8 |
|    4 |
|    4 |
+------+
8 rows in set (0.00 sec)

mysql> SELECT * FROM test2;
+------+
| a2   |
+------+
|    1 |
|    3 |
|    1 |
|    7 |
|    1 |
|    8 |
|    4 |
|    4 |
+------+
8 rows in set (0.00 sec)

mysql> SELECT * FROM test3;
+----+
| a3 |
+----+
|  2 |
|  5 |
|  6 |
|  9 |
| 10 |
+----+
```

```
5 rows in set (0.00 sec)

mysql> SELECT * FROM test4;
+----+------+
| a4 | b4   |
+----+------+
|  1 |    3 |
|  2 |    0 |
|  3 |    1 |
|  4 |    2 |
|  5 |    0 |
|  6 |    0 |
|  7 |    1 |
|  8 |    1 |
|  9 |    0 |
| 10 |    0 |
+----+------+
10 rows in set (0.00 sec)
```

19.3.2 Trigger Metadata

Metadata about triggers can be obtained as follows:

- Query the `TRIGGERS` table of the `INFORMATION_SCHEMA` database. See Section 20.23, "The INFORMATION_SCHEMA TRIGGERS Table".

- Use the `SHOW CREATE TRIGGER` statement. See Section 13.7.5.13, "SHOW CREATE TRIGGER Syntax".

- Use the `SHOW TRIGGERS` statement. See Section 13.7.5.40, "SHOW TRIGGERS Syntax".

19.4 Using the Event Scheduler

The *MySQL Event Scheduler* manages the scheduling and execution of events: Tasks that run according to schedule. Event support was added in MySQL 5.1.6. The following discussion covers the Event Scheduler and is divided into the following sections:

- Section 19.4.1, "Event Scheduler Overview", provides an introduction to and conceptual overview of MySQL Events.

- Section 19.4.3, "Event Syntax", discusses the SQL statements for creating, altering, and dropping MySQL Events.

- Section 19.4.4, "Event Metadata", shows how to obtain information about events and how this information is stored by the MySQL Server.

- Section 19.4.6, "The Event Scheduler and MySQL Privileges", discusses the privileges required to work with events and the ramifications that events have with regard to privileges when executing.

Stored routines require the `event` table in the `mysql` database. This table is created during the MySQL 5.1 installation procedure. If you are upgrading to MySQL 5.1 from an earlier version, be sure to update your grant tables to make sure that the `event` table exists. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

Additional Resources

- You may find the MySQL Event Scheduler User Forum of use when working with scheduled events.

- There are some restrictions on the use of events; see Section C.1, "Restrictions on Stored Programs".

- Binary logging for events takes place as described in Section 19.7, "Binary Logging of Stored Programs".

19.4.1 Event Scheduler Overview

MySQL Events are tasks that run according to a schedule. Therefore, we sometimes refer to them as *scheduled* events. When you create an event, you are creating a named database object containing one or more SQL statements to be executed at one or more regular intervals, beginning and ending at a specific date and time. Conceptually, this is similar to the idea of the Unix `crontab` (also known as a "cron job") or the Windows Task Scheduler.

Scheduled tasks of this type are also sometimes known as "temporal triggers", implying that these are objects that are triggered by the passage of time. While this is essentially correct, we prefer to use the term *events* to avoid confusion with triggers of the type discussed in Section 19.3, "Using Triggers". Events should more specifically not be confused with "temporary triggers". Whereas a trigger is a database object whose statements are executed in response to a specific type of event that occurs on a given table, a (scheduled) event is an object whose statements are executed in response to the passage of a specified time interval.

While there is no provision in the SQL Standard for event scheduling, there are precedents in other database systems, and you may notice some similarities between these implementations and that found in the MySQL Server.

MySQL Events have the following major features and properties:

- In MySQL 5.1.12 and later, an event is uniquely identified by its name and the schema to which it is assigned. (Previously, an event was also unique to its definer.)

- An event performs a specific action according to a schedule. This action consists of an SQL statement, which can be a compound statement in a `BEGIN ... END` block if desired (see Section 13.6, "MySQL Compound-Statement Syntax"). An event's timing can be either *one-time* or *recurrent*. A one-time event executes one time only. A recurrent event repeats its action at a regular interval, and the schedule for a recurring event can be assigned a specific start day and time, end day and time, both, or neither. (By default, a recurring event's schedule begins as soon as it is created, and continues indefinitely, until it is disabled or dropped.)

  If a repeating event does not terminate within its scheduling interval, the result may be multiple instances of the event executing simultaneously. If this is undesirable, you should institute a mechanism to prevent simultaneous instances. For example, you could use the `GET_LOCK()` function, or row or table locking.

- Users can create, modify, and drop scheduled events using SQL statements intended for these purposes. Syntactically invalid event creation and modification statements fail with an appropriate error message. *A user may include statements in an event's action which require privileges that the user does not actually have.* The event creation or modification statement succeeds but the event's action fails. See Section 19.4.6, "The Event Scheduler and MySQL Privileges" for details.

- Many of the properties of an event can be set or modified using SQL statements. These properties include the event's name, timing, persistence (that is, whether it is preserved following the expiration of its schedule), status (enabled or disabled), action to be performed, and the schema to which it is assigned. See Section 13.1.2, "ALTER EVENT Syntax".

  The default definer of an event is the user who created the event, unless the event has been altered, in which case the definer is the user who issued the last `ALTER EVENT` statement affecting that event. An event can be modified by any user having the `EVENT` privilege on the database for which the event is defined. (Prior to MySQL 5.1.12, only an event's definer, or a user having privileges on the `mysql.event` table, could modify a given event.) See Section 19.4.6, "The Event Scheduler and MySQL Privileges".

- An event's action statement may include most SQL statements permitted within stored routines. For restrictions, see Section C.1, "Restrictions on Stored Programs".

19.4.2 Event Scheduler Configuration

Events are executed by a special *event scheduler thread*; when we refer to the Event Scheduler, we actually refer to this thread. When running, the event scheduler thread and its current state can be seen by users having the PROCESS privilege in the output of SHOW PROCESSLIST, as shown in the discussion that follows.

The global event_scheduler system variable determines whether the Event Scheduler is enabled and running on the server. Beginning with MySQL 5.1.12, it has one of these 3 values, which affect event scheduling as described here:

- OFF: The Event Scheduler is stopped. The event scheduler thread does not run, is not shown in the output of SHOW PROCESSLIST, and no scheduled events are executed. OFF is the default value for event_scheduler.

  When the Event Scheduler is stopped (event_scheduler is OFF), it can be started by setting the value of event_scheduler to ON. (See next item.)

- ON: The Event Scheduler is started; the event scheduler thread runs and executes all scheduled events.

  When the Event Scheduler is ON, the event scheduler thread is listed in the output of SHOW PROCESSLIST as a daemon process, and its state is represented as shown here:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 1
   User: root
   Host: localhost
     db: NULL
Command: Query
   Time: 0
  State: NULL
   Info: show processlist
*************************** 2. row ***************************
     Id: 2
   User: event_scheduler
   Host: localhost
     db: NULL
Command: Daemon
   Time: 3
  State: Waiting for next activation
   Info: NULL
2 rows in set (0.00 sec)
```

  Event scheduling can be stopped by setting the value of event_scheduler to OFF.

- DISABLED: This value renders the Event Scheduler nonoperational. When the Event Scheduler is DISABLED, the event scheduler thread does not run (and so does not appear in the output of SHOW PROCESSLIST). In addition, the Event Scheduler state cannot be changed at runtime.

If the Event Scheduler status has not been set to DISABLED, event_scheduler can be toggled between ON and OFF (using SET). It is also possible to use 0 for OFF, and 1 for ON when setting this variable. Thus, any of the following 4 statements can be used in the mysql client to turn on the Event Scheduler:

```
SET GLOBAL event_scheduler = ON;
SET @@global.event_scheduler = ON;
```

```
SET GLOBAL event_scheduler = 1;
SET @@global.event_scheduler = 1;
```

Similarly, any of these 4 statements can be used to turn off the Event Scheduler:

```
SET GLOBAL event_scheduler = OFF;
SET @@global.event_scheduler = OFF;
SET GLOBAL event_scheduler = 0;
SET @@global.event_scheduler = 0;
```

Although `ON` and `OFF` have numeric equivalents, the value displayed for `event_scheduler` by `SELECT` or `SHOW VARIABLES` is always one of `OFF`, `ON`, or `DISABLED`. *DISABLED has no numeric equivalent*. For this reason, `ON` and `OFF` are usually preferred over `1` and `0` when setting this variable.

Note that attempting to set `event_scheduler` without specifying it as a global variable causes an error:

```
mysql< SET @@event_scheduler = OFF;
ERROR 1229 (HY000): Variable 'event_scheduler' is a GLOBAL
variable and should be set with SET GLOBAL
```

> **Important**
>
> It is possible to set the Event Scheduler to `DISABLED` only at server startup. If `event_scheduler` is `ON` or `OFF`, you cannot set it to `DISABLED` at runtime. Also, if the Event Scheduler is set to `DISABLED` at startup, you cannot change the value of `event_scheduler` at runtime.

To disable the event scheduler, use one of the following two methods:

- As a command-line option when starting the server:

  ```
  --event-scheduler=DISABLED
  ```

- In the server configuration file (`my.cnf`, or `my.ini` on Windows systems), include the line where it will be read by the server (for example, in a `[mysqld]` section):

  ```
  event_scheduler=DISABLED
  ```

To enable the Event Scheduler, restart the server without the `--event-scheduler=DISABLED` command-line option, or after removing or commenting out the line containing `event-scheduler=DISABLED` in the server configuration file, as appropriate. Alternatively, you can use `ON` (or `1`) or `OFF` (or `0`) in place of the `DISABLED` value when starting the server.

> **Note**
>
> You can issue event-manipulation statements when `event_scheduler` is set to `DISABLED`. No warnings or errors are generated in such cases (provided that the statements are themselves valid). However, scheduled events cannot execute until this variable is set to `ON` (or `1`). Once this has been done, the event scheduler thread executes all events whose scheduling conditions are satisfied.

In MySQL 5.1.11, `event_scheduler` behaved as follows: this variable could take one of the values `0` (or `OFF`), `1` (or `ON`), or `2`. Setting it to `0` turned event scheduling off, so that the event scheduler thread did not run; the `event_scheduler` variable could not be set to this value while the server was running. Setting it to `1` so that the event scheduler thread ran and executed scheduled events. In this state, the event scheduler thread appeared to be sleeping when viewed with `SHOW PROCESSLIST`. When

`event_scheduler` was set to `2` (which was the default value), the Event Scheduler was considered to be "suspended"; the event scheduler thread ran and could be seen in the output of `SHOW PROCESSLIST` (where `Suspended` was displayed in the `State` column), but did not execute any scheduled events. The value of `event_scheduler` could be changed only between `1` (or `ON`) and `2` while the server was running. Setting it to `0` (or `OFF`) required a server restart, as did changing its value from `0` (or `OFF`) to `1` (or `ON`) or `2`.

Prior to MySQL 5.1.11, `event_scheduler` could take one of only the 2 values `0|OFF` or `1|ON`, and the default value was `0|OFF`. It was also possible to start and stop the event scheduler thread while the MySQL server was running.

For more information concerning the reasons for these changes in behavior, see Bug #17619.

Beginning with MySQL 5.1.17, starting the MySQL server with the `--skip-grant-tables` option causes `event_scheduler` to be set to `DISABLED`, overriding any other value set either on the command line or in the `my.cnf` or `my.ini` file (Bug #26807).

For SQL statements used to create, alter, and drop events, see Section 19.4.3, "Event Syntax".

MySQL 5.1.6 and later provides an `EVENTS` table in the `INFORMATION_SCHEMA` database. This table can be queried to obtain information about scheduled events which have been defined on the server. See Section 19.4.4, "Event Metadata", and Section 20.7, "The INFORMATION_SCHEMA EVENTS Table", for more information.

For information regarding event scheduling and the MySQL privilege system, see Section 19.4.6, "The Event Scheduler and MySQL Privileges".

19.4.3 Event Syntax

MySQL 5.1.6 and later provides several SQL statements for working with scheduled events:

- New events are defined using the `CREATE EVENT` statement. See Section 13.1.11, "CREATE EVENT Syntax".

- The definition of an existing event can be changed by means of the `ALTER EVENT` statement. See Section 13.1.2, "ALTER EVENT Syntax".

- When a scheduled event is no longer wanted or needed, it can be deleted from the server by its definer using the `DROP EVENT` statement. See Section 13.1.22, "DROP EVENT Syntax". Whether an event persists past the end of its schedule also depends on its `ON COMPLETION` clause, if it has one. See Section 13.1.11, "CREATE EVENT Syntax".

  An event can be dropped by any user having the `EVENT` privilege for the database on which the event is defined. Prior to MySQL 5.1.12, a user other than the definer required privileges on the `mysql.event` table. See Section 19.4.6, "The Event Scheduler and MySQL Privileges".

19.4.4 Event Metadata

Metadata about events can be obtained as follows:

- Query the `event` table of the `mysql` database.

- Query the `EVENTS` table of the `INFORMATION_SCHEMA` database. See Section 20.7, "The INFORMATION_SCHEMA EVENTS Table".

- Use the `SHOW CREATE EVENT` statement. See Section 13.7.5.9, "SHOW CREATE EVENT Syntax".

- Use the `SHOW EVENTS` statement. See Section 13.7.5.19, "SHOW EVENTS Syntax".

Event Scheduler Time Representation

Each session in MySQL has a session time zone (STZ). This is the session `time_zone` value that is initialized from the server's global `time_zone` value when the session begins but may be changed during the session.

The session time zone that is current when a `CREATE EVENT` or `ALTER EVENT` statement executes is used to interpret times specified in the event definition. This becomes the event time zone (ETZ); that is, the time zone that is used for event scheduling and is in effect within the event as it executes.

For representation of event information in the `mysql.event` table, the `execute_at`, `starts`, and `ends` times are converted to UTC and stored along with the event time zone. This enables event execution to proceed as defined regardless of any subsequent changes to the server time zone or daylight saving time effects. The `last_executed` time is also stored in UTC.

If you select information from `mysql.event`, the times just mentioned are retrieved as UTC values. These times can also be obtained by selecting from the `INFORMATION_SCHEMA.EVENTS` table or from `SHOW EVENTS`, but they are reported as ETZ values. Other times available from these sources indicate when an event was created or last altered; these are displayed as STZ values. The following table summarizes representation of event times.

Value	`mysql.event`	`INFORMATION_SCHEMA.EVENTS`	`SHOW EVENTS`
Execute at	UTC	ETZ	ETZ
Starts	UTC	ETZ	ETZ
Ends	UTC	ETZ	ETZ
Last executed	UTC	ETZ	n/a
Created	STZ	STZ	n/a
Last altered	STZ	STZ	n/a

The preceding table applies for MySQL 5.1.17 and up. Prior to MySQL 5.1.17, the event time zone is not stored in the `mysql.event` table or available from `INFORMATION_SCHEMA.EVENTS` or `SHOW EVENTS`. Times that are displayed using ETZ from 5.1.17 and up are displayed in UTC before 5.1.17, as shown in the following table.

Value	`mysql.event`	`INFORMATION_SCHEMA.EVENTS`	`SHOW EVENTS`
Execute at	UTC	UTC	UTC
Starts	UTC	UTC	UTC
Ends	UTC	UTC	UTC
Last executed	UTC	UTC	n/a
Created	STZ	STZ	n/a
Last altered	STZ	STZ	n/a

19.4.5 Event Scheduler Status

The Event Scheduler writes information about event execution that terminates with an error or warning to the MySQL Server's error log. See Section 19.4.6, "The Event Scheduler and MySQL Privileges" for an example. (Before MySQL 5.1.31, the Event Scheduler also logged messages when events started execution and terminated successfully.)

Information about the state of the Event Scheduler for debugging and troubleshooting purposes can be obtained as follows:

- In debugging builds of MySQL 5.1.11, you can use the `SHOW SCHEDULER STATUS` statement; see Section 13.7.5.34, "SHOW SCHEDULER STATUS Syntax". This statement was removed in MySQL 5.1.12. We intend to implement an SQL statement providing similar functionality in a future MySQL release.

- Beginning with MySQL 5.1.12, event scheduler status information can be obtained by running `mysqladmin debug` (see Section 4.5.2, "`mysqladmin` — Client for Administering a MySQL Server"); after running this command, the server's error log contains output relating to the Event Scheduler, similar to what is shown here:

```
Events status:
LLA = Last Locked At  LUA = Last Unlocked At
WOC = Waiting On Condition  DL = Data Locked

Event scheduler status:
State      : INITIALIZED
Thread id  : 0
LLA        : init_scheduler:313
LUA        : init_scheduler:318
WOC        : NO
Workers    : 0
Executed   : 0
Data locked: NO

Event queue status:
Element count   : 1
Data locked     : NO
Attempting lock : NO
LLA             : init_queue:148
LUA             : init_queue:168
WOC             : NO
Next activation : 0000-00-00 00:00:00
```

In statements that occur as part of events executed by the Event Scheduler, diagnostics messages (not only errors, but also warnings) are written to the error log, and, on Windows, to the application event log. For frequently executed events, it is possible for this to result in many logged messages. For example, for `SELECT ... INTO var_list` statements, if the query returns no rows, a warning with error code 1329 occurs (`No data`), and the variable values remain unchanged. If the query returns multiple rows, error 1172 occurs (`Result consisted of more than one row`). For either condition, you can avoid having the warnings be logged by declaring a condition handler; see Section 13.6.7.2, "DECLARE ... HANDLER Syntax". For statements that may retrieve multiple rows, another strategy is to use `LIMIT 1` to limit the result set to a single row.

19.4.6 The Event Scheduler and MySQL Privileges

To enable or disable the execution of scheduled events, it is necessary to set the value of the global `event_scheduler` system variable. This requires the `SUPER` privilege.

MySQL 5.1.6 introduces a privilege governing the creation, modification, and deletion of events, the `EVENT` privilege. This privilege can be bestowed using `GRANT`. For example, this `GRANT` statement confers the `EVENT` privilege for the schema named `myschema` on the user `jon@ghidora`:

```
GRANT EVENT ON myschema.* TO jon@ghidora;
```

(We assume that this user account already exists, and that we wish for it to remain unchanged otherwise.)

To grant this same user the `EVENT` privilege on all schemas, use the following statement:

```
GRANT EVENT ON *.* TO jon@ghidora;
```

The EVENT privilege has global or schema-level scope. Therefore, trying to grant it on a single table results in an error as shown:

```
mysql> GRANT EVENT ON myschema.mytable TO jon@ghidora;
ERROR 1144 (42000): Illegal GRANT/REVOKE command; please
consult the manual to see which privileges can be used
```

It is important to understand that an event is executed with the privileges of its definer, and that it cannot perform any actions for which its definer does not have the requisite privileges. For example, suppose that jon@ghidora has the EVENT privilege for myschema. Suppose also that this user has the SELECT privilege for myschema, but no other privileges for this schema. It is possible for jon@ghidora to create a new event such as this one:

```
CREATE EVENT e_store_ts
    ON SCHEDULE
      EVERY 10 SECOND
    DO
      INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP());
```

The user waits for a minute or so, and then performs a SELECT * FROM mytable; query, expecting to see several new rows in the table. Instead, the table is empty. Since the user does not have the INSERT privilege for the table in question, the event has no effect.

If you inspect the MySQL error log (hostname.err), you can see that the event is executing, but the action it is attempting to perform fails, as indicated by RetCode=0:

```
060209 22:39:44 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:39:44 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
060209 22:39:54 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:39:54 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
060209 22:40:04 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:40:04 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
```

Since this user very likely does not have access to the error log, it is possible to verify whether the event's action statement is valid by executing it directly:

```
mysql> INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP());
ERROR 1142 (42000): INSERT command denied to user
'jon'@'ghidora' for table 'mytable'
```

Inspection of the INFORMATION_SCHEMA.EVENTS table shows that e_store_ts exists and is enabled, but its LAST_EXECUTED column is NULL:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.EVENTS
    >      WHERE EVENT_NAME='e_store_ts'
    >      AND EVENT_SCHEMA='myschema'\G
*************************** 1. row ***************************
   EVENT_CATALOG: NULL
    EVENT_SCHEMA: myschema
      EVENT_NAME: e_store_ts
         DEFINER: jon@ghidora
      EVENT_BODY: SQL
EVENT_DEFINITION: INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP())
      EVENT_TYPE: RECURRING
      EXECUTE_AT: NULL
  INTERVAL_VALUE: 5
```

```
   INTERVAL_FIELD: SECOND
        SQL_MODE: NULL
          STARTS: 0000-00-00 00:00:00
            ENDS: 0000-00-00 00:00:00
          STATUS: ENABLED
   ON_COMPLETION: NOT PRESERVE
         CREATED: 2006-02-09 22:36:06
    LAST_ALTERED: 2006-02-09 22:36:06
   LAST_EXECUTED: NULL
   EVENT_COMMENT:
1 row in set (0.00 sec)
```

Note

Prior to MySQL 5.1.12, there was no `EVENT_DEFINITION` column, and `EVENT_BODY` contained the SQL statement or statements to be executed. See Section 20.7, "The INFORMATION_SCHEMA EVENTS Table", for more information.

To rescind the `EVENT` privilege, use the `REVOKE` statement. In this example, the `EVENT` privilege on the schema `myschema` is removed from the `jon@ghidora` user account:

```
REVOKE EVENT ON myschema.* FROM jon@ghidora;
```

Important

Revoking the `EVENT` privilege from a user does not delete or disable any events that may have been created by that user.

An event is not migrated or dropped as a result of renaming or dropping the user who created it.

Suppose that the user `jon@ghidora` has been granted the `EVENT` and `INSERT` privileges on the `myschema` schema. This user then creates the following event:

```
CREATE EVENT e_insert
    ON SCHEDULE
      EVERY 7 SECOND
    DO
      INSERT INTO myschema.mytable;
```

After this event has been created, `root` revokes the `EVENT` privilege for `jon@ghidora`. However, `e_insert` continues to execute, inserting a new row into `mytable` each seven seconds. The same would be true if `root` had issued either of these statements:

- `DROP USER jon@ghidora;`

- `RENAME USER jon@ghidora TO someotherguy@ghidora;`

You can verify that this is true by examining the `mysql.event` table (discussed later in this section) or the `INFORMATION_SCHEMA.EVENTS` table (see Section 20.7, "The INFORMATION_SCHEMA EVENTS Table") before and after issuing a `DROP USER` or `RENAME USER` statement.

Event definitions are stored in the `mysql.event` table, which was added in MySQL 5.1.6. To drop an event created by another user account, the MySQL `root` user (or another user with the necessary privileges) can delete rows from this table. For example, to remove the event `e_insert` shown previously, `root` can use the following statement:

```
DELETE FROM mysql.event
```

```
    WHERE db = 'myschema'
      AND definer = 'jon@ghidora'
      AND name = 'e_insert';
```

It is very important to match the event name, database schema name, and user account when deleting rows from the `mysql.event` table. This is because the same user can create different events of the same name in different schemas.

> **Note**
>
> The namespace for scheduled events changed in MySQL 5.1.12. Prior to that MySQL version, different users could create different events having the same name in the same database; in MySQL 5.1.12 and later, that is no longer the case. When upgrading to MySQL 5.1.12 or later from MySQL 5.1.11 or earlier, it is extremely important to make sure that no events in the same database share the same name, *prior to performing the upgrade.*

Users' `EVENT` privileges are stored in the `Event_priv` columns of the `mysql.user` and `mysql.db` tables. In both cases, this column holds one of the values 'Y' or 'N'. 'N' is the default. `mysql.user.Event_priv` is set to 'Y' for a given user only if that user has the global `EVENT` privilege (that is, if the privilege was bestowed using `GRANT EVENT ON *.*`). For a schema-level `EVENT` privilege, `GRANT` creates a row in `mysql.db` and sets that row's `Db` column to the name of the schema, the `User` column to the name of the user, and the `Event_priv` column to 'Y'. There should never be any need to manipulate these tables directly, since the `GRANT EVENT` and `REVOKE EVENT` statements perform the required operations on them.

MySQL 5.1.6 introduces five status variables providing counts of event-related operations (but *not* of statements executed by events; see Section C.1, "Restrictions on Stored Programs"). These are:

- `Com_create_event`: The number of `CREATE EVENT` statements executed since the last server restart.

- `Com_alter_event`: The number of `ALTER EVENT` statements executed since the last server restart.

- `Com_drop_event`: The number of `DROP EVENT` statements executed since the last server restart.

- `Com_show_create_event`: The number of `SHOW CREATE EVENT` statements executed since the last server restart.

- `Com_show_events`: The number of `SHOW EVENTS` statements executed since the last server restart.

You can view current values for all of these at one time by running the statement `SHOW STATUS LIKE '%event%';`.

19.5 Using Views

MySQL supports views, including updatable views. Views are stored queries that when invoked produce a result set. A view acts as a virtual table.

To use views if you have upgraded to MySQL 5.1 from an older release that did not support views, you should upgrade your grant tables so that they contain the view-related privileges. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".

The following discussion describes the syntax for creating and dropping views, and shows some examples of how to use them.

Additional Resources

- You may find the Views User Forum of use when working with views.

- For answers to some commonly asked questions regarding views in MySQL, see Section A.6, "MySQL 5.1 FAQ: Views".

- There are some restrictions on the use of views; see Section C.4, "Restrictions on Views".

19.5.1 View Syntax

The `CREATE VIEW` statement creates a new view (see Section 13.1.20, "CREATE VIEW Syntax"). To alter the definition of a view or drop a view, use `ALTER VIEW` (see Section 13.1.9, "ALTER VIEW Syntax"), or `DROP VIEW` (see Section 13.1.31, "DROP VIEW Syntax").

A view can be created from many kinds of `SELECT` statements. It can refer to base tables or other views. It can use joins, `UNION`, and subqueries. The `SELECT` need not even refer to any tables. The following example defines a view that selects two columns from another table, as well as an expression calculated from those columns:

```
mysql> CREATE TABLE t (qty INT, price INT);
mysql> INSERT INTO t VALUES(3, 50), (5, 60);
mysql> CREATE VIEW v AS SELECT qty, price, qty*price AS value FROM t;
mysql> SELECT * FROM v;
+------+-------+-------+
| qty  | price | value |
+------+-------+-------+
|    3 |    50 |   150 |
|    5 |    60 |   300 |
+------+-------+-------+
mysql> SELECT * FROM v WHERE qty = 5;
+------+-------+-------+
| qty  | price | value |
+------+-------+-------+
|    5 |    60 |   300 |
+------+-------+-------+
```

19.5.2 View Processing Algorithms

The optional `ALGORITHM` clause for `CREATE VIEW` or `ALTER VIEW` is a MySQL extension to standard SQL. It affects how MySQL processes the view. `ALGORITHM` takes three values: `MERGE`, `TEMPTABLE`, or `UNDEFINED`.

- For `MERGE`, the text of a statement that refers to the view and the view definition are merged such that parts of the view definition replace corresponding parts of the statement.

- For `TEMPTABLE`, the results from the view are retrieved into a temporary table, which then is used to execute the statement.

- For `UNDEFINED`, MySQL chooses which algorithm to use. It prefers `MERGE` over `TEMPTABLE` if possible, because `MERGE` is usually more efficient and because a view cannot be updatable if a temporary table is used.

- If no `ALGORITHM` clause is present, `UNDEFINED` is the default algorithm.

A reason to specify `TEMPTABLE` explicitly is that locks can be released on underlying tables after the temporary table has been created and before it is used to finish processing the statement. This might result in quicker lock release than the `MERGE` algorithm so that other clients that use the view are not blocked as long.

A view algorithm can be `UNDEFINED` for three reasons:

- No `ALGORITHM` clause is present in the `CREATE VIEW` statement.

- The `CREATE VIEW` statement has an explicit `ALGORITHM = UNDEFINED` clause.

- `ALGORITHM = MERGE` is specified for a view that can be processed only with a temporary table. In this case, MySQL generates a warning and sets the algorithm to `UNDEFINED`.

As mentioned earlier, `MERGE` is handled by merging corresponding parts of a view definition into the statement that refers to the view. The following examples briefly illustrate how the `MERGE` algorithm works. The examples assume that there is a view `v_merge` that has this definition:

```
CREATE ALGORITHM = MERGE VIEW v_merge (vc1, vc2) AS
SELECT c1, c2 FROM t WHERE c3 > 100;
```

Example 1: Suppose that we issue this statement:

```
SELECT * FROM v_merge;
```

MySQL handles the statement as follows:

- `v_merge` becomes `t`

- `*` becomes `vc1, vc2`, which corresponds to `c1, c2`

- The view `WHERE` clause is added

The resulting statement to be executed becomes:

```
SELECT c1, c2 FROM t WHERE c3 > 100;
```

Example 2: Suppose that we issue this statement:

```
SELECT * FROM v_merge WHERE vc1 < 100;
```

This statement is handled similarly to the previous one, except that `vc1 < 100` becomes `c1 < 100` and the view `WHERE` clause is added to the statement `WHERE` clause using an `AND` connective (and parentheses are added to make sure the parts of the clause are executed with correct precedence). The resulting statement to be executed becomes:

```
SELECT c1, c2 FROM t WHERE (c3 > 100) AND (c1 < 100);
```

Effectively, the statement to be executed has a `WHERE` clause of this form:

```
WHERE (select WHERE) AND (view WHERE)
```

If the `MERGE` algorithm cannot be used, a temporary table must be used instead. `MERGE` cannot be used if the view contains any of the following constructs:

- Aggregate functions (`SUM()`, `MIN()`, `MAX()`, `COUNT()`, and so forth)

- `DISTINCT`

- `GROUP BY`

- `HAVING`

- `LIMIT`

- `UNION` or `UNION ALL`

- Subquery in the select list

- Assignment to user variables

- Refers only to literal values (in this case, there is no underlying table)

19.5.3 Updatable and Insertable Views

Some views are updatable and references to them can be used to specify tables to be updated in data change statements. That is, you can use them in statements such as `UPDATE`, `DELETE`, or `INSERT` to update the contents of the underlying table.

For a view to be updatable, there must be a one-to-one relationship between the rows in the view and the rows in the underlying table. There are also certain other constructs that make a view nonupdatable. To be more specific, a view is not updatable if it contains any of the following:

- Aggregate functions (`SUM()`, `MIN()`, `MAX()`, `COUNT()`, and so forth)

- `DISTINCT`

- `GROUP BY`

- `HAVING`

- `UNION` or `UNION ALL`

- Subquery in the select list

- Certain joins (see additional join discussion later in this section)

- Reference to nonupdatable view in the `FROM` clause

- Subquery in the `WHERE` clause that refers to a table in the `FROM` clause

- Refers only to literal values (in this case, there is no underlying table to update)

- `ALGORITHM = TEMPTABLE` (use of a temporary table always makes a view nonupdatable)

- Multiple references to any column of a base table

It is sometimes possible for a multiple-table view to be updatable, assuming that it can be processed with the `MERGE` algorithm. For this to work, the view must use an inner join (not an outer join or a `UNION`). Also, only a single table in the view definition can be updated, so the `SET` clause must name only columns from one of the tables in the view. Views that use `UNION ALL` are not permitted even though they might be theoretically updatable.

With respect to insertability (being updatable with `INSERT` statements), an updatable view is insertable if it also satisfies these additional requirements for the view columns:

- There must be no duplicate view column names.

- The view must contain all columns in the base table that do not have a default value.

- The view columns must be simple column references. They must not be expressions or composite expressions, such as these:

```
3.14159
col1 + 3
UPPER(col2)
```

```
col3 / col4
(subquery)
```

MySQL sets a flag, called the view updatability flag, at `CREATE VIEW` time. The flag is set to `YES` (true) if `UPDATE` and `DELETE` (and similar operations) are legal for the view. Otherwise, the flag is set to `NO` (false). The `IS_UPDATABLE` column in the `INFORMATION_SCHEMA.VIEWS` table displays the status of this flag. It means that the server always knows whether a view is updatable.

If a view is not updatable, statements such `UPDATE`, `DELETE`, and `INSERT` are illegal and are rejected. (Note that even if a view is updatable, it might not be possible to insert into it, as described elsewhere in this section.)

The updatability of views may be affected by the value of the `updatable_views_with_limit` system variable. See Section 5.1.4, "Server System Variables".

Earlier discussion in this section pointed out that a view is not insertable if not all columns are simple column references (for example, if it contains columns that are expressions or composite expressions). Although such a view is not insertable, it can be updatable if you update only columns that are not expressions. Consider this view:

```
CREATE VIEW v AS SELECT col1, 1 AS col2 FROM t;
```

This view is not insertable because `col2` is an expression. But it is updatable if the update does not try to update `col2`. This update is permissible:

```
UPDATE v SET col1 = 0;
```

This update is not permissible because it attempts to update an expression column:

```
UPDATE v SET col2 = 0;
```

For a multiple-table updatable view, `INSERT` can work if it inserts into a single table. `DELETE` is not supported.

`INSERT DELAYED` is not supported for views.

If a table contains an `AUTO_INCREMENT` column, inserting into an insertable view on the table that does not include the `AUTO_INCREMENT` column does not change the value of `LAST_INSERT_ID()`, because the side effects of inserting default values into columns not part of the view should not be visible.

19.5.4 The View WITH CHECK OPTION Clause

The `WITH CHECK OPTION` clause can be given for an updatable view to prevent inserts to rows for which the `WHERE` clause in the `select_statement` is not true. It aslo prevents updates to rows for which the `WHERE` clause is true but the update would cause it to be not true (in other words, it prevents visible rows from being updated to nonvisible rows).

In a `WITH CHECK OPTION` clause for an updatable view, the `LOCAL` and `CASCADED` keywords determine the scope of check testing when the view is defined in terms of another view. When neither keyword is given, the default is `CASCADED`. The `LOCAL` keyword restricts the `CHECK OPTION` only to the view being defined. `CASCADED` causes the checks for underlying views to be evaluated as well.

Consider the definitions for the following table and set of views:

```
CREATE TABLE t1 (a INT);
CREATE VIEW v1 AS SELECT * FROM t1 WHERE a < 2
```

```
WITH CHECK OPTION;
CREATE VIEW v2 AS SELECT * FROM v1 WHERE a > 0
WITH LOCAL CHECK OPTION;
CREATE VIEW v3 AS SELECT * FROM v1 WHERE a > 0
WITH CASCADED CHECK OPTION;
```

Here the `v2` and `v3` views are defined in terms of another view, `v1`. `v2` has a `LOCAL` check option, so inserts are tested only against the `v2` check. `v3` has a `CASCADED` check option, so inserts are tested not only against its own check, but against those of underlying views. The following statements illustrate these differences:

```
mysql> INSERT INTO v2 VALUES (2);
Query OK, 1 row affected (0.00 sec)
mysql> INSERT INTO v3 VALUES (2);
ERROR 1369 (HY000): CHECK OPTION failed 'test.v3'
```

19.5.5 View Metadata

Metadata about views can be obtained as follows:

- Query the `VIEWS` table of the `INFORMATION_SCHEMA` database. See Section 20.25, "The INFORMATION_SCHEMA VIEWS Table".

- Use the `SHOW CREATE VIEW` statement. See Section 13.7.5.14, "SHOW CREATE VIEW Syntax".

19.6 Access Control for Stored Programs and Views

Stored programs and views are defined prior to use and, when referenced, execute within a security context that determines their privileges. These privileges are controlled by their `DEFINER` attribute, and, if there is one, their `SQL SECURITY` characteristic.

All stored programs (procedures, functions, triggers, and events) and views can have a `DEFINER` attribute that names a MySQL account. If the `DEFINER` attribute is omitted from a stored program or view definition, the default account is the user who creates the object.

In addition, stored routines (procedures and functions) and views can have a `SQL SECURITY` characteristic with a value of `DEFINER` or `INVOKER` to specify whether the object executes in definer or invoker context. If the `SQL SECURITY` characteristic is omitted, the default is definer context.

Triggers and events have no `SQL SECURITY` characteristic and always execute in definer context. The server invokes these objects automatically as necessary, so there is no invoking user.

Definer and invoker security contexts differ as follows:

- A stored program or view that executes in definer security context executes with the privileges of the account named by its `DEFINER` attribute. These privileges may be entirely different from those of the invoking user. The invoker must have appropriate privileges to reference the object (for example, `EXECUTE` to call a stored procedure or `SELECT` to select from a view), but when the object executes, the invoker's privileges are ignored and only the `DEFINER` account privileges matter. If this account has few privileges, the object is correspondingly limited in the operations it can perform. If the `DEFINER` account is highly privileged (such as a `root` account), the object can perform powerful operations *no matter who invokes it.*

- A stored routine or view that executes in invoker security context can perform only operations for which the invoker has privileges. The `DEFINER` attribute can be specified but has no effect for objects that execute in invoker context.

Consider the following stored procedure:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE p1()
SQL SECURITY DEFINER
BEGIN
  UPDATE t1 SET counter = counter + 1;
END;
```

Any user who has the `EXECUTE` privilege for `p1` can invoke it with a `CALL` statement. However, when `p1` executes, it does so in `DEFINER` security context and thus executes with the privileges of `'admin'@'localhost'`, the account named in the `DEFINER` attribute. This account must have the `EXECUTE` privilege for `p1` as well as the `UPDATE` privilege for the table `t1`. Otherwise, the procedure fails.

Now consider this stored procedure, which is identical to `p1` except that its `SQL SECURITY` characteristic is `INVOKER`:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE p2()
SQL SECURITY INVOKER
BEGIN
  UPDATE t1 SET counter = counter + 1;
END;
```

`p2`, unlike `p1`, executes in `INVOKER` security context. The `DEFINER` attribute is irrelevant and `p2` executes with the privileges of the invoking user. `p2` fails if the invoker lacks the `EXECUTE` privilege for `p2` or the `UPDATE` privilege for the table `t1`.

MySQL uses the following rules to control which accounts a user can specify in an object `DEFINER` attribute:

- You can specify a `DEFINER` value other than your own account only if you have the `SUPER` privilege.

- If you do not have the `SUPER` privilege, the only legal user value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.

To minimize the risk potential for stored program and view creation and use, follow these guidelines:

- For a stored routine or view, use `SQL SECURITY INVOKER` in the object definition when possible so that it can be used only by users with permissions appropriate for the operations performed by the object.

- If you create definer-context stored programs or views while using an account that has the `SUPER` privilege, specify an explicit `DEFINER` attribute that names an account possessing only the privileges required for the operations performed by the object. Specify a highly privileged `DEFINER` account only when absolutely necessary.

- Administrators can prevent users from specifying highly privileged `DEFINER` accounts by not granting them the `SUPER` privilege.

- Definer-context objects should be written keeping in mind that they may be able to access data for which the invoking user has no privileges. In some cases, you can prevent reference to these objects by not granting unauthorized users particular privileges:

  - A stored procedure or function cannot be referenced by a user who does not have the `EXECUTE` privilege for it.

  - A view cannot be referenced by a user who does not have the appropriate privilege for it (`SELECT` to select from it, `INSERT` to insert into it, and so forth).

  However, no such control exists for triggers because users do not reference them directly. A trigger always executes in `DEFINER` context and is activated by access to the table with which it is associated,

even ordinary table accesses by users with no special privileges. If the `DEFINER` account is highly privileged, the trigger can perform sensitive or dangerous operations. This remains true if the `SUPER` and `TRIGGER` privileges needed to create the trigger are revoked from the account of the user who created it. Administrators should be especially careful about granting users that combination of privileges.

19.7 Binary Logging of Stored Programs

The binary log contains information about SQL statements that modify database contents. This information is stored in the form of "events" that describe the modifications. The binary log has two important purposes:

- For replication, the binary log is used on master replication servers as a record of the statements to be sent to slave servers. The master server sends the events contained in its binary log to its slaves, which execute those events to make the same data changes that were made on the master. See Section 16.2, "Replication Implementation".

- Certain data recovery operations require use of the binary log. After a backup file has been restored, the events in the binary log that were recorded after the backup was made are re-executed. These events bring databases up to date from the point of the backup. See Section 7.3.2, "Using Backups for Recovery".

However, there are certain binary logging issues that apply with respect to stored programs (stored procedures and functions, triggers, and events), if logging occurs at the statement level:

- In some cases, it is possible that a statement will affect different sets of rows on a master and a slave.

- Replicated statements executed on a slave are processed by the slave SQL thread, which has full privileges. It is possible for a procedure to follow different execution paths on master and slave servers, so a user can write a routine containing a dangerous statement that will execute only on the slave where it is processed by a thread that has full privileges.

- If a stored program that modifies data is nondeterministic, it is not repeatable. This can result in different data on a master and slave, or cause restored data to differ from the original data.

This section describes how MySQL 5.1 handles binary logging for stored programs. It states the current conditions that the implementation places on the use of stored programs, and what you can do to avoid problems. It also provides additional information about the reasons for these conditions.

In general, the issues described here result when binary logging occurs at the SQL statement level. If you use row-based binary logging, the log contains changes made to individual rows as a result of executing SQL statements. When routines or triggers execute, row changes are logged, not the statements that make the changes. For stored procedures, this means that the `CALL` statement is not logged. For stored functions, row changes made within the function are logged, not the function invocation. For triggers, row changes made by the trigger are logged. On the slave side, only the row changes are seen, not the stored program invocation. For general information about row-based logging, see Section 16.1.2, "Replication Formats".

Unless noted otherwise, the remarks here assume that you have enabled binary logging by starting the server with the `--log-bin` option. (See Section 5.4.4, "The Binary Log".) If the binary log is not enabled, replication is not possible, nor is the binary log available for data recovery.

The current conditions on the use of stored functions in MySQL 5.1 can be summarized as follows. These conditions do not apply to stored procedures or Event Scheduler events and they do not apply unless binary logging is enabled.

- To create or alter a stored function, you must have the `SUPER` privilege, in addition to the `CREATE ROUTINE` or `ALTER ROUTINE` privilege that is normally required. (Depending on the `DEFINER` value in

the function definition, SUPER might be required regardless of whether binary logging is enabled. See Section 13.1.15, "CREATE PROCEDURE and CREATE FUNCTION Syntax".)

- When you create a stored function, you must declare either that it is deterministic or that it does not modify data. Otherwise, it may be unsafe for data recovery or replication.

  By default, for a CREATE FUNCTION statement to be accepted, at least one of DETERMINISTIC, NO SQL, or READS SQL DATA must be specified explicitly. Otherwise an error occurs:

  ```
  ERROR 1418 (HY000): This function has none of DETERMINISTIC, NO SQL,
  or READS SQL DATA in its declaration and binary logging is enabled
  (you *might* want to use the less safe log_bin_trust_function_creators
  variable)
  ```

  This function is deterministic (and does not modify data), so it is safe:

  ```
  CREATE FUNCTION f1(i INT)
  RETURNS INT
  DETERMINISTIC
  READS SQL DATA
  BEGIN
    RETURN i;
  END;
  ```

  This function uses UUID(), which is not deterministic, so the function also is not deterministic and is not safe:

  ```
  CREATE FUNCTION f2()
  RETURNS CHAR(36) CHARACTER SET utf8
  BEGIN
    RETURN UUID();
  END;
  ```

  This function modifies data, so it may not be safe:

  ```
  CREATE FUNCTION f3(p_id INT)
  RETURNS INT
  BEGIN
    UPDATE t SET modtime = NOW() WHERE id = p_id;
    RETURN ROW_COUNT();
  END;
  ```

  Assessment of the nature of a function is based on the "honesty" of the creator: MySQL does not check that a function declared DETERMINISTIC is free of statements that produce nondeterministic results.

- Although it is possible to create a deterministic stored function without specifying DETERMINISTIC, you cannot as of MySQL 5.1.15 execute this function using statement-based binary logging. To execute such a function, you must use row-based or mixed binary logging. Alternatively, if you explicitly specify DETERMINISTIC in the function definition, you can use any kind of logging, including statement-based logging.

- To relax the preceding conditions on function creation (that you must have the SUPER privilege and that a function must be declared deterministic or to not modify data), set the global log_bin_trust_function_creators system variable to 1. By default, this variable has a value of 0, but you can change it like this:

  ```
  mysql> SET GLOBAL log_bin_trust_function_creators = 1;
  ```

You can also set this variable by using the `--log-bin-trust-function-creators=1` option when starting the server.

If binary logging is not enabled, `log_bin_trust_function_creators` does not apply. `SUPER` is not required for function creation unless, as described previously, the `DEFINER` value in the function definition requires it.

- For information about built-in functions that may be unsafe for replication (and thus cause stored functions that use them to be unsafe as well), see Section 16.4.1, "Replication Features and Issues".

Triggers are similar to stored functions, so the preceding remarks regarding functions also apply to triggers with the following exception: `CREATE TRIGGER` does not have an optional `DETERMINISTIC` characteristic, so triggers are assumed to be always deterministic. However, this assumption might in some cases be invalid. For example, the `UUID()` function is nondeterministic (and does not replicate). You should be careful about using such functions in triggers.

Triggers can update tables, so error messages similar to those for stored functions occur with `CREATE TRIGGER` if you do not have the required privileges. On the slave side, the slave uses the trigger `DEFINER` attribute to determine which user is considered to be the creator of the trigger.

The rest of this section provides additional detail about the logging implementation and its implications. You need not read it unless you are interested in the background on the rationale for the current logging-related conditions on stored routine use. This discussion applies only for statement-based logging, and not for row-based logging, with the exception of the first item: `CREATE` and `DROP` statements are logged as statements regardless of the logging mode.

- The server writes `CREATE EVENT`, `CREATE PROCEDURE`, `CREATE FUNCTION`, `ALTER EVENT`, `ALTER PROCEDURE`, `ALTER FUNCTION`, `DROP EVENT`, `DROP PROCEDURE`, and `DROP FUNCTION` statements to the binary log.

- A stored function invocation is logged as a `SELECT` statement if the function changes data and occurs within a statement that would not otherwise be logged. This prevents nonreplication of data changes that result from use of stored functions in nonlogged statements. For example, `SELECT` statements are not written to the binary log, but a `SELECT` might invoke a stored function that makes changes. To handle this, a `SELECT func_name()` statement is written to the binary log when the given function makes a change. Suppose that the following statements are executed on the master:

```
CREATE FUNCTION f1(a INT) RETURNS INT
BEGIN
  IF (a < 3) THEN
    INSERT INTO t2 VALUES (a);
  END IF;
  RETURN 0;
END;

CREATE TABLE t1 (a INT);
INSERT INTO t1 VALUES (1),(2),(3);

SELECT f1(a) FROM t1;
```

When the `SELECT` statement executes, the function `f1()` is invoked three times. Two of those invocations insert a row, and MySQL logs a `SELECT` statement for each of them. That is, MySQL writes the following statements to the binary log:

```
SELECT f1(1);
SELECT f1(2);
```

The server also logs a `SELECT` statement for a stored function invocation when the function invokes a stored procedure that causes an error. In this case, the server writes the `SELECT` statement to the log along with the expected error code. On the slave, if the same error occurs, that is the expected result and replication continues. Otherwise, replication stops.

Note: Before MySQL 5.1.7, you will see these `SELECT` *func_name()* statements logged as `DO` *func_name()*. The change to `SELECT` was made because use of `DO` was found to yield insufficient control over error code checking.

- Logging stored function invocations rather than the statements executed by a function has a security implication for replication, which arises from two factors:

  - It is possible for a function to follow different execution paths on master and slave servers.

  - Statements executed on a slave are processed by the slave SQL thread which has full privileges.

  The implication is that although a user must have the `CREATE ROUTINE` privilege to create a function, the user can write a function containing a dangerous statement that will execute only on the slave where it is processed by a thread that has full privileges. For example, if the master and slave servers have server ID values of 1 and 2, respectively, a user on the master server could create and invoke an unsafe function `unsafe_func()` as follows:

```
mysql> delimiter //
mysql> CREATE FUNCTION unsafe_func () RETURNS INT
    -> BEGIN
    ->   IF @@server_id=2 THEN dangerous_statement; END IF;
    ->   RETURN 1;
    -> END;
    -> //
mysql> delimiter ;
mysql> INSERT INTO t VALUES(unsafe_func());
```

The `CREATE FUNCTION` and `INSERT` statements are written to the binary log, so the slave will execute them. Because the slave SQL thread has full privileges, it will execute the dangerous statement. Thus, the function invocation has different effects on the master and slave and is not replication-safe.

To guard against this danger for servers that have binary logging enabled, stored function creators must have the `SUPER` privilege, in addition to the usual `CREATE ROUTINE` privilege that is required. Similarly, to use `ALTER FUNCTION`, you must have the `SUPER` privilege in addition to the `ALTER ROUTINE` privilege. Without the `SUPER` privilege, an error will occur:

```
ERROR 1419 (HY000): You do not have the SUPER privilege and
binary logging is enabled (you *might* want to use the less safe
log_bin_trust_function_creators variable)
```

If you do not want to require function creators to have the `SUPER` privilege (for example, if all users with the `CREATE ROUTINE` privilege on your system are experienced application developers), set the global `log_bin_trust_function_creators` system variable to 1. You can also set this variable by using the `--log-bin-trust-function-creators=1` option when starting the server. If binary logging is not enabled, `log_bin_trust_function_creators` does not apply. `SUPER` is not required for function creation unless, as described previously, the `DEFINER` value in the function definition requires it.

- If a function that performs updates is nondeterministic, it is not repeatable. This can have two undesirable effects:

  - It will make a slave different from the master.

- Restored data will be different from the original data.

To deal with these problems, MySQL enforces the following requirement: On a master server, creation and alteration of a function is refused unless you declare the function to be deterministic or to not modify data. Two sets of function characteristics apply here:

- The `DETERMINISTIC` and `NOT DETERMINISTIC` characteristics indicate whether a function always produces the same result for given inputs. The default is `NOT DETERMINISTIC` if neither characteristic is given. To declare that a function is deterministic, you must specify `DETERMINISTIC` explicitly.

- The `CONTAINS SQL`, `NO SQL`, `READS SQL DATA`, and `MODIFIES SQL DATA` characteristics provide information about whether the function reads or writes data. Either `NO SQL` or `READS SQL DATA` indicates that a function does not change data, but you must specify one of these explicitly because the default is `CONTAINS SQL` if no characteristic is given.

By default, for a `CREATE FUNCTION` statement to be accepted, at least one of `DETERMINISTIC`, `NO SQL`, or `READS SQL DATA` must be specified explicitly. Otherwise an error occurs:

```
ERROR 1418 (HY000): This function has none of DETERMINISTIC, NO SQL,
or READS SQL DATA in its declaration and binary logging is enabled
(you *might* want to use the less safe log_bin_trust_function_creators
variable)
```

If you set `log_bin_trust_function_creators` to 1, the requirement that functions be deterministic or not modify data is dropped.

- Stored procedure calls are logged at the statement level rather than at the `CALL` level. That is, the server does not log the `CALL` statement, it logs those statements within the procedure that actually execute. As a result, the same changes that occur on the master will be observed on slave servers. This prevents problems that could result from a procedure having different execution paths on different machines.

In general, statements executed within a stored procedure are written to the binary log using the same rules that would apply were the statements to be executed in standalone fashion. Some special care is taken when logging procedure statements because statement execution within procedures is not quite the same as in nonprocedure context:

- A statement to be logged might contain references to local procedure variables. These variables do not exist outside of stored procedure context, so a statement that refers to such a variable cannot be logged literally. Instead, each reference to a local variable is replaced by this construct for logging purposes:

```
NAME_CONST(var_name, var_value)
```

var_name is the local variable name, and *var_value* is a constant indicating the value that the variable has at the time the statement is logged. `NAME_CONST()` has a value of *var_value*, and a "name" of *var_name*. Thus, if you invoke this function directly, you get a result like this:

```
mysql> SELECT NAME_CONST('myname', 14);
+--------+
| myname |
+--------+
|     14 |
+--------+
```

NAME_CONST() enables a logged standalone statement to be executed on a slave with the same effect as the original statement that was executed on the master within a stored procedure.

The use of NAME_CONST() can result in a problem for CREATE TABLE ... SELECT statements when the source column expressions refer to local variables. Converting these references to NAME_CONST() expressions can result in column names that are different on the master and slave servers, or names that are too long to be legal column identifiers. A workaround is to supply aliases for columns that refer to local variables. Consider this statement when myvar has a value of 1:

```
CREATE TABLE t1 SELECT myvar;
```

That will be rewritten as follows:

```
CREATE TABLE t1 SELECT NAME_CONST(myvar, 1);
```

To ensure that the master and slave tables have the same column names, write the statement like this:

```
CREATE TABLE t1 SELECT myvar AS myvar;
```

The rewritten statement becomes:

```
CREATE TABLE t1 SELECT NAME_CONST(myvar, 1) AS myvar;
```

- A statement to be logged might contain references to user-defined variables. To handle this, MySQL writes a SET statement to the binary log to make sure that the variable exists on the slave with the same value as on the master. For example, if a statement refers to a variable @my_var, that statement will be preceded in the binary log by the following statement, where *value* is the value of @my_var on the master:

```
SET @my_var = value;
```

- Procedure calls can occur within a committed or rolled-back transaction. Transactional context is accounted for so that the transactional aspects of procedure execution are replicated correctly. That is, the server logs those statements within the procedure that actually execute and modify data, and also logs BEGIN, COMMIT, and ROLLBACK statements as necessary. For example, if a procedure updates only transactional tables and is executed within a transaction that is rolled back, those updates are not logged. If the procedure occurs within a committed transaction, BEGIN and COMMIT statements are logged with the updates. For a procedure that executes within a rolled-back transaction, its statements are logged using the same rules that would apply if the statements were executed in standalone fashion:

  - Updates to transactional tables are not logged.

  - Updates to nontransactional tables are logged because rollback does not cancel them.

  - Updates to a mix of transactional and nontransactional tables are logged surrounded by BEGIN and ROLLBACK so that slaves will make the same changes and rollbacks as on the master.

- A stored procedure call is *not* written to the binary log at the statement level if the procedure is invoked from within a stored function. In that case, the only thing logged is the statement that invokes the function (if it occurs within a statement that is logged) or a DO statement (if it occurs within a statement

that is not logged). For this reason, care should be exercised in the use of stored functions that invoke a procedure, even if the procedure is otherwise safe in itself.

Chapter 20 INFORMATION_SCHEMA Tables

Table of Contents

`INFORMATION_SCHEMA` provides access to database *metadata*, information about the MySQL server such as the name of a database or table, the data type of a column, or access privileges. Other terms that are sometimes used for this information are *data dictionary* and *system catalog*.

INFORMATION_SCHEMA Usage Notes

`INFORMATION_SCHEMA` is a database within each MySQL instance, the place that stores information about all the other databases that the MySQL server maintains. The `INFORMATION_SCHEMA` database contains several read-only tables. They are actually views, not base tables, so there are no files associated with them, and you cannot set triggers on them. Also, there is no database directory with that name.

Although you can select `INFORMATION_SCHEMA` as the default database with a `USE` statement, you can only read the contents of tables, not perform `INSERT`, `UPDATE`, or `DELETE` operations on them.

Example

Here is an example of a statement that retrieves information from `INFORMATION_SCHEMA`:

```
mysql> SELECT table_name, table_type, engine
    -> FROM information_schema.tables
    -> WHERE table_schema = 'db5'
    -> ORDER BY table_name;
+------------+------------+--------+
| table_name | table_type | engine |
+------------+------------+--------+
| fk         | BASE TABLE | InnoDB |
| fk2        | BASE TABLE | InnoDB |
| goto       | BASE TABLE | MyISAM |
| into       | BASE TABLE | MyISAM |
| k          | BASE TABLE | MyISAM |
| kurs       | BASE TABLE | MyISAM |
| loop       | BASE TABLE | MyISAM |
| pk         | BASE TABLE | InnoDB |
| t          | BASE TABLE | MyISAM |
| t2         | BASE TABLE | MyISAM |
| t3         | BASE TABLE | MyISAM |
| t7         | BASE TABLE | MyISAM |
| tables     | BASE TABLE | MyISAM |
| v          | VIEW       | NULL   |
| v2         | VIEW       | NULL   |
| v3         | VIEW       | NULL   |
| v56        | VIEW       | NULL   |
+------------+------------+--------+
17 rows in set (0.01 sec)
```

Explanation: The statement requests a list of all the tables in database `db5`, showing just three pieces of information: the name of the table, its type, and its storage engine.

Character Set Considerations

The definition for character columns (for example, `TABLES.TABLE_NAME`) is generally `VARCHAR(N) CHARACTER SET utf8` where N is at least 64. MySQL uses the default collation for this character set (`utf8_general_ci`) for all searches, sorts, comparisons, and other string operations on such columns.

Because some MySQL objects are represented as files, searches in `INFORMATION_SCHEMA` string columns can be affected by file system case sensitivity. For more information, see Section 10.1.7.9, "Collation and INFORMATION_SCHEMA Searches".

INFORMATION_SCHEMA as Alternative to SHOW Statements

The `SELECT ... FROM INFORMATION_SCHEMA` statement is intended as a more consistent way to provide access to the information provided by the various `SHOW` statements that MySQL supports (`SHOW DATABASES`, `SHOW TABLES`, and so forth). Using `SELECT` has these advantages, compared to `SHOW`:

- It conforms to Codd's rules, because all access is done on tables.

- You can use the familiar syntax of the `SELECT` statement, and only need to learn some table and column names.

- The implementor need not worry about adding keywords.

- You can filter, sort, concatenate, and transform the results from `INFORMATION_SCHEMA` queries into whatever format your application needs, such as a data structure or a text representation to parse.

- This technique is more interoperable with other database systems. For example, Oracle Database users are familiar with querying tables in the Oracle data dictionary.

Because `SHOW` is familiar and widely used, the `SHOW` statements remain as an alternative. In fact, along with the implementation of `INFORMATION_SCHEMA`, there are enhancements to `SHOW` as described in Section 20.27, "Extensions to SHOW Statements".

Privileges

Each MySQL user has the right to access these tables, but can see only the rows in the tables that correspond to objects for which the user has the proper access privileges. In some cases (for example, the `ROUTINE_DEFINITION` column in the `INFORMATION_SCHEMA.ROUTINES` table), users who have insufficient privileges see `NULL`. These restrictions do not apply for `InnoDB` tables; you can see them with only the `PROCESS` privilege.

The same privileges apply to selecting information from `INFORMATION_SCHEMA` and viewing the same information through `SHOW` statements. In either case, you must have some privilege on an object to see information about it.

Performance Considerations

`INFORMATION_SCHEMA` queries that search for information from more than one database might take a long time and impact performance. To check the efficiency of a query, you can use `EXPLAIN`. For information about using `EXPLAIN` output to tune `INFORMATION_SCHEMA` queries, see Section 8.2.4, "INFORMATION_SCHEMA Optimization".

Standards Considerations

The implementation for the `INFORMATION_SCHEMA` table structures in MySQL follows the ANSI/ISO SQL:2003 standard Part 11 *Schemata*. Our intent is approximate compliance with SQL:2003 core feature F021 *Basic information schema*.

Users of SQL Server 2000 (which also follows the standard) may notice a strong similarity. However, MySQL has omitted many columns that are not relevant for our implementation, and added columns that are MySQL-specific. One such column is the `ENGINE` column in the `INFORMATION_SCHEMA.TABLES` table.

To avoid using any name that is reserved in the standard or in DB2, SQL Server, or Oracle, we changed the names of some columns marked "MySQL extension". (For example, we changed `COLLATION` to `TABLE_COLLATION` in the `TABLES` table.) See the list of reserved words near the end of this article: https://web.archive.org/web/20070428032454/http://www.dbazine.com/db2/db2-disarticles/gulutzan5.

Conventions in the INFORMATION_SCHEMA Reference Sections

The following sections describe each of the tables and columns in `INFORMATION_SCHEMA`. For each column, there are three pieces of information:

- "`INFORMATION_SCHEMA` Name" indicates the name for the column in the `INFORMATION_SCHEMA` table. This corresponds to the standard SQL name unless the "Remarks" field says "MySQL extension."

- "`SHOW` Name" indicates the equivalent field name in the closest `SHOW` statement, if there is one.

- "Remarks" provides additional information where applicable. If this field is `NULL`, it means that the value of the column is always `NULL`. If this field says "MySQL extension," the column is a MySQL extension to standard SQL.

Many sections indicate what `SHOW` statement is equivalent to a `SELECT` that retrieves information from `INFORMATION_SCHEMA`. For `SHOW` statements that display information for the default database if you omit a `FROM` *db_name* clause, you can often select information for the default database by adding an `AND TABLE_SCHEMA = SCHEMA()` condition to the `WHERE` clause of a query that retrieves information from an `INFORMATION_SCHEMA` table.

For information about `INFORMATION_SCHEMA` tables specific to the `NDB` storage engine (MySQL Cluster), see Section 20.26, "INFORMATION_SCHEMA Tables for MySQL Cluster".

For answers to questions that are often asked concerning the `INFORMATION_SCHEMA` database, see Section A.7, "MySQL 5.1 FAQ: INFORMATION_SCHEMA".

20.1 The INFORMATION_SCHEMA CHARACTER_SETS Table

The `CHARACTER_SETS` table provides information about available character sets.

`INFORMATION_SCHEMA` **Name**	`SHOW` **Name**	**Remarks**
`CHARACTER_SET_NAME`	`Charset`	
`DEFAULT_COLLATE_NAME`	`Default collation`	
`DESCRIPTION`	`Description`	MySQL extension
`MAXLEN`	`Maxlen`	MySQL extension

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.CHARACTER_SETS
  [WHERE CHARACTER_SET_NAME LIKE 'wild']

SHOW CHARACTER SET
  [LIKE 'wild']
```

20.2 The INFORMATION_SCHEMA COLLATIONS Table

The `COLLATIONS` table provides information about collations for each character set.

`INFORMATION_SCHEMA` **Name**	`SHOW` **Name**	**Remarks**
`COLLATION_NAME`	`Collation`	
`CHARACTER_SET_NAME`	`Charset`	MySQL extension
`ID`	`Id`	MySQL extension
`IS_DEFAULT`	`Default`	MySQL extension
`IS_COMPILED`	`Compiled`	MySQL extension
`SORTLEN`	`Sortlen`	MySQL extension

- `COLLATION_NAME` is the collation name.

- `CHARACTER_SET_NAME` is the name of the character set with which the collation is associated.

- `ID` is the collation ID.

- `IS_DEFAULT` indicates whether the collation is the default for its character set.

- `IS_COMPILED` indicates whether the character set is compiled into the server.

- `SORTLEN` is related to the amount of memory required to sort strings expressed in the character set.

Collation information is also available from the `SHOW COLLATION` statement. The following statements are equivalent:

```
SELECT COLLATION_NAME FROM INFORMATION_SCHEMA.COLLATIONS
  [WHERE COLLATION_NAME LIKE 'wild']

SHOW COLLATION
  [LIKE 'wild']
```

20.3 The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table

The COLLATION_CHARACTER_SET_APPLICABILITY table indicates what character set is applicable for what collation. The columns are equivalent to the first two display fields that we get from SHOW COLLATION.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
COLLATION_NAME	Collation	
CHARACTER_SET_NAME	Charset	

20.4 The INFORMATION_SCHEMA COLUMNS Table

The COLUMNS table provides information about columns in tables.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLE_CATALOG		NULL
TABLE_SCHEMA		
TABLE_NAME		
COLUMN_NAME	Field	
ORDINAL_POSITION		see notes
COLUMN_DEFAULT	Default	
IS_NULLABLE	Null	
DATA_TYPE	Type	
CHARACTER_MAXIMUM_LENGTH	Type	
CHARACTER_OCTET_LENGTH		
NUMERIC_PRECISION	Type	
NUMERIC_SCALE	Type	
CHARACTER_SET_NAME		
COLLATION_NAME	Collation	
COLUMN_TYPE	Type	MySQL extension
COLUMN_KEY	Key	MySQL extension
EXTRA	Extra	MySQL extension
PRIVILEGES	Privileges	MySQL extension
COLUMN_COMMENT	Comment	MySQL extension

Notes:

- In SHOW, the Type display includes values from several different COLUMNS columns.

- `ORDINAL_POSITION` is necessary because you might want to say `ORDER BY ORDINAL_POSITION`. Unlike `SHOW`, `SELECT` does not have automatic ordering.

- `CHARACTER_OCTET_LENGTH` should be the same as `CHARACTER_MAXIMUM_LENGTH`, except for multibyte character sets.

- `CHARACTER_SET_NAME` can be derived from `Collation`. For example, if you say `SHOW FULL COLUMNS FROM t`, and you see in the `Collation` column a value of `latin1_swedish_ci`, the character set is what is before the first underscore: `latin1`.

The following statements are nearly equivalent:

```
SELECT COLUMN_NAME, DATA_TYPE, IS_NULLABLE, COLUMN_DEFAULT
  FROM INFORMATION_SCHEMA.COLUMNS
  WHERE table_name = 'tbl_name'
  [AND table_schema = 'db_name']
  [AND column_name LIKE 'wild']

SHOW COLUMNS
  FROM tbl_name
  [FROM db_name]
  [LIKE 'wild']
```

20.5 The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table

The `COLUMN_PRIVILEGES` table provides information about column privileges. This information comes from the `mysql.columns_priv` grant table.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
GRANTEE		`'user_name'@'host_name'` value
TABLE_CATALOG		NULL
TABLE_SCHEMA		
TABLE_NAME		
COLUMN_NAME		
PRIVILEGE_TYPE		
IS_GRANTABLE		

Notes:

- In the output from `SHOW FULL COLUMNS`, the privileges are all in one field and in lowercase, for example, `select,insert,update,references`. In `COLUMN_PRIVILEGES`, there is one privilege per row, in uppercase.

- `PRIVILEGE_TYPE` can contain one (and only one) of these values: `SELECT`, `INSERT`, `UPDATE`, `REFERENCES`.

- If the user has `GRANT OPTION` privilege, `IS_GRANTABLE` should be `YES`. Otherwise, `IS_GRANTABLE` should be `NO`. The output does not list `GRANT OPTION` as a separate privilege.

The following statements are *not* equivalent:

```
SELECT ... FROM INFORMATION_SCHEMA.COLUMN_PRIVILEGES
```

```
SHOW GRANTS ...
```

20.6 The INFORMATION_SCHEMA ENGINES Table

The `ENGINES` table provides information about storage engines.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
ENGINE	Engine	MySQL extension
SUPPORT	Support	MySQL extension
COMMENT	Comment	MySQL extension
TRANSACTIONS	Transactions	MySQL extension
XA	XA	MySQL extension
SAVEPOINTS	Savepoints	MySQL extension

Notes:

- The `ENGINES` table is a nonstandard table. It was added in MySQL 5.1.5. Its contents correspond to the columns of the `SHOW ENGINES` statement. For descriptions of its columns, see Section 13.7.5.17, "SHOW ENGINES Syntax".

See also Section 13.7.5.17, "SHOW ENGINES Syntax".

20.7 The INFORMATION_SCHEMA EVENTS Table

The `EVENTS` table provides information about scheduled events, which are discussed in Section 19.4, "Using the Event Scheduler". The `SHOW Name` values correspond to column names of the `SHOW EVENTS` statement.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
EVENT_CATALOG		NULL, MySQL extension
EVENT_SCHEMA	Db	MySQL extension
EVENT_NAME	Name	MySQL extension
DEFINER	Definer	MySQL extension
TIME_ZONE	Time zone	MySQL extension
EVENT_BODY		MySQL extension
EVENT_DEFINITION		MySQL extension
EVENT_TYPE	Type	MySQL extension
EXECUTE_AT	Execute at	MySQL extension
INTERVAL_VALUE	Interval value	MySQL extension
INTERVAL_FIELD	Interval field	MySQL extension
SQL_MODE		MySQL extension
STARTS	Starts	MySQL extension
ENDS	Ends	MySQL extension
STATUS	Status	MySQL extension
ON_COMPLETION		MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CREATED		MySQL extension
LAST_ALTERED		MySQL extension
LAST_EXECUTED		MySQL extension
EVENT_COMMENT		MySQL extension
ORIGINATOR	Originator	MySQL extension
CHARACTER_SET_CLIENT	character_set_client	MySQL extension
COLLATION_CONNECTION	collation_connection	MySQL extension
DATABASE_COLLATION	Database Collation	MySQL extension

Notes:

- The EVENTS table is a nonstandard table. It was added in MySQL 5.1.6.

- EVENT_CATALOG: The value of this column is always NULL.

- EVENT_SCHEMA: The name of the schema (database) to which this event belongs.

- EVENT_NAME: The name of the event.

- DEFINER: The account of the user who created the event, in `'user_name'@'host_name'` format.

- TIME_ZONE: The event time zone, which is the time zone used for scheduling the event and that is in effect within the event as it executes. The default value is SYSTEM.

  This column was added in MySQL 5.1.17. See Release Notes for MySQL 5.1.17 for important information if you are using the Event Scheduler and are upgrading to MySQL 5.1.17 or later from an earlier version.

- EVENT_BODY: The language used for the statements in the event's DO clause; in MySQL 5.1, this is always SQL.

  This column was added in MySQL 5.1.12. It is not to be confused with the column of the same name (now named EVENT_DEFINITION) that existed in earlier MySQL versions.

- EVENT_DEFINITION: The text of the SQL statement making up the event's DO clause; in other words, the statement executed by this event.

  > **Note**
  >
  > Prior to MySQL 5.1.12, this column was named EVENT_BODY.

- EVENT_TYPE: The event repetition type, either ONE TIME (transient) or RECURRING (repeating).

- EXECUTE_AT: For a one-time event, this is the DATETIME value specified in the AT clause of the CREATE EVENT statement used to create the event, or of the last ALTER EVENT statement that modified the event. The value shown in this column reflects the addition or subtraction of any INTERVAL value included in the event's AT clause. For example, if an event is created using ON SCHEDULE AT CURRENT_TIMESTAMP + '1:6' DAY_HOUR, and the event was created at 2006-02-09 14:05:30, the value shown in this column would be `'2006-02-10 20:05:30'`.

  If the event's timing is determined by an EVERY clause instead of an AT clause (that is, if the event is recurring), the value of this column is NULL.

- `INTERVAL_VALUE`: For recurring events, this column contains the numeric portion of the event's `EVERY` clause.

  For a one-time event (that is, an event whose timing is determined by an `AT` clause), this column is `NULL`.

- `INTERVAL_FIELD`: For recurring events, this column contains the units portion of the `EVERY` clause governing the timing of the event. Thus, this column contains a value such as `'YEAR'`, `'QUARTER'`, `'DAY'`, and so on.

  > **Note**
  >
  > In early MySQL 5.1 releases, this value was prefixed with `'INTERVAL_'`, and was displayed as `'INTERVAL_YEAR'`, `'INTERVAL_QUARTER'`, `'INTERVAL_DAY'`, and so on.

  For a one-time event (that is, an event whose timing is determined by an `AT` clause), this column is `NULL`.

- `SQL_MODE`: The SQL mode in effect when the event was created or altered, and under which the event executes. For the permitted values, see Section 5.1.7, "Server SQL Modes".

- `STARTS`: For a recurring event whose definition includes a `STARTS` clause, this column contains the corresponding `DATETIME` value. As with the `EXECUTE_AT` column, this value resolves any expressions used.

  If there is no `STARTS` clause affecting the timing of the event, this column is `NULL`. (Prior to MySQL 5.1.8, it contained `0000-00-00 00:00:00` in such cases.)

- `ENDS`: For a recurring event whose definition includes a `ENDS` clause, this column contains the corresponding `DATETIME` value. As with the `EXECUTE_AT` column, this value resolves any expressions used.

  If there is no `ENDS` clause affecting the timing of the event, this column is `NULL`.

- `STATUS`: One of the three values `ENABLED`, `DISABLED`, or `SLAVESIDE_DISABLED`.

  `SLAVESIDE_DISABLED` was added to the list of possible values for this column in MySQL 5.1.18. This value indicates that the creation of the event occurred on another MySQL server acting as a replication master and was replicated to the current MySQL server which is acting as a slave, but the event is not presently being executed on the slave. See Section 16.4.1.12, "Replication of Invoked Features", for more information.

- `ON_COMPLETION`: One of the two values `PRESERVE` or `NOT PRESERVE`.

- `CREATED`: The date and time when the event was created. This is a `TIMESTAMP` value.

- `LAST_ALTERED`: The date and time when the event was last modified. This is a `TIMESTAMP` value. If the event has not been modified since its creation, this column holds the same value as the `CREATED` column.

- `LAST_EXECUTED`: The date and time when the event last executed. A `DATETIME` value. If the event has never executed, this column is `NULL`.

  Before MySQL 5.1.23, `LAST_EXECUTED` indicates when event finished executing. As of 5.1.23, `LAST_EXECUTED` instead indicates when the event started. As a result, the `ENDS` column is never less than `LAST_EXECUTED`.

- EVENT_COMMENT: The text of a comment, if the event has one. If not, the value of this column is an empty string.

- ORIGINATOR: The server ID of the MySQL server on which the event was created; used in replication. The default value is 0. This column was added in MySQL 5.1.18.

- CHARACTER_SET_CLIENT: The session value of the character_set_client system variable when the event was created. This column was added in MySQL 5.1.21.

- COLLATION_CONNECTION: The session value of the collation_connection system variable when the event was created. This column was added in MySQL 5.1.21.

- DATABASE_COLLATION: The collation of the database with which the event is associated. This column was added in MySQL 5.1.21.

Example: Suppose that the user jon@ghidora creates an event named e_daily, and then modifies it a few minutes later using an ALTER EVENT statement, as shown here:

```
DELIMITER |

CREATE EVENT e_daily
    ON SCHEDULE
      EVERY 1 DAY
    COMMENT 'Saves total number of sessions then clears the table each day'
    DO
      BEGIN
        INSERT INTO site_activity.totals (time, total)
          SELECT CURRENT_TIMESTAMP, COUNT(*)
            FROM site_activity.sessions;
        DELETE FROM site_activity.sessions;
      END |

DELIMITER ;

ALTER EVENT e_daily
    ENABLE;
```

(Note that comments can span multiple lines.)

This user can then run the following SELECT statement, and obtain the output shown:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.EVENTS
    > WHERE EVENT_NAME = 'e_daily'
    > AND EVENT_SCHEMA = 'myschema'\G
*************************** 1. row ***************************
       EVENT_CATALOG: NULL
        EVENT_SCHEMA: test
          EVENT_NAME: e_daily
             DEFINER: me@localhost
           TIME_ZONE: SYSTEM
          EVENT_BODY: SQL
    EVENT_DEFINITION: BEGIN
        INSERT INTO site_activity.totals (time, total)
          SELECT CURRENT_TIMESTAMP, COUNT(*)
            FROM site_activity.sessions;
        DELETE FROM site_activity.sessions;
      END
          EVENT_TYPE: RECURRING
          EXECUTE_AT: NULL
      INTERVAL_VALUE: 1
      INTERVAL_FIELD: DAY
            SQL_MODE:
```

```
        STARTS: 2008-09-03 12:13:39
          ENDS: NULL
        STATUS: ENABLED
 ON_COMPLETION: NOT PRESERVE
       CREATED: 2008-09-03 12:13:39
  LAST_ALTERED: 2008-09-03 12:13:39
 LAST_EXECUTED: NULL
 EVENT_COMMENT: Saves total number of sessions then clears the
                table each day
     ORIGINATOR: 1
CHARACTER_SET_CLIENT: latin1
COLLATION_CONNECTION: latin1_swedish_ci
  DATABASE_COLLATION: latin1_swedish_ci
```

Times in the `EVENTS` table are displayed using the event time zone or the current session time zone. Prior to MySQL 5.1.17, some of the times are displayed in UTC rather than the event time zone. For details, see Section 19.4.4, "Event Metadata".

See also Section 13.7.5.19, "SHOW EVENTS Syntax".

20.8 The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables

The `GLOBAL_STATUS` and `SESSION_STATUS` tables provide information about server status variables. Their contents correspond to the information produced by the `SHOW GLOBAL STATUS` and `SHOW SESSION STATUS` statements (see Section 13.7.5.37, "SHOW STATUS Syntax").

INFORMATION_SCHEMA Name	SHOW Name	Remarks
VARIABLE_NAME	Variable_name	
VARIABLE_VALUE	Value	

Notes:

• The `GLOBAL_STATUS` and `SESSION_STATUS` tables were added in MySQL 5.1.12.

• The `VARIABLE_VALUE` column for each of these tables is defined as `VARCHAR(1024)`. Previously, this column had the data type `DECIMAL(22,7)`, but was changed to `VARCHAR(20480)` in 5.1.19 to avoid loss of data when working with status variables whose values were strings, and shortened to `VARCHAR(1024)` in 5.1.31 to improve performance.

20.9 The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables

The `GLOBAL_VARIABLES` and `SESSION_VARIABLES` tables provide information about server status variables. Their contents correspond to the information produced by the `SHOW GLOBAL VARIABLES` and `SHOW SESSION VARIABLES` statements (see Section 13.7.5.41, "SHOW VARIABLES Syntax").

INFORMATION_SCHEMA Name	SHOW Name	Remarks
VARIABLE_NAME	Variable_name	
VARIABLE_VALUE	Value	

Notes:

• The `GLOBAL_VARIABLES` and `SESSION_VARIABLES` tables were added in MySQL 5.1.12.

- The `VARIABLE_VALUE` column for each of these tables is defined as `VARCHAR(1024)`. Previously, this column had the data type `LONGTEXT`; this was changed in MySQL 5.1.19 to `VARCHAR(20480)` and in 5.1.31 to `VARCHAR(1024)` to make these tables consistent with the `GLOBAL_STATUS` and `SESSION_STATUS` tables, whose definitions were changed in those versions (see Section 20.8, "The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables").

  For variables with very long values that are not completely displayed, use `SELECT` as a workaround. For example:

```
SELECT @@GLOBAL.innodb_data_file_path;
```

20.10 The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table

The `KEY_COLUMN_USAGE` table describes which key columns have constraints.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CONSTRAINT_CATALOG		NULL
CONSTRAINT_SCHEMA		
CONSTRAINT_NAME		
TABLE_CATALOG		
TABLE_SCHEMA		
TABLE_NAME		
COLUMN_NAME		
ORDINAL_POSITION		
POSITION_IN_UNIQUE_CONSTRAINT		
REFERENCED_TABLE_SCHEMA		
REFERENCED_TABLE_NAME		
REFERENCED_COLUMN_NAME		

Notes:

- If the constraint is a foreign key, then this is the column of the foreign key, not the column that the foreign key references.

- The value of `ORDINAL_POSITION` is the column's position within the constraint, not the column's position within the table. Column positions are numbered beginning with 1.

- The value of `POSITION_IN_UNIQUE_CONSTRAINT` is `NULL` for unique and primary-key constraints. For foreign-key constraints, it is the ordinal position in key of the table that is being referenced.

  Suppose that there are two tables name `t1` and `t3` that have the following definitions:

```
CREATE TABLE t1
(
    s1 INT,
    s2 INT,
    s3 INT,
    PRIMARY KEY(s3)
) ENGINE=InnoDB;

CREATE TABLE t3
(
```

```
    s1 INT,
    s2 INT,
    s3 INT,
    KEY(s1),
    CONSTRAINT CO FOREIGN KEY (s2) REFERENCES t1(s3)
) ENGINE=InnoDB;
```

For those two tables, the `KEY_COLUMN_USAGE` table has two rows:

- One row with `CONSTRAINT_NAME = 'PRIMARY'`, `TABLE_NAME = 't1'`, `COLUMN_NAME = 's3'`, `ORDINAL_POSITION = 1`, `POSITION_IN_UNIQUE_CONSTRAINT = NULL`.

- One row with `CONSTRAINT_NAME = 'CO'`, `TABLE_NAME = 't3'`, `COLUMN_NAME = 's2'`, `ORDINAL_POSITION = 1`, `POSITION_IN_UNIQUE_CONSTRAINT = 1`.

20.11 The INFORMATION_SCHEMA PARTITIONS Table

The `PARTITIONS` table provides information about table partitions. See Chapter 18, *Partitioning*, for more information about partitioning tables.

INFORMATION_SCHEMA Name	**SHOW Name**	**Remarks**
TABLE_CATALOG		MySQL extension
TABLE_SCHEMA		MySQL extension
TABLE_NAME		MySQL extension
PARTITION_NAME		MySQL extension
SUBPARTITION_NAME		MySQL extension
PARTITION_ORDINAL_POSITION		MySQL extension
SUBPARTITION_ORDINAL_POSITION		MySQL extension
PARTITION_METHOD		MySQL extension
SUBPARTITION_METHOD		MySQL extension
PARTITION_EXPRESSION		MySQL extension
SUBPARTITION_EXPRESSION		MySQL extension
PARTITION_DESCRIPTION		MySQL extension
TABLE_ROWS		MySQL extension
AVG_ROW_LENGTH		MySQL extension
DATA_LENGTH		MySQL extension
MAX_DATA_LENGTH		MySQL extension
INDEX_LENGTH		MySQL extension
DATA_FREE		MySQL extension
CREATE_TIME		MySQL extension
UPDATE_TIME		MySQL extension
CHECK_TIME		MySQL extension
CHECKSUM		MySQL extension
PARTITION_COMMENT		MySQL extension
NODEGROUP		MySQL extension
TABLESPACE_NAME		MySQL extension

Notes:

- The `PARTITIONS` table is a nonstandard table. It was added in MySQL 5.1.6.

  Each record in this table corresponds to an individual partition or subpartition of a partitioned table.

- `TABLE_CATALOG`: This column is always `NULL`.

- `TABLE_SCHEMA`: This column contains the name of the database to which the table belongs.

- `TABLE_NAME`: This column contains the name of the table containing the partition.

- `PARTITION_NAME`: The name of the partition.

- `SUBPARTITION_NAME`: If the `PARTITIONS` table record represents a subpartition, then this column contains the name of subpartition; otherwise it is `NULL`.

- `PARTITION_ORDINAL_POSITION`: All partitions are indexed in the same order as they are defined, with `1` being the number assigned to the first partition. The indexing can change as partitions are added, dropped, and reorganized; the number shown is this column reflects the current order, taking into account any indexing changes.

- `SUBPARTITION_ORDINAL_POSITION`: Subpartitions within a given partition are also indexed and reindexed in the same manner as partitions are indexed within a table.

- `PARTITION_METHOD`: One of the values `RANGE`, `LIST`, `HASH`, `LINEAR HASH`, `KEY`, or `LINEAR KEY`; that is, one of the available partitioning types as discussed in Section 18.2, "Partitioning Types".

- `SUBPARTITION_METHOD`: One of the values `HASH`, `LINEAR HASH`, `KEY`, or `LINEAR KEY`; that is, one of the available subpartitioning types as discussed in Section 18.2.5, "Subpartitioning".

- `PARTITION_EXPRESSION`: This is the expression for the partitioning function used in the `CREATE TABLE` or `ALTER TABLE` statement that created the table's current partitioning scheme.

  For example, consider a partitioned table created in the `test` database using this statement:

```
CREATE TABLE tp (
    c1 INT,
    c2 INT,
    c3 VARCHAR(25)
)
PARTITION BY HASH(c1 + c2)
PARTITIONS 4;
```

  The `PARTITION_EXPRESSION` column in a PARTITIONS table record for a partition from this table displays `c1 + c2`, as shown here:

```
mysql> SELECT DISTINCT PARTITION_EXPRESSION
    >        FROM INFORMATION_SCHEMA.PARTITIONS
    >        WHERE TABLE_NAME='tp' AND TABLE_SCHEMA='test';
+----------------------+
| PARTITION_EXPRESSION |
+----------------------+
| c1 + c2              |
+----------------------+
1 row in set (0.09 sec)
```

- `SUBPARTITION_EXPRESSION`: This works in the same fashion for the subpartitioning expression that defines the subpartitioning for a table as `PARTITION_EXPRESSION` does for the partitioning expression used to define a table's partitioning.

If the table has no subpartitions, then this column is `NULL`.

- `PARTITION_DESCRIPTION`: This column is used for RANGE and LIST partitions. For a `RANGE` partition, it contains the value set in the partition's `VALUES LESS THAN` clause, which can be either an integer or `MAXVALUE`. For a `LIST` partition, this column contains the values defined in the partition's `VALUES IN` clause, which is a comma-separated list of integer values.

  For partitions whose `PARTITION_METHOD` is other than `RANGE` or `LIST`, this column is always `NULL`.

- `TABLE_ROWS`: The number of table rows in the partition.

  For partitioned `InnoDB` tables, the row count given in the `TABLE_ROWS` column is only an estimated value used in SQL optimization, and may not always be exact.

  Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, `TABLE_ROWS` shows correct information for `NDB` tables. Previously, for partitions of `NDB` tables, the `TABLE_ROWS` column value was always 0.

  For `NDB` tables, you can also obtain this information using the `ndb_desc` utility.

- `AVG_ROW_LENGTH`: The average length of the rows stored in this partition or subpartition, in bytes.

  This is the same as `DATA_LENGTH` divided by `TABLE_ROWS`.

  Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, `AVG_ROW_LENGTH` includes statistics for partitions of `NDB` tables, whether the tables use implicit or explicit partitioning. (Previously the value of this column was always 0 for partitions of `NDB` tables.)

  You can also obtain equivalent information using the `ndb_desc` utility.

- `DATA_LENGTH`: The total length of all rows stored in this partition or subpartition, in bytes—that is, the total number of bytes stored in the partition or subpartition.

  Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, `DATA_LENGTH` shows correct information for in-memory data in `NDB` tables. Previously, for partitions of `NDB` tables, the `DATA_LENGTH` column value was always 0.

  For `NDB` tables, you can also obtain this information using the `ndb_desc` utility.

- `MAX_DATA_LENGTH`: The maximum number of bytes that can be stored in this partition or subpartition.

  Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, `MAX_DATA_LENGTH` shows the space allocated for the disk part of a MySQL Cluster Disk Data table or fragment. (Previously, for partitions of `NDB` tables, the `MAX_DATA_LENGTH` column value was always `NULL`.)

  For `NDB` tables, you can also obtain this information using the `ndb_desc` utility.

- `INDEX_LENGTH`: The length of the index file for this partition or subpartition, in bytes.

  For partitions of `NDB` tables, whether the tables use implicit or explicit partitioning, the `INDEX_LENGTH` column value is always 0. However, you can obtain equivalent information using the `ndb_desc` utility.

- `DATA_FREE`: The number of bytes allocated to the partition or subpartition but not used.

  For MySQL Cluster Disk Data tables, beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, `DATA_FREE` shows the space allocated on disk for, but not used by, a Disk Data table or fragment on disk. (Previously, for partitions of `NDB` tables, the value of this column was always 0.)

For `NDB` tables, you can also obtain this information using the `ndb_desc` utility.

- `CREATE_TIME`: The time of the partition's or subpartition's creation.

  For partitioned `InnoDB` tables, this column is always `NULL`.

- `UPDATE_TIME`: The time that the partition or subpartition was last modified.

  For partitioned `InnoDB` tables, this column is always `NULL`.

- `CHECK_TIME`: The last time that the table to which this partition or subpartition belongs was checked.

  For partitioned `InnoDB` tables, this column is always `NULL`.

- `CHECKSUM`: The checksum value, if any; otherwise, this column is `NULL`.

- `PARTITION_COMMENT`: This column contains the text of any comment made for the partition.

  In MySQL 5.1, the display width of this column is 80 characters, and partition comments which exceed this length are truncated to fit. This issue is fixed in MySQL 5.6. (Bug #11748924, Bug #37728)

  The default value for this column is an empty string.

- `NODEGROUP`: This is the nodegroup to which the partition belongs. This is relevant only to MySQL Cluster tables; otherwise the value of this column is always `0`.

- `TABLESPACE_NAME`: This column contains the name of the tablespace to which the partition belongs. The value of this column is always `DEFAULT`.

- ⚠️ **Important**

  If any partitioned tables created in a MySQL version prior to MySQL 5.1.6 are present following an upgrade to MySQL 5.1.6 or later, it is not possible to `SELECT` from, `SHOW`, or `DESCRIBE` the `PARTITIONS` table. See the Release Notes for MySQL 5.1.6 *before* upgrading from MySQL 5.1.5 or earlier to MySQL 5.1.6 or later.

- A nonpartitioned table has one record in `INFORMATION_SCHEMA.PARTITIONS`; however, the values of the `PARTITION_NAME`, `SUBPARTITION_NAME`, `PARTITION_ORDINAL_POSITION`, `SUBPARTITION_ORDINAL_POSITION`, `PARTITION_METHOD`, `SUBPARTITION_METHOD`, `PARTITION_EXPRESSION`, `SUBPARTITION_EXPRESSION`, and `PARTITION_DESCRIPTION` columns are all `NULL`. (The `PARTITION_COMMENT` column in this case is blank.)

  In MySQL 5.1, there is also only one record in the `PARTITIONS` table for a table using the `NDBCLUSTER` storage engine. The same columns are also `NULL` (or empty) as for a nonpartitioned table.

20.12 The INFORMATION_SCHEMA PLUGINS Table

The `PLUGINS` table provides information about server plugins.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
PLUGIN_NAME	Name	MySQL extension
PLUGIN_VERSION		MySQL extension
PLUGIN_STATUS	Status	MySQL extension
PLUGIN_TYPE	Type	MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
PLUGIN_TYPE_VERSION		MySQL extension
PLUGIN_LIBRARY	Library	MySQL extension
PLUGIN_LIBRARY_VERSION		MySQL extension
PLUGIN_AUTHOR		MySQL extension
PLUGIN_DESCRIPTION		MySQL extension
PLUGIN_LICENSE		MySQL extension

Notes:

- The PLUGINS table is a nonstandard table. It was added in MySQL 5.1.5.

- PLUGIN_NAME is the name used to refer to the plugin in statements such as INSTALL PLUGIN and UNINSTALL PLUGIN.

- PLUGIN_VERSION is the version from the plugin's general type descriptor.

- PLUGIN_STATUS indicates the plugin status, one of ACTIVE, INACTIVE, DISABLED, or DELETED.

- PLUGIN_TYPE indicates the type of plugin, such as STORAGE ENGINE or INFORMATION_SCHEMA.

- PLUGIN_TYPE_VERSION is the version from the plugin's type-specific descriptor.

- PLUGIN_LIBRARY is the name of the plugin shared object file. This is the name used to refer to the plugin file in statements such as INSTALL PLUGIN and UNINSTALL PLUGIN. This file is located in the directory named by the plugin_dir system variable. If the library name is NULL, the plugin is compiled in and cannot be uninstalled with UNINSTALL PLUGIN.

- PLUGIN_LIBRARY_VERSION indicates the plugin API interface version.

- PLUGIN_AUTHOR names the plugin author.

- PLUGIN_DESCRIPTION provides a short description of the plugin.

- PLUGIN_LICENSE indicates how the plugin is licensed; for example, GPL. This column was added in MySQL 5.1.12.

For plugins installed with INSTALL PLUGIN, the PLUGIN_NAME and PLUGIN_LIBRARY values are also registered in the mysql.plugin table.

These statements are equivalent:

```
SELECT
  PLUGIN_NAME, PLUGIN_STATUS, PLUGIN_TYPE,
  PLUGIN_LIBRARY, PLUGIN_LICENSE
FROM INFORMATION_SCHEMA.PLUGINS;

SHOW PLUGINS;
```

For information about plugin data structures that form the basis of the information in the PLUGINS table, see Section 22.2, "The MySQL Plugin API".

Plugin information is also available using the SHOW PLUGINS statement. See Section 13.7.5.27, "SHOW PLUGINS Syntax".

20.13 The INFORMATION_SCHEMA PROCESSLIST Table

The `PROCESSLIST` table provides information about which threads are running.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
ID	Id	MySQL extension
USER	User	MySQL extension
HOST	Host	MySQL extension
DB	db	MySQL extension
COMMAND	Command	MySQL extension
TIME	Time	MySQL extension
STATE	State	MySQL extension
INFO	Info	MySQL extension

For an extensive description of the table columns, see Section 13.7.5.31, "SHOW PROCESSLIST Syntax".

Notes:

- The `PROCESSLIST` table is a nonstandard table. It was added in MySQL 5.1.7.

- Like the output from the corresponding `SHOW` statement, the `PROCESSLIST` table will only show information about your own threads, unless you have the `PROCESS` privilege, in which case you will see information about other threads, too. As an anonymous user, you cannot see any rows at all.

- If an SQL statement refers to `INFORMATION_SCHEMA.PROCESSLIST`, MySQL populates the entire table once, when statement execution begins, so there is read consistency during the statement. There is no read consistency for a multi-statement transaction, though.

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.PROCESSLIST

SHOW FULL PROCESSLIST
```

20.14 The INFORMATION_SCHEMA PROFILING Table

The `PROFILING` table provides statement profiling information. Its contents correspond to the information produced by the `SHOW PROFILES` and `SHOW PROFILE` statements (see Section 13.7.5.33, "SHOW PROFILES Syntax"). The table is empty unless the `profiling` session variable is set to 1.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
QUERY_ID	Query_ID	
SEQ		
STATE	Status	
DURATION	Duration	
CPU_USER	CPU_user	
CPU_SYSTEM	CPU_system	
CONTEXT_VOLUNTARY	Context_voluntary	
CONTEXT_INVOLUNTARY	Context_involuntary	
BLOCK_OPS_IN	Block_ops_in	
BLOCK_OPS_OUT	Block_ops_out	

INFORMATION_SCHEMA Name	SHOW Name	Remarks
MESSAGES_SENT	Messages_sent	
MESSAGES_RECEIVED	Messages_received	
PAGE_FAULTS_MAJOR	Page_faults_major	
PAGE_FAULTS_MINOR	Page_faults_minor	
SWAPS	Swaps	
SOURCE_FUNCTION	Source_function	
SOURCE_FILE	Source_file	
SOURCE_LINE	Source_line	

Notes:

- The PROFILING table was added in MySQL 5.1.24 but contains no information unless the SHOW PROFILE feature is enabled. The SHOW PROFILE feature is not included in binary distributions by default until MySQL 5.1.28.

- QUERY_ID is a numeric statement identifier.

- SEQ is a sequence number indicating the display order for rows with the same QUERY_ID value.

- STATE is the profiling state to which the row measurements apply.

- DURATION indicates how long statement execution remained in the given state, in seconds.

- CPU_USER and CPU_SYSTEM indicate user and system CPU use, in seconds.

- CONTEXT_VOLUNTARY and CONTEXT_INVOLUNTARY indicate how many voluntary and involuntary context switches occurred.

- BLOCK_OPS_IN and BLOCK_OPS_OUT indicate the number of block input and output operations.

- MESSAGES_SENT and MESSAGES_RECEIVED indicate the number of communication messages sent and received.

- PAGE_FAULTS_MAJOR and PAGE_FAULTS_MINOR indicate the number of major and minor page faults.

- SWAPS indicates how many swaps occurred.

- SOURCE_FUNCTION, SOURCE_FILE, and SOURCE_LINE provide information indicating where in the source code the profiled state executes.

20.15 The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table

The REFERENTIAL_CONSTRAINTS table provides information about foreign keys.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CONSTRAINT_CATALOG		NULL
CONSTRAINT_SCHEMA		
CONSTRAINT_NAME		
UNIQUE_CONSTRAINT_CATALOG		NULL

INFORMATION_SCHEMA Name	SHOW Name	Remarks
UNIQUE_CONSTRAINT_SCHEMA		
UNIQUE_CONSTRAINT_NAME		
MATCH_OPTION		
UPDATE_RULE		
DELETE_RULE		
TABLE_NAME		
REFERENCED_TABLE_NAME		

Notes:

- The REFERENTIAL_CONSTRAINTS table was added in MySQL 5.1.10. The REFERENCED_TABLE_NAME column was added in MySQL 5.1.16.

- TABLE_NAME has the same value as TABLE_NAME in INFORMATION_SCHEMA.TABLE_CONSTRAINTS.

- CONSTRAINT_SCHEMA and CONSTRAINT_NAME identify the foreign key.

- UNIQUE_CONSTRAINT_SCHEMA, UNIQUE_CONSTRAINT_NAME, and REFERENCED_TABLE_NAME identify the referenced key. (Note: Before MySQL 5.1.16, UNIQUE_CONSTRAINT_NAME incorrectly named the referenced table, not the constraint.)

- The only valid value at this time for MATCH_OPTION is NONE.

- The possible values for UPDATE_RULE or DELETE_RULE are CASCADE, SET NULL, SET DEFAULT, RESTRICT, NO ACTION.

20.16 The INFORMATION_SCHEMA ROUTINES Table

The ROUTINES table provides information about stored routines (both procedures and functions). The ROUTINES table does not include user-defined functions (UDFs).

The column named "mysql.proc name" indicates the mysql.proc table column that corresponds to the INFORMATION_SCHEMA.ROUTINES table column, if any.

INFORMATION_SCHEMA Name	mysql.proc Name	Remarks
SPECIFIC_NAME	specific_name	
ROUTINE_CATALOG		NULL
ROUTINE_SCHEMA	db	
ROUTINE_NAME	name	
ROUTINE_TYPE	type	{PROCEDURE|FUNCTION}
DTD_IDENTIFIER		data type descriptor
ROUTINE_BODY		SQL
ROUTINE_DEFINITION	body or body_utf8	see Notes
EXTERNAL_NAME		NULL
EXTERNAL_LANGUAGE	language	NULL
PARAMETER_STYLE		SQL
IS_DETERMINISTIC	is_deterministic	

INFORMATION_SCHEMA Name	mysql.proc Name	Remarks
SQL_DATA_ACCESS	sql_data_access	
SQL_PATH		NULL
SECURITY_TYPE	security_type	
CREATED	created	
LAST_ALTERED	modified	
SQL_MODE	sql_mode	MySQL extension
ROUTINE_COMMENT	comment	MySQL extension
DEFINER	definer	MySQL extension
CHARACTER_SET_CLIENT		MySQL extension
COLLATION_CONNECTION		MySQL extension
DATABASE_COLLATION		MySQL extension

Notes:

- MySQL calculates EXTERNAL_LANGUAGE thus:

  - If mysql.proc.language='SQL', EXTERNAL_LANGUAGE is NULL

  - Otherwise, EXTERNAL_LANGUAGE is what is in mysql.proc.language. However, we do not have external languages yet, so it is always NULL.

- ROUTINE_DEFINITION is what is in mysql.proc.body_utf8 as of MySQL 5.1.21, mysql.proc.body before 5.1.21.

- CREATED: The date and time when the routine was created. This is a TIMESTAMP value.

- LAST_ALTERED: The date and time when the routine was last modified. This is a TIMESTAMP value. If the routine has not been modified since its creation, this column holds the same value as the CREATED column.

- SQL_MODE: The SQL mode in effect when the routine was created or altered, and under which the routine executes. For the permitted values, see Section 5.1.7, "Server SQL Modes".

- CHARACTER_SET_CLIENT: The session value of the character_set_client system variable when the routine was created. This column was added in MySQL 5.1.21.

- COLLATION_CONNECTION: The session value of the collation_connection system variable when the routine was created. This column was added in MySQL 5.1.21.

- DATABASE_COLLATION: The collation of the database with which the routine is associated. This column was added in MySQL 5.1.21.

20.17 The INFORMATION_SCHEMA SCHEMATA Table

A schema is a database, so the SCHEMATA table provides information about databases.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CATALOG_NAME		NULL
SCHEMA_NAME	Database	
DEFAULT_CHARACTER_SET_NAME		

INFORMATION_SCHEMA Name	SHOW Name	Remarks
DEFAULT_COLLATION_NAME		
SQL_PATH		NULL

The following statements are equivalent:

```
SELECT SCHEMA_NAME AS `Database`
  FROM INFORMATION_SCHEMA.SCHEMATA
  [WHERE SCHEMA_NAME LIKE 'wild']

SHOW DATABASES
  [LIKE 'wild']
```

20.18 The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table

The SCHEMA_PRIVILEGES table provides information about schema (database) privileges. This information comes from the mysql.db grant table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
GRANTEE		'user_name'@'host_name' value, MySQL extension
TABLE_CATALOG		NULL, MySQL extension
TABLE_SCHEMA		MySQL extension
PRIVILEGE_TYPE		MySQL extension
IS_GRANTABLE		MySQL extension

Notes:

• This is a nonstandard table. It takes its values from the mysql.db table.

20.19 The INFORMATION_SCHEMA STATISTICS Table

The STATISTICS table provides information about table indexes.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLE_CATALOG		NULL
TABLE_SCHEMA		= Database
TABLE_NAME	Table	
NON_UNIQUE	Non_unique	
INDEX_SCHEMA		= Database
INDEX_NAME	Key_name	
SEQ_IN_INDEX	Seq_in_index	
COLUMN_NAME	Column_name	
COLLATION	Collation	
CARDINALITY	Cardinality	
SUB_PART	Sub_part	MySQL extension
PACKED	Packed	MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
NULLABLE	Null	MySQL extension
INDEX_TYPE	Index_type	MySQL extension
COMMENT	Comment	MySQL extension

Notes:

- There is no standard table for indexes. The preceding list is similar to what SQL Server 2000 returns for `sp_statistics`, except that we replaced the name `QUALIFIER` with `CATALOG` and we replaced the name `OWNER` with `SCHEMA`.

  Clearly, the preceding table and the output from `SHOW INDEX` are derived from the same parent. So the correlation is already close.

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.STATISTICS
  WHERE table_name = 'tbl_name'
  AND table_schema = 'db_name'

SHOW INDEX
  FROM tbl_name
  FROM db_name
```

20.20 The INFORMATION_SCHEMA TABLES Table

The `TABLES` table provides information about tables in databases.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLE_CATALOG		NULL
TABLE_SCHEMA	Table_...	
TABLE_NAME	Table_...	
TABLE_TYPE		
ENGINE	Engine	MySQL extension
VERSION	Version	The version number of the table's `.frm` file, MySQL extension
ROW_FORMAT	Row_format	MySQL extension
TABLE_ROWS	Rows	MySQL extension
AVG_ROW_LENGTH	Avg_row_length	MySQL extension
DATA_LENGTH	Data_length	MySQL extension
MAX_DATA_LENGTH	Max_data_length	MySQL extension
INDEX_LENGTH	Index_length	MySQL extension
DATA_FREE	Data_free	MySQL extension
AUTO_INCREMENT	Auto_increment	MySQL extension
CREATE_TIME	Create_time	MySQL extension
UPDATE_TIME	Update_time	MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CHECK_TIME	Check_time	MySQL extension
TABLE_COLLATION	Collation	MySQL extension
CHECKSUM	Checksum	MySQL extension
CREATE_OPTIONS	Create_options	MySQL extension
TABLE_COMMENT	Comment	MySQL extension
INDEX_COMMENT	Index_comment	MySQL extension

Notes:

- Refer to SHOW TABLE STATUS for field descriptions.

- TABLE_SCHEMA and TABLE_NAME are a single field in a SHOW display, for example Table_in_db1.

- TABLE_TYPE should be BASE TABLE or VIEW. The TABLES table does not list TEMPORARY tables.

- For partitioned tables, beginning with MySQL 5.1.9, the ENGINE column shows the name of the storage engine used by all partitions. (Previously, this column showed PARTITION for such tables.)

- The TABLE_ROWS column is NULL if the table is in the INFORMATION_SCHEMA database.

  For InnoDB tables, the row count is only a rough estimate used in SQL optimization. (This is also true if the InnoDB table is partitioned.)

- Prior to MySQL 5.1.12, MySQL Cluster allocated storage for variable-width columns in 10-page extents of 32 kilobytes each; thus, the DATA_LENGTH for such columns was reported in increments of 320 KB. Beginning with MySQL 5.1.12, the DATA_LENGTH column reflects the true amount of storage for variable-width columns of NDB tables. (Bug #18413)

  For NDB tables, DATA_LENGTH includes data stored in main memory only; the MAX_DATA_LENGTH and DATA_FREE columns apply to Disk Data.

- Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, for MySQL Cluster Disk Data tables, MAX_DATA_LENGTH shows the space allocated for the disk part of a Disk Data table or fragment. (In-memory data resource usage is reported by the DATA_LENGTH column.)

- Beginning with MySQL 5.1.28, the DATA_FREE column shows the free space in bytes for InnoDB tables.

  Beginning with MySQL Cluster NDB 7.0.22 and MySQL Cluster NDB 7.1.11, DATA_FREE shows the space allocated on disk for, but not used by, a Disk Data table or fragment on disk. (In-memory data resource usage is reported by the DATA_LENGTH column.)

- For partitioned InnoDB tables, the CREATE_TIME, UPDATE_TIME, and CHECK_TIME columns are always NULL.

- We have nothing for the table's default character set. TABLE_COLLATION is close, because collation names begin with a character set name.

- Beginning with MySQL 5.1.9, the CREATE_OPTIONS column shows partitioned if the table is partitioned.

The following statements are equivalent:

```
SELECT table_name FROM INFORMATION_SCHEMA.TABLES
  WHERE table_schema = 'db_name'
```

```
   [AND table_name LIKE 'wild']

SHOW TABLES
  FROM db_name
  [LIKE 'wild']
```

20.21 The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table

The `TABLE_CONSTRAINTS` table describes which tables have constraints.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CONSTRAINT_CATALOG		NULL
CONSTRAINT_SCHEMA		
CONSTRAINT_NAME		
TABLE_SCHEMA		
TABLE_NAME		
CONSTRAINT_TYPE		

Notes:

• The `CONSTRAINT_TYPE` value can be `UNIQUE`, `PRIMARY KEY`, or `FOREIGN KEY`.

• The `UNIQUE` and `PRIMARY KEY` information is about the same as what you get from the `Key_name` field in the output from `SHOW INDEX` when the `Non_unique` field is `0`.

• The `CONSTRAINT_TYPE` column can contain one of these values: `UNIQUE`, `PRIMARY KEY`, `FOREIGN KEY`, `CHECK`. This is a `CHAR` (not `ENUM`) column. The `CHECK` value is not available until we support `CHECK`.

20.22 The INFORMATION_SCHEMA TABLE_PRIVILEGES Table

The `TABLE_PRIVILEGES` table provides information about table privileges. This information comes from the `mysql.tables_priv` grant table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
GRANTEE		`'user_name'@'host_name'` value
TABLE_CATALOG		NULL
TABLE_SCHEMA		
TABLE_NAME		
PRIVILEGE_TYPE		
IS_GRANTABLE		

Notes:

• `PRIVILEGE_TYPE` can contain one (and only one) of these values: `SELECT`, `INSERT`, `UPDATE`, `REFERENCES`, `ALTER`, `INDEX`, `DROP`, `CREATE VIEW`.

The following statements are *not* equivalent:

```
SELECT ... FROM INFORMATION_SCHEMA.TABLE_PRIVILEGES
```

```
SHOW GRANTS ...
```

20.23 The INFORMATION_SCHEMA TRIGGERS Table

The `TRIGGERS` table provides information about triggers. To see information about a table's triggers, you must have the `TRIGGER` privilege for the table (prior to MySQL 5.1.23, you must have the `SUPER` privilege).

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`TRIGGER_CATALOG`		`NULL`
`TRIGGER_SCHEMA`		
`TRIGGER_NAME`	`Trigger`	
`EVENT_MANIPULATION`	`Event`	
`EVENT_OBJECT_CATALOG`		`NULL`
`EVENT_OBJECT_SCHEMA`		
`EVENT_OBJECT_TABLE`	`Table`	
`ACTION_ORDER`		`0`
`ACTION_CONDITION`		`NULL`
`ACTION_STATEMENT`	`Statement`	
`ACTION_ORIENTATION`		`ROW`
`ACTION_TIMING`	`Timing`	
`ACTION_REFERENCE_OLD_TABLE`		`NULL`
`ACTION_REFERENCE_NEW_TABLE`		`NULL`
`ACTION_REFERENCE_OLD_ROW`		`OLD`
`ACTION_REFERENCE_NEW_ROW`		`NEW`
`CREATED`	`Created`	
`SQL_MODE`	`sql_mode`	MySQL extension
`DEFINER`	`Definer`	MySQL extension
`CHARACTER_SET_CLIENT`	`character_set_client`	MySQL extension
`COLLATION_CONNECTION`	`collation_connection`	MySQL extension
`DATABASE_COLLATION`	`Database Collation`	MySQL extension

Notes:

- The names in the "`SHOW` Name" column refer to the `SHOW TRIGGERS` statement, not `SHOW CREATE TRIGGER`. See Section 13.7.5.40, "SHOW TRIGGERS Syntax".

- `TRIGGER_SCHEMA` and `TRIGGER_NAME`: The name of the database in which the trigger occurs and the trigger name, respectively.

- `EVENT_MANIPULATION`: The trigger event. This is the type of operation on the associated table for which the trigger activates. The value is `'INSERT'` (a row was inserted), `'DELETE'` (a row was deleted), or `'UPDATE'` (a row was modified).

- `EVENT_OBJECT_SCHEMA` and `EVENT_OBJECT_TABLE`: As noted in Section 19.3, "Using Triggers", every trigger is associated with exactly one table. These columns indicate the database in which this table occurs, and the table name, respectively.

- `ACTION_ORDER`: The ordinal position of the trigger's action within the list of all similar triggers on the same table. This value is always `0`, because it is not possible to have more than one trigger with the same `EVENT_MANIPULATION` and `ACTION_TIMING` on the same table.

- `ACTION_STATEMENT`: The trigger body; that is, the statement executed when the trigger activates. This text uses UTF-8 encoding.

- `ACTION_ORIENTATION`: Always contains the value `'ROW'`.

- `ACTION_TIMING`: Whether the trigger activates before or after the triggering event. The value is `'BEFORE'` or `'AFTER'`.

- `ACTION_REFERENCE_OLD_ROW` and `ACTION_REFERENCE_NEW_ROW`: The old and new column identifiers, respectively. This means that `ACTION_REFERENCE_OLD_ROW` always contains the value `'OLD'` and `ACTION_REFERENCE_NEW_ROW` always contains the value `'NEW'`.

- `SQL_MODE`: The SQL mode in effect when the trigger was created, and under which the trigger executes. For the permitted values, see Section 5.1.7, "Server SQL Modes".

- `DEFINER`: The account of the user who created the trigger, in `'user_name'@'host_name'` format. This column was added in MySQL 5.1.2.

- `CHARACTER_SET_CLIENT`: The session value of the `character_set_client` system variable when the trigger was created. This column was added in MySQL 5.1.21.

- `COLLATION_CONNECTION`: The session value of the `collation_connection` system variable when the trigger was created. This column was added in MySQL 5.1.21.

- `DATABASE_COLLATION`: The collation of the database with which the trigger is associated. This column was added in MySQL 5.1.21.

- The following columns currently always contain `NULL`: `TRIGGER_CATALOG`, `EVENT_OBJECT_CATALOG`, `ACTION_CONDITION`, `ACTION_REFERENCE_OLD_TABLE`, `ACTION_REFERENCE_NEW_TABLE`, and `CREATED`.

Example, using the `ins_sum` trigger defined in Section 19.3, "Using Triggers":

```
mysql> SELECT * FROM INFORMATION_SCHEMA.TRIGGERS
    -> WHERE TRIGGER_SCHEMA='test' AND TRIGGER_NAME='ins_sum'\G
*************************** 1. row ***************************
           TRIGGER_CATALOG: def
            TRIGGER_SCHEMA: test
              TRIGGER_NAME: ins_sum
         EVENT_MANIPULATION: INSERT
       EVENT_OBJECT_CATALOG: def
        EVENT_OBJECT_SCHEMA: test
         EVENT_OBJECT_TABLE: account
               ACTION_ORDER: 0
           ACTION_CONDITION: NULL
           ACTION_STATEMENT: SET @sum = @sum + NEW.amount
         ACTION_ORIENTATION: ROW
              ACTION_TIMING: BEFORE
ACTION_REFERENCE_OLD_TABLE: NULL
ACTION_REFERENCE_NEW_TABLE: NULL
  ACTION_REFERENCE_OLD_ROW: OLD
  ACTION_REFERENCE_NEW_ROW: NEW
                    CREATED: NULL
                   SQL_MODE:
                    DEFINER: me@localhost
       CHARACTER_SET_CLIENT: utf8
```

```
       COLLATION_CONNECTION: utf8_general_ci
          DATABASE_COLLATION: latin1_swedish_ci
```

20.24 The INFORMATION_SCHEMA USER_PRIVILEGES Table

The `USER_PRIVILEGES` table provides information about global privileges. This information comes from the `mysql.user` grant table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
GRANTEE		`'user_name'@'host_name'` value, MySQL extension
TABLE_CATALOG		NULL, MySQL extension
PRIVILEGE_TYPE		MySQL extension
IS_GRANTABLE		MySQL extension

Notes:

• This is a nonstandard table. It takes its values from the `mysql.user` table.

20.25 The INFORMATION_SCHEMA VIEWS Table

The `VIEWS` table provides information about views in databases. You must have the `SHOW VIEW` privilege to access this table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLE_CATALOG		NULL
TABLE_SCHEMA		
TABLE_NAME		
VIEW_DEFINITION		
CHECK_OPTION		
IS_UPDATABLE		
DEFINER		
SECURITY_TYPE		
CHARACTER_SET_CLIENT		MySQL extension
COLLATION_CONNECTION		MySQL extension

Notes:

• The `VIEW_DEFINITION` column has most of what you see in the `Create Table` field that `SHOW CREATE VIEW` produces. Skip the words before `SELECT` and skip the words `WITH CHECK OPTION`. Suppose that the original statement was:

```
CREATE VIEW v AS
  SELECT s2,s1 FROM t
  WHERE s1 > 5
  ORDER BY s1
  WITH CHECK OPTION;
```

Then the view definition looks like this:

```
SELECT s2,s1 FROM t WHERE s1 > 5 ORDER BY s1
```

- The `CHECK_OPTION` column has a value of `NONE`, `CASCADE`, or `LOCAL`.

- MySQL sets a flag, called the view updatability flag, at `CREATE VIEW` time. The flag is set to `YES` (true) if `UPDATE` and `DELETE` (and similar operations) are legal for the view. Otherwise, the flag is set to `NO` (false). The `IS_UPDATABLE` column in the `VIEWS` table displays the status of this flag. It means that the server always knows whether a view is updatable.

  If a view is not updatable, statements such `UPDATE`, `DELETE`, and `INSERT` are illegal and will be rejected. (Note that even if a view is updatable, it might not be possible to insert into it; for details, refer to Section 19.5.3, "Updatable and Insertable Views".)

- `DEFINER`: The account of the user who created the view, in `'user_name'@'host_name'` format. `SECURITY_TYPE` has a value of `DEFINER` or `INVOKER`.

- `CHARACTER_SET_CLIENT`: The session value of the `character_set_client` system variable when the view was created. This column was added in MySQL 5.1.21.

- `COLLATION_CONNECTION`: The session value of the `collation_connection` system variable when the view was created. This column was added in MySQL 5.1.21.

MySQL lets you use different `sql_mode` settings to tell the server the type of SQL syntax to support. For example, you might use the `ANSI` SQL mode to ensure MySQL correctly interprets the standard SQL concatenation operator, the double bar (`||`), in your queries. If you then create a view that concatenates items, you might worry that changing the `sql_mode` setting to a value different from `ANSI` could cause the view to become invalid. But this is not the case. No matter how you write out a view definition, MySQL always stores it the same way, in a canonical form. Here is an example that shows how the server changes a double bar concatenation operator to a `CONCAT()` function:

```
mysql> SET sql_mode = 'ANSI';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE VIEW test.v AS SELECT 'a' || 'b' as col1;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT VIEW_DEFINITION FROM INFORMATION_SCHEMA.VIEWS
    -> WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 'v';
+--------------------------------+
| VIEW_DEFINITION                |
+--------------------------------+
| select concat('a','b') AS `col1` |
+--------------------------------+
1 row in set (0.00 sec)
```

The advantage of storing a view definition in canonical form is that changes made later to the value of `sql_mode` will not affect the results from the view. However an additional consequence is that comments prior to `SELECT` are stripped from the definition by the server.

20.26 INFORMATION_SCHEMA Tables for MySQL Cluster

The following sections provide information about `INFORMATION_SCHEMA` tables which are specific to MySQL Cluster. The `FILES` table was added in MySQL Server 5.1.6 as part of MySQL Cluster data-on-disk support (it is available in standard MySQL 5.5 but is not used there). The `ndb_transid_mysql_connection_map` table was added as part of additions made to MySQL Cluster's `ndbinfo` information database in MySQL Cluster NDB 7.1.17; it is implemented as an

`INFORMATION_SCHEMA` plugin available only in MySQL Cluster binaries or source, and does not exist in MySQL Server 5.1.

Additional statistical and other data about MySQL Cluster transactions, operations, threads, blocks, and other aspects of performance can be obtained from the tables in the `ndbinfo` database. Information about these tables, see Section 17.5.10, "The ndbinfo MySQL Cluster Information Database".

20.26.1 The INFORMATION_SCHEMA FILES Table

The `FILES` table provides information about the files in which MySQL `NDB` Disk Data tables are stored.

> **Note**
>
> This table provides information about Disk Data *files* only; you cannot use it for determining disk space allocation or availability for individual `NDB` tables. However, beginning with MySQL Cluster NDB 6.3.27 and MySQL Cluster NDB 7.0.8, it is possible to see how much space is allocated for each `NDB` table having data stored on disk, as well as how much remains available for storage of data on disk for that table, using `ndb_desc`. For more information, see Section 17.4.10, "`ndb_desc` — Describe NDB Tables".

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`FILE_ID`		MySQL extension
`FILE_NAME`		MySQL extension
`FILE_TYPE`		MySQL extension
`TABLESPACE_NAME`		MySQL extension
`TABLE_CATALOG`		MySQL extension
`TABLE_SCHEMA`		MySQL extension
`TABLE_NAME`		MySQL extension
`LOGFILE_GROUP_NAME`		MySQL extension
`LOGFILE_GROUP_NUMBER`		MySQL extension
`ENGINE`		MySQL extension
`FULLTEXT_KEYS`		MySQL extension
`DELETED_ROWS`		MySQL extension
`UPDATE_COUNT`		MySQL extension
`FREE_EXTENTS`		MySQL extension
`TOTAL_EXTENTS`		MySQL extension
`EXTENT_SIZE`		MySQL extension
`INITIAL_SIZE`		MySQL extension
`MAXIMUM_SIZE`		MySQL extension
`AUTOEXTEND_SIZE`		MySQL extension
`CREATION_TIME`		MySQL extension
`LAST_UPDATE_TIME`		MySQL extension
`LAST_ACCESS_TIME`		MySQL extension
`RECOVER_TIME`		MySQL extension
`TRANSACTION_COUNTER`		MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
VERSION		MySQL extension
ROW_FORMAT		MySQL extension
TABLE_ROWS		MySQL extension
AVG_ROW_LENGTH		MySQL extension
DATA_LENGTH		MySQL extension
MAX_DATA_LENGTH		MySQL extension
INDEX_LENGTH		MySQL extension
DATA_FREE		MySQL extension
CREATE_TIME		MySQL extension
UPDATE_TIME		MySQL extension
CHECK_TIME		MySQL extension
CHECKSUM		MySQL extension
STATUS		MySQL extension
EXTRA		MySQL extension

Notes:

- `FILE_ID` column values are auto-generated.

- `FILE_NAME` is the name of an `UNDO` log file created by `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP`, or of a data file created by `CREATE TABLESPACE` or `ALTER TABLESPACE`.

- `FILE_TYPE` is one of the values `UNDOFILE` or `DATAFILE`.

  Beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2, this column can also have the value `TABLESPACE`.

- `TABLESPACE_NAME` is the name of the tablespace with which the file is associated.

- The value of the `TABLESPACE_CATALOG` column is always `NULL`.

- `TABLE_NAME` is the name of the Disk Data table with which the file is associated, if any.

- The `LOGFILE_GROUP_NAME` column gives the name of the log file group to which the log file or data file belongs.

- For an `UNDO` log file, the `LOGFILE_GROUP_NUMBER` contains the auto-generated ID number of the log file group to which the log file belongs.

- For a MySQL Cluster Disk Data log file or data file, the value of the `ENGINE` column is always `NDB` or `NDBCLUSTER`.

- For a MySQL Cluster Disk Data log file or data file, the value of the `FULLTEXT_KEYS` column is always empty.

- The `FREE EXTENTS` column displays the number of extents which have not yet been used by the file. The `TOTAL EXTENTS` column show the total number of extents allocated to the file.

  The difference between these two columns is the number of extents currently in use by the file:

```
SELECT TOTAL_EXTENTS - FREE_EXTENTS AS extents_used
```

```
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

You can approximate the amount of disk space in use by the file by multiplying this difference by the value of the `EXTENT_SIZE` column, which gives the size of an extent for the file in bytes:

```
SELECT (TOTAL_EXTENTS - FREE_EXTENTS) * EXTENT_SIZE AS bytes_used
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

Similarly, you can estimate the amount of space that remains available in a given file by multiplying `FREE_EXTENTS` by `EXTENT_SIZE`:

```
SELECT FREE_EXTENTS * EXTENT_SIZE AS bytes_free
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

> **Important**
>
> The byte values produced by the preceding queries are approximations only, and their precision is inversely proportional to the value of `EXTENT_SIZE`. That is, the larger `EXTENT_SIZE` becomes, the less accurate the approximations are.

It is also important to remember that once an extent is used, it cannot be freed again without dropping the data file of which it is a part. This means that deletes from a Disk Data table do *not* release disk space.

The extent size can be set in a `CREATE TABLESPACE` statement. See Section 13.1.18, "CREATE TABLESPACE Syntax", for more information.

- The `INITIAL_SIZE` column shows the size in bytes of the file. This is the same value that was used in the `INITIAL_SIZE` clause of the `CREATE LOGFILE GROUP`, `ALTER LOGFILE GROUP`, `CREATE TABLESPACE`, or `ALTER TABLESPACE` statement used to create the file.

  For MySQL Cluster Disk Data files, the value of the `MAXIMUM_SIZE` column is always the same as `INITIAL_SIZE`, and the `AUTOEXTEND_SIZE` column is always empty.

- The `CREATION_TIME` column shows the date and time when the file was created. The `LAST_UPDATE_TIME` column displays the date and time when the file was last modified. The `LAST_ACCESSED` column provides the date and time when the file was last accessed by the server.

  The values of these columns are as reported by the operating system, and are not supplied by the `NDB` storage engine. Where no value is provided by the operating system, these columns display `0000-00-00 00:00:00`.

- For MySQL Cluster Disk Data files, the value of the `RECOVER_TIME` and `TRANSACTION_COUNTER` columns is always `0`.

- For MySQL Cluster Disk Data files, the following columns are always `NULL`:

  - `VERSION`

  - `ROW_FORMAT`

  - `TABLE_ROWS`

  - `AVG_ROW_LENGTH`

- DATA_LENGTH

- MAX_DATA_LENGTH

- INDEX_LENGTH

- DATA_FREE

- CREATE_TIME

- UPDATE_TIME

- CHECK_TIME

- CHECKSUM

- For MySQL Cluster Disk Data files, the value of the STATUS column is always NORMAL.

- For MySQL Cluster Disk Data files, the EXTRA column shows which data node the file belongs to, as each data node has its own copy of the file. Suppose that you use this statement on a MySQL Cluster with four data nodes:

```
CREATE LOGFILE GROUP mygroup
    ADD UNDOFILE 'new_undo.dat'
    INITIAL_SIZE 2G
    ENGINE NDB;
```

After running the CREATE LOGFILE GROUP statement successfully, you should see a result similar to the one shown here for this query against the FILES table:

```
mysql> SELECT LOGFILE_GROUP_NAME, FILE_TYPE, EXTRA
    ->     FROM INFORMATION_SCHEMA.FILES
    ->     WHERE FILE_NAME = 'new_undo.dat';
+--------------------+------------+----------------+
| LOGFILE_GROUP_NAME | FILE_TYPE  | EXTRA          |
+--------------------+------------+----------------+
| mygroup            | UNDO FILE  | CLUSTER_NODE=3 |
| mygroup            | UNDO FILE  | CLUSTER_NODE=4 |
| mygroup            | UNDO FILE  | CLUSTER_NODE=5 |
| mygroup            | UNDO FILE  | CLUSTER_NODE=6 |
+--------------------+------------+----------------+
4 rows in set (0.01 sec)
```

- The FILES table is a nonstandard table. It was added in MySQL 5.1.6.

- Beginning with MySQL 5.1.14, an additional row is present in the FILES table following the creation of a logfile group. This row has NULL for the value of the FILE_NAME column. For this row, the value of the FILE_ID column is always 0, that of the FILE_TYPE column is always UNDO FILE, and that of the STATUS column is always NORMAL. The value of the ENGINE column is always NDBCLUSTER.

  The FREE_EXTENTS column in this row shows the total number of free extents available to all undo files belonging to a given log file group whose name and number are shown in the LOGFILE_GROUP_NAME and LOGFILE_GROUP_NUMBER columns, respectively.

  Suppose there are no existing log file groups on your MySQL Cluster, and you create one using the following statement:

```
mysql> CREATE LOGFILE GROUP lg1
    ->     ADD UNDOFILE 'undofile.dat'
    ->     INITIAL_SIZE = 16M
    ->     UNDO_BUFFER_SIZE = 1M
    ->     ENGINE = NDB;
Query OK, 0 rows affected (3.81 sec)
```

You can now see this NULL row when you query the FILES table:

```
mysql> SELECT DISTINCT
    ->     FILE_NAME AS File,
    ->     FREE_EXTENTS AS Free,
    ->     TOTAL_EXTENTS AS Total,
    ->     EXTENT_SIZE AS Size,
    ->     INITIAL_SIZE AS Initial
    ->     FROM INFORMATION_SCHEMA.FILES;
+--------------+---------+---------+------+----------+
| File         | Free    | Total   | Size | Initial  |
+--------------+---------+---------+------+----------+
| undofile.dat |    NULL | 4194304 |    4 | 16777216 |
| NULL         | 4184068 |    NULL |    4 |     NULL |
+--------------+---------+---------+------+----------+
2 rows in set (0.01 sec)
```

The total number of free extents available for undo logging is always somewhat less than the sum of the TOTAL_EXTENTS column values for all undo files in the log file group due to overhead required for maintaining the undo files. This can be seen by adding a second undo file to the log file group, then repeating the previous query against the FILES table:

```
mysql> ALTER LOGFILE GROUP lg1
    ->     ADD UNDOFILE 'undofile02.dat'
    ->     INITIAL_SIZE = 4M
    ->     ENGINE = NDB;
Query OK, 0 rows affected (1.02 sec)

mysql> SELECT DISTINCT
    ->     FILE_NAME AS File,
    ->     FREE_EXTENTS AS Free,
    ->     TOTAL_EXTENTS AS Total,
    ->     EXTENT_SIZE AS Size,
    ->     INITIAL_SIZE AS Initial
    ->     FROM INFORMATION_SCHEMA.FILES;
+----------------+---------+---------+------+----------+
| File           | Free    | Total   | Size | Initial  |
+----------------+---------+---------+------+----------+
| undofile.dat   |    NULL | 4194304 |    4 | 16777216 |
| undofile02.dat |    NULL | 1048576 |    4 |  4194304 |
| NULL           | 5223944 |    NULL |    4 |     NULL |
+----------------+---------+---------+------+----------+
3 rows in set (0.01 sec)
```

The amount of free space in bytes which is available for undo logging by Disk Data tables using this log file group can be approximated by multiplying the number of free extents by the initial size:

```
mysql> SELECT
    ->     FREE_EXTENTS AS 'Free Extents',
    ->     FREE_EXTENTS * EXTENT_SIZE AS 'Free Bytes'
    ->     FROM INFORMATION_SCHEMA.FILES
    ->     WHERE LOGFILE_GROUP_NAME = 'lg1'
    ->     AND FILE_NAME IS NULL;
+--------------+------------+
| Free Extents | Free Bytes |
```

```
+--------------+------------+
|      5223944 |   20895776 |
+--------------+------------+
1 row in set (0.02 sec)
```

If you create a MySQL Cluster Disk Data table and then insert some rows into it, you can see approximately how much space remains for undo logging afterward, for example:

```
mysql> CREATE TABLESPACE ts1
    ->     ADD DATAFILE 'data1.dat'
    ->     USE LOGFILE GROUP lg1
    ->     INITIAL_SIZE 512M
    ->     ENGINE = NDB;
Query OK, 0 rows affected (8.71 sec)

mysql> CREATE TABLE dd (
    ->     c1 INT NOT NULL PRIMARY KEY,
    ->     c2 INT,
    ->     c3 DATE
    ->     )
    ->     TABLESPACE ts1 STORAGE DISK
    ->     ENGINE = NDB;
Query OK, 0 rows affected (2.11 sec)

mysql> INSERT INTO dd VALUES
    ->     (NULL, 1234567890, '2007-02-02'),
    ->     (NULL, 1126789005, '2007-02-03'),
    ->     (NULL, 1357924680, '2007-02-04'),
    ->     (NULL, 1642097531, '2007-02-05');
Query OK, 4 rows affected (0.01 sec)

mysql> SELECT
    ->     FREE_EXTENTS AS 'Free Extents',
    ->     FREE_EXTENTS * EXTENT_SIZE AS 'Free Bytes'
    ->     FROM INFORMATION_SCHEMA.FILES
    ->     WHERE LOGFILE_GROUP_NAME = 'lg1'
    ->     AND FILE_NAME IS NULL;
+--------------+------------+
| Free Extents | Free Bytes |
+--------------+------------+
|      5207565 |   20830260 |
+--------------+------------+
1 row in set (0.01 sec)
```

- Beginning with MySQL Cluster NDB 6.2.19, MySQL Cluster NDB 6.3.32, MySQL Cluster NDB 7.0.13, and MySQL Cluster NDB 7.1.2, an additional row is present in the FILES table for any tablespace, whether or not any data files are associated with the tablespace. This row has NULL for the value of the FILE_NAME column. For this row, the value of the FILE_ID column is always 0, that of the FILE_TYPE column is always TABLESPACE, and that of the STATUS column is always NORMAL. The value of the ENGINE column is always NDBCLUSTER.

- There are no SHOW statements associated with the FILES table.

- For additional information, and examples of creating and dropping MySQL Cluster Disk Data objects, see Section 17.5.12, "MySQL Cluster Disk Data Tables".

20.26.2 The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table

The ndb_transid_mysql_connection_map table provides a mapping between NDB transactions, NDB transaction coordinators, and MySQL Servers attached to a MySQL Cluster as API nodes. This information

is used when populating the `server_operations` and `server_transactions` tables of the `ndbinfo` MySQL Cluster information database.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
`mysql_connection_id`		MySQL Server connection ID
`node_id`		Transaction coordinator node ID
`ndb_transid`		`NDB` transaction ID

The `mysql_connection_id` is the same as the connection or session ID shown in the output of `SHOW PROCESSLIST`.

There are no `SHOW` statements associated with this table.

This is a nonstandard table, added in MySQL Cluster NDB 7.1.17. It is implemented as an `INFORMATION_SCHEMA` plugin; you can verify that it is supported by checking the output of `SHOW PLUGINS`. If `ndb_transid_mysql_connection_map` support is enabled, the output from this statement includes a plugin having this name, of type `INFORMATION SCHEMA`, and having status `ACTIVE`, as shown here (using emphasized text):

```
mysql> SHOW PLUGINS;
+---------------------------------+--------+--------------------+---------+---------+
| Name                            | Status | Type               | Library | License |
+---------------------------------+--------+--------------------+---------+---------+
| binlog                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| CSV                             | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MEMORY                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MRG_MYISAM                      | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MyISAM                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| PERFORMANCE_SCHEMA              | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| BLACKHOLE                       | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ARCHIVE                         | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbcluster                      | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbinfo                         | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndb_transid_mysql_connection_map | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| InnoDB                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| INNODB_TRX                      | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_LOCKS                    | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_LOCK_WAITS               | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMP                      | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMP_RESET                | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMPMEM                   | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMPMEM_RESET             | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| partition                       | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
+---------------------------------+--------+--------------------+---------+---------+
```

The plugin is enabled by default. You can disable it (or force the server not to run unless the plugin starts) by starting the server with the `--ndb-transid-mysql-connection-map` option. If the plugin is disabled, the status is shown by `SHOW PLUGINS` as `DISABLED`. The plugin cannot be enabled or disabled at runtime.

Although the names of this table and its columns are displayed using lowercase, you can use uppercase or lowercase when referring to them in SQL statements.

For this table to be created, the MySQL Server must be a binary that wass supplied with the MySQL Cluster distribution, or one that was built from the MySQL Cluster sources with `NDB` storage engine support enabled. It is not available in the standard MySQL 5.1 Server.

20.27 Extensions to SHOW Statements

Some extensions to SHOW statements accompany the implementation of INFORMATION_SCHEMA:

- SHOW can be used to get information about the structure of INFORMATION_SCHEMA itself.

- Several SHOW statements accept a WHERE clause that provides more flexibility in specifying which rows to display.

INFORMATION_SCHEMA is an information database, so its name is included in the output from SHOW DATABASES. Similarly, SHOW TABLES can be used with INFORMATION_SCHEMA to obtain a list of its tables:

```
mysql> SHOW TABLES FROM INFORMATION_SCHEMA;
+---------------------------------------+
| Tables_in_INFORMATION_SCHEMA          |
+---------------------------------------+
| CHARACTER_SETS                        |
| COLLATIONS                            |
| COLLATION_CHARACTER_SET_APPLICABILITY |
| COLUMNS                               |
| COLUMN_PRIVILEGES                     |
| ENGINES                               |
| EVENTS                                |
| FILES                                 |
| GLOBAL_STATUS                         |
| GLOBAL_VARIABLES                      |
| KEY_COLUMN_USAGE                      |
| PARTITIONS                            |
| PLUGINS                               |
| PROCESSLIST                           |
| REFERENTIAL_CONSTRAINTS               |
| ROUTINES                              |
| SCHEMATA                              |
| SCHEMA_PRIVILEGES                     |
| SESSION_STATUS                        |
| SESSION_VARIABLES                     |
| STATISTICS                            |
| TABLES                                |
| TABLE_CONSTRAINTS                     |
| TABLE_PRIVILEGES                      |
| TRIGGERS                              |
| USER_PRIVILEGES                       |
| VIEWS                                 |
+---------------------------------------+
27 rows in set (0.00 sec)
```

SHOW COLUMNS and DESCRIBE can display information about the columns in individual INFORMATION_SCHEMA tables.

SHOW statements that accept a LIKE clause to limit the rows displayed also permit a WHERE clause that specifies more general conditions that selected rows must satisfy:

```
SHOW CHARACTER SET
SHOW COLLATION
SHOW COLUMNS
SHOW DATABASES
SHOW FUNCTION STATUS
SHOW INDEX
SHOW OPEN TABLES
SHOW PROCEDURE STATUS
SHOW STATUS
```

```
SHOW TABLE STATUS
SHOW TABLES
SHOW TRIGGERS
SHOW VARIABLES
```

The WHERE clause, if present, is evaluated against the column names displayed by the SHOW statement. For example, the SHOW CHARACTER SET statement produces these output columns:

```
mysql> SHOW CHARACTER SET;
+---------+---------------------------+---------------------+--------+
| Charset | Description               | Default collation   | Maxlen |
+---------+---------------------------+---------------------+--------+
| big5    | Big5 Traditional Chinese  | big5_chinese_ci     |      2 |
| dec8    | DEC West European         | dec8_swedish_ci     |      1 |
| cp850   | DOS West European         | cp850_general_ci    |      1 |
| hp8     | HP West European          | hp8_english_ci      |      1 |
| koi8r   | KOI8-R Relcom Russian     | koi8r_general_ci    |      1 |
| latin1  | cp1252 West European      | latin1_swedish_ci   |      1 |
| latin2  | ISO 8859-2 Central European | latin2_general_ci |      1 |
...
```

To use a WHERE clause with SHOW CHARACTER SET, you would refer to those column names. As an example, the following statement displays information about character sets for which the default collation contains the string 'japanese':

```
mysql> SHOW CHARACTER SET WHERE `Default collation` LIKE '%japanese%';
+---------+-------------------------+---------------------+--------+
| Charset | Description             | Default collation   | Maxlen |
+---------+-------------------------+---------------------+--------+
| ujis    | EUC-JP Japanese         | ujis_japanese_ci    |      3 |
| sjis    | Shift-JIS Japanese      | sjis_japanese_ci    |      2 |
| cp932   | SJIS for Windows Japanese | cp932_japanese_ci |      2 |
| eucjpms | UJIS for Windows Japanese | eucjpms_japanese_ci |    3 |
+---------+-------------------------+---------------------+--------+
```

This statement displays the multibyte character sets:

```
mysql> SHOW CHARACTER SET WHERE Maxlen > 1;
+---------+-------------------------+---------------------+--------+
| Charset | Description             | Default collation   | Maxlen |
+---------+-------------------------+---------------------+--------+
| big5    | Big5 Traditional Chinese | big5_chinese_ci    |      2 |
| ujis    | EUC-JP Japanese         | ujis_japanese_ci    |      3 |
| sjis    | Shift-JIS Japanese      | sjis_japanese_ci    |      2 |
| euckr   | EUC-KR Korean           | euckr_korean_ci     |      2 |
| gb2312  | GB2312 Simplified Chinese | gb2312_chinese_ci |      2 |
| gbk     | GBK Simplified Chinese   | gbk_chinese_ci      |      2 |
| utf8    | UTF-8 Unicode           | utf8_general_ci     |      3 |
| ucs2    | UCS-2 Unicode           | ucs2_general_ci     |      2 |
| cp932   | SJIS for Windows Japanese | cp932_japanese_ci |      2 |
| eucjpms | UJIS for Windows Japanese | eucjpms_japanese_ci |    3 |
+---------+-------------------------+---------------------+--------+
```

Chapter 21 Connectors and APIs

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MySQL Connectors provide connectivity to the MySQL server for client programs. APIs provide low-level access to the MySQL protocol and MySQL resources. Both Connectors and the APIs enable you to connect and execute MySQL statements from another language or environment, including ODBC, Java (JDBC), Perl, Python, PHP, Ruby, and native C and embedded MySQL instances.

> **Note**
>
> Connector version numbers do not correlate with MySQL Server version numbers.
> See Table 21.2, "MySQL Connector Versions and MySQL Server Versions".

MySQL Connectors

Oracle develops a number of connectors:

- Connector/ODBC provides driver support for connecting to MySQL using the Open Database Connectivity (ODBC) API. Support is available for ODBC connectivity from Windows, Unix, and OS X platforms.

- Connector/Net enables developers to create .NET applications that connect to MySQL. Connector/Net implements a fully functional ADO.NET interface and provides support for use with ADO.NET aware tools. Applications that use Connector/Net can be written in any supported .NET language.

  The MySQL Visual Studio Plugin works with Connector/Net and Visual Studio 2005. The plugin is a MySQL DDEX Provider, which means that you can use the schema and data manipulation tools available in Visual Studio to create and edit objects within a MySQL database.

- Connector/J provides driver support for connecting to MySQL from Java applications using the standard Java Database Connectivity (JDBC) API.

- Connector/Python provides driver support for connecting to MySQL from Python applications using an API that is compliant with the Python DB API version 2.0. No additional Python modules or MySQL client libraries are required.

- Connector/C++ enables C++ applications to connect to MySQL.

- Connector/C is a standalone replacement for the MySQL Client Library (`libmysqlclient`), to be used for C applications.

The MySQL C API

For direct access to using MySQL natively within a C application, there are two methods:

- The C API provides low-level access to the MySQL client/server protocol through the `libmysqlclient` client library. This is the primary method used to connect to an instance of the MySQL server, and is used both by MySQL command-line clients and many of the MySQL Connectors and third-party APIs detailed here.

  `libmysqlclient` is included in MySQL distributions and in Connector/C distributions.

- `libmysqld` is an embedded MySQL server library that enables you to embed an instance of the MySQL server into your C applications.

  `libmysqld` is included in MySQL distributions, but not in Connector/C distributions.

See also Section 21.8.1, "MySQL C API Implementations".

To access MySQL from a C application, or to build an interface to MySQL for a language not supported by the Connectors or APIs in this chapter, the C API is where to start. A number of programmer's utilities are available to help with the process; see Section 4.7, "MySQL Program Development Utilities".

Third-Party MySQL APIs

The remaining APIs described in this chapter provide an interface to MySQL from specific application languages. These third-party solutions are not developed or supported by Oracle. Basic information on their usage and abilities is provided here for reference purposes only.

All the third-party language APIs are developed using one of two methods, using `libmysqlclient` or by implementing a *native driver*. The two solutions offer different benefits:

- Using *`libmysqlclient`* offers complete compatibility with MySQL because it uses the same libraries as the MySQL client applications. However, the feature set is limited to the implementation and interfaces exposed through `libmysqlclient` and the performance may be lower as data is copied between the native language, and the MySQL API components.

- *Native drivers* are an implementation of the MySQL network protocol entirely within the host language or environment. Native drivers are fast, as there is less copying of data between components, and they can offer advanced functionality not available through the standard MySQL API. Native drivers are also easier for end users to build and deploy because no copy of the MySQL client libraries is needed to build the native driver components.

Table 21.1, "MySQL APIs and Interfaces" lists many of the libraries and interfaces available for MySQL. Table 21.2, "MySQL Connector Versions and MySQL Server Versions" shows which MySQL Server versions each connector supports.

Table 21.1 MySQL APIs and Interfaces

Environment	API	Type	Notes
Ada	GNU Ada MySQL Bindings	`libmysqlclient`	See MySQL Bindings for GNU Ada
C	C API	`libmysqlclient`	See Section 21.8, "MySQL C API".
C	Connector/C	Replacement for `libmysqlclient`	See MySQL Connector/C Developer Guide.
C++	Connector/C++	`libmysqlclient`	See MySQL Connector/C++ Developer Guide.
	MySQL++	`libmysqlclient`	See MySQL++ Web site.
	MySQL wrapped	`libmysqlclient`	See MySQL wrapped.
Cocoa	MySQL-Cocoa	`libmysqlclient`	Compatible with the Objective-C Cocoa environment. See http://mysql-cocoa.sourceforge.net/
D	MySQL for D	`libmysqlclient`	See MySQL for D.
Eiffel	Eiffel MySQL	`libmysqlclient`	See Section 21.14, "MySQL Eiffel Wrapper".
Erlang	`erlang-mysql-driver`	`libmysqlclient`	See `erlang-mysql-driver`.
Haskell	Haskell MySQL Bindings	Native Driver	See Brian O'Sullivan's pure Haskell MySQL bindings.
	`hsql-mysql`	`libmysqlclient`	See MySQL driver for Haskell .
Java/JDBC	Connector/J	Native Driver	See MySQL Connector/J 5.1 Developer Guide.
Kaya	MyDB	`libmysqlclient`	See MyDB.
Lua	LuaSQL	`libmysqlclient`	See LuaSQL.

Environment	API	Type	Notes
.NET/ Mono	Connector/Net	Native Driver	See MySQL Connector/Net Developer Guide.
Objective Caml	OBjective Caml MySQL Bindings	`libmysqlclient`	See MySQL Bindings for Objective Caml.
Octave	Database bindings for GNU Octave	`libmysqlclient`	See Database bindings for GNU Octave.
ODBC	Connector/ODBC	`libmysqlclient`	See MySQL Connector/ODBC Developer Guide.
Perl	`DBI`/`DBD::mysql`	`libmysqlclient`	See Section 21.10, "MySQL Perl API".
	`Net::MySQL`	Native Driver	See `Net::MySQL` at CPAN
PHP	`mysql`, `ext/mysql` interface (deprecated)	`libmysqlclient`	See Original MySQL API.
	`mysqli`, `ext/mysqli` interface	`libmysqlclient`	See MySQL Improved Extension.
	`PDO_MYSQL`	`libmysqlclient`	See MySQL Functions (PDO_MYSQL).
	PDO mysqlnd	Native Driver	
Python	Connector/Python	Native Driver	See MySQL Connector/Python Developer Guide.
Python	Connector/Python C Extension	`libmysqlclient`	See MySQL Connector/Python Developer Guide.
	MySQLdb	`libmysqlclient`	See Section 21.11, "MySQL Python API".
Ruby	MySQL/Ruby	`libmysqlclient`	Uses `libmysqlclient`. See Section 21.12.1, "The MySQL/Ruby API".
	Ruby/MySQL	Native Driver	See Section 21.12.2, "The Ruby/MySQL API".
Scheme	`Myscsh`	`libmysqlclient`	See `Myscsh`.
SPL	`sql_mysql`	`libmysqlclient`	See `sql_mysql` for SPL.
Tcl	MySQLtcl	`libmysqlclient`	See Section 21.13, "MySQL Tcl API".

Table 21.2 MySQL Connector Versions and MySQL Server Versions

Connector	Connector version	MySQL Server version
Connector/C	6.1.0 GA	5.6, 5.5, 5.1, 5.0, 4.1
Connector/C++	1.0.5 GA	5.6, 5.5, 5.1
Connector/J	5.1.8	5.6, 5.5, 5.1, 5.0, 4.1
Connector/Net	6.5	5.6, 5.5, 5.1, 5.0
Connector/Net	6.4	5.6, 5.5, 5.1, 5.0
Connector/Net	6.3	5.6, 5.5, 5.1, 5.0
Connector/Net	6.2 (No longer supported)	5.6, 5.5, 5.1, 5.0
Connector/Net	6.1 (No longer supported)	5.6, 5.5, 5.1, 5.0
Connector/Net	6.0 (No longer supported)	5.6, 5.5, 5.1, 5.0
Connector/Net	5.2 (No longer supported)	5.6, 5.5, 5.1, 5.0
Connector/Net	1.0 (No longer supported)	5.0, 4.0
Connector/ODBC	5.1	5.6, 5.5, 5.1, 5.0, 4.1.1+

Connector	Connector version	MySQL Server version
Connector/ODBC	3.51 (Unicode not supported)	5.6, 5.5, 5.1, 5.0, 4.1
Connector/Python	2.0	5.7, 5.6, 5.5
Connector/Python	1.2	5.7, 5.6, 5.5

21.1 MySQL Connector/ODBC

The MySQL Connector/ODBC manual is now published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

• Main manual: MySQL Connector/ODBC Developer Guide

• Release notes: MySQL Connector/ODBC Release Notes

21.2 MySQL Connector/Net

The MySQL Connector/Net manual is now published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

• Main manual: MySQL Connector/Net Developer Guide

• Release notes: MySQL Connector/Net Release Notes

21.3 MySQL Connector/J

The MySQL Connector/J manual is now published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

• Main manual: MySQL Connector/J 5.1 Developer Guide

• Release notes: MySQL Connector/J Release Notes

21.4 MySQL Connector/C++

The MySQL Connector/C++ manual is now published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

• Main manual: MySQL Connector/C++ Developer Guide

• Release notes: MySQL Connector/C++ Release Notes

21.5 MySQL Connector/C

The MySQL Connector/C manual is now published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

• Main manual: MySQL Connector/C Developer Guide

• Release notes: MySQL Connector/C Release Notes

21.6 MySQL Connector/Python

The MySQL Connector/Python manual is now published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/Python Developer Guide

- Release notes: MySQL Connector/Python Release Notes

21.7 libmysqld, the Embedded MySQL Server Library

The embedded MySQL server library makes it possible to run a full-featured MySQL server inside a client application. The main benefits are increased speed and more simple management for embedded applications.

The embedded server library is based on the client/server version of MySQL, which is written in C/C++. Consequently, the embedded server also is written in C/C++. There is no embedded server available in other languages.

The API is identical for the embedded MySQL version and the client/server version. To change an old threaded application to use the embedded library, you normally only have to add calls to the following functions.

Table 21.3 MySQL Embedded Server Library Functions

Function	When to Call
`mysql_library_init()`	Call it before any other MySQL function is called, preferably early in the `main()` function.
`mysql_library_end()`	Call it before your program exits.
`mysql_thread_init()`	Call it in each thread you create that accesses MySQL.
`mysql_thread_end()`	Call it before calling `pthread_exit()`.

Then you must link your code with `libmysqld.a` instead of `libmysqlclient.a`. To ensure binary compatibility between your application and the server library, be sure to compile your application against headers for the same series of MySQL that was used to compile the server library. For example, if `libmysqld` was compiled against MySQL 5.0 headers, do not compile your application against MySQL 5.1 headers, or vice versa.

The `mysql_library_xxx()` functions are also included in `libmysqlclient.a` to enable you to change between the embedded and the client/server version by just linking your application with the right library. See Section 21.8.7.40, "mysql_library_init()".

One difference between the embedded server and the standalone server is that for the embedded server, authentication for connections is disabled by default. To use authentication for the embedded server, specify the `--with-embedded-privilege-control` option when you invoke `configure` to configure your MySQL distribution.

21.7.1 Compiling Programs with libmysqld

In precompiled binary MySQL distributions that include `libmysqld`, the embedded server library, MySQL builds the library using the appropriate vendor compiler if there is one.

To get a `libmysqld` library if you build MySQL from source yourself, you should configure MySQL with the `--with-embedded-server` option. See Section 2.11.4, "MySQL Source-Configuration Options".

When you link your program with `libmysqld`, you must also include the system-specific `pthread` libraries and some libraries that the MySQL server uses. You can get the full list of libraries by executing `mysql_config --libmysqld-libs`.

The correct flags for compiling and linking a threaded program must be used, even if you do not directly call any thread functions in your code.

To compile a C program to include the necessary files to embed the MySQL server library into an executable version of a program, the compiler will need to know where to find various files and need instructions on how to compile the program. The following example shows how a program could be compiled from the command line, assuming that you are using `gcc`, use the GNU C compiler:

```
gcc mysql_test.c -o mysql_test -lz \
`/usr/local/mysql/bin/mysql_config --include --libmysqld-libs`
```

Immediately following the `gcc` command is the name of the C program source file. After it, the `-o` option is given to indicate that the file name that follows is the name that the compiler is to give to the output file, the compiled program. The next line of code tells the compiler to obtain the location of the include files and libraries and other settings for the system on which it is compiled. Because of a problem with `mysql_config`, the option `-lz` (for compression) is added here. The `mysql_config` command is contained in backticks, not single quotation marks.

On some non-`gcc` platforms, the embedded library depends on C++ runtime libraries and linking against the embedded library might result in missing-symbol errors. To solve this, link using a C++ compiler or explicitly list the required libraries on the link command line.

21.7.2 Restrictions When Using the Embedded MySQL Server

The embedded server has the following limitations:

- No user-defined functions (UDFs).

- No stack trace on core dump.

- You cannot set this up as a master or a slave (no replication).

- Very large result sets may be unusable on low memory systems.

- You cannot connect to an embedded server from an outside process with sockets or TCP/IP. However, you can connect to an intermediate application, which in turn can connect to an embedded server on the behalf of a remote client or outside process.

- `InnoDB` is not reentrant in the embedded server and cannot be used for multiple connections, either successively or simultaneously.

- The Event Scheduler is not available. Because of this, the `event_scheduler` system variable is disabled.

Some of these limitations can be changed by editing the `mysql_embed.h` include file and recompiling MySQL.

21.7.3 Options with the Embedded Server

Any options that may be given with the `mysqld` server daemon, may be used with an embedded server library. Server options may be given in an array as an argument to the `mysql_library_init()`, which initializes the server. They also may be given in an option file like `my.cnf`. To specify an option file for a C program, use the `--defaults-file` option as one of the elements of the second argument of the `mysql_library_init()` function. See Section 21.8.7.40, "mysql_library_init()", for more information on the `mysql_library_init()` function.

Using option files can make it easier to switch between a client/server application and one where MySQL is embedded. Put common options under the `[server]` group. These are read by both MySQL versions.

Client/server-specific options should go under the `[mysqld]` section. Put options specific to the embedded MySQL server library in the `[embedded]` section. Options specific to applications go under section labeled `[ApplicationName_SERVER]`. See Section 4.2.6, "Using Option Files".

21.7.4 Embedded Server Examples

These two example programs should work without any changes on a Linux or FreeBSD system. For other operating systems, minor changes are needed, mostly with file paths. These examples are designed to give enough details for you to understand the problem, without the clutter that is a necessary part of a real application. The first example is very straightforward. The second example is a little more advanced with some error checking. The first is followed by a command-line entry for compiling the program. The second is followed by a GNUmake file that may be used for compiling instead.

Example 1

test1_libmysqld.c

```c
#include <stdio.h>
#include <stdlib.h>
#include <stdarg.h>
#include "mysql.h"

MYSQL *mysql;
MYSQL_RES *results;
MYSQL_ROW record;

static char *server_options[] = \
        { "mysql_test", "--defaults-file=my.cnf", NULL };
int num_elements = (sizeof(server_options) / sizeof(char *)) - 1;

static char *server_groups[] = { "libmysqld_server",
                                 "libmysqld_client", NULL };

int main(void)
{
   mysql_library_init(num_elements, server_options, server_groups);
   mysql = mysql_init(NULL);
   mysql_options(mysql, MYSQL_READ_DEFAULT_GROUP, "libmysqld_client");
   mysql_options(mysql, MYSQL_OPT_USE_EMBEDDED_CONNECTION, NULL);

   mysql_real_connect(mysql, NULL,NULL,NULL, "database1", 0,NULL,0);

   mysql_query(mysql, "SELECT column1, column2 FROM table1");

   results = mysql_store_result(mysql);

   while((record = mysql_fetch_row(results))) {
      printf("%s - %s \n", record[0], record[1]);
   }

   mysql_free_result(results);
   mysql_close(mysql);
   mysql_library_end();

   return 0;
}
```

Here is the command line for compiling the above program:

```
gcc test1_libmysqld.c -o test1_libmysqld -lz \
 `/usr/local/mysql/bin/mysql_config --include --libmysqld-libs`
```

Example 2

To try the example, create an `test2_libmysqld` directory at the same level as the MySQL source directory. Save the `test2_libmysqld.c` source and the `GNUmakefile` in the directory, and run GNU `make` from inside the `test2_libmysqld` directory.

`test2_libmysqld.c`

```
/*
 * A simple example client, using the embedded MySQL server library
*/

#include <mysql.h>
#include <stdarg.h>
#include <stdio.h>
#include <stdlib.h>

MYSQL *db_connect(const char *dbname);
void db_disconnect(MYSQL *db);
void db_do_query(MYSQL *db, const char *query);

const char *server_groups[] = {
  "test2_libmysqld_SERVER", "embedded", "server", NULL
};

int
main(int argc, char **argv)
{
  MYSQL *one, *two;

  /* mysql_library_init() must be called before any other mysql
   * functions.
   *
   * You can use mysql_library_init(0, NULL, NULL), and it
   * initializes the server using groups = {
   *   "server", "embedded", NULL
   *  }.
   *
   * In your $HOME/.my.cnf file, you probably want to put:

[test2_libmysqld_SERVER]
language = /path/to/source/of/mysql/sql/share/english

   * You could, of course, modify argc and argv before passing
   * them to this function.  Or you could create new ones in any
   * way you like.  But all of the arguments in argv (except for
   * argv[0], which is the program name) should be valid options
   * for the MySQL server.
   *
   * If you link this client against the normal mysqlclient
   * library, this function is just a stub that does nothing.
   */
  mysql_library_init(argc, argv, (char **)server_groups);

  one = db_connect("test");
  two = db_connect(NULL);

  db_do_query(one, "SHOW TABLE STATUS");
  db_do_query(two, "SHOW DATABASES");

  mysql_close(two);
  mysql_close(one);

  /* This must be called after all other mysql functions */
  mysql_library_end();
```

```
    exit(EXIT_SUCCESS);
}

static void
die(MYSQL *db, char *fmt, ...)
{
  va_list ap;
  va_start(ap, fmt);
  vfprintf(stderr, fmt, ap);
  va_end(ap);
  (void)putc('\n', stderr);
  if (db)
    db_disconnect(db);
  exit(EXIT_FAILURE);
}

MYSQL *
db_connect(const char *dbname)
{
  MYSQL *db = mysql_init(NULL);
  if (!db)
    die(db, "mysql_init failed: no memory");
  /*
   * Notice that the client and server use separate group names.
   * This is critical, because the server does not accept the
   * client's options, and vice versa.
   */
  mysql_options(db, MYSQL_READ_DEFAULT_GROUP, "test2_libmysqld_CLIENT");
  if (!mysql_real_connect(db, NULL, NULL, NULL, dbname, 0, NULL, 0))
    die(db, "mysql_real_connect failed: %s", mysql_error(db));

  return db;
}

void
db_disconnect(MYSQL *db)
{
  mysql_close(db);
}

void
db_do_query(MYSQL *db, const char *query)
{
  if (mysql_query(db, query) != 0)
    goto err;

  if (mysql_field_count(db) > 0)
  {
    MYSQL_RES   *res;
    MYSQL_ROW    row, end_row;
    int num_fields;

    if (!(res = mysql_store_result(db)))
      goto err;
    num_fields = mysql_num_fields(res);
    while ((row = mysql_fetch_row(res)))
    {
      (void)fputs(">> ", stdout);
      for (end_row = row + num_fields; row < end_row; ++row)
        (void)printf("%s\t", row ? (char*)*row : "NULL");
      (void)fputc('\n', stdout);
    }
    (void)fputc('\n', stdout);
    mysql_free_result(res);
  }
  else
```

```
    (void)printf("Affected rows: %lld\n", mysql_affected_rows(db));

  return;

err:
  die(db, "db_do_query failed: %s [%s]", mysql_error(db), query);
}
```

GNUmakefile

```
# This assumes the MySQL software is installed in /usr/local/mysql
inc      := /usr/local/mysql/include/mysql
lib      := /usr/local/mysql/lib

# If you have not installed the MySQL software yet, try this instead
#inc       := $(HOME)/mysql-5.1/include
#lib       := $(HOME)/mysql-5.1/libmysqld

CC       := gcc
CPPFLAGS := -I$(inc) -D_THREAD_SAFE -D_REENTRANT
CFLAGS   := -g -W -Wall
LDFLAGS  := -static
# You can change -lmysqld to -lmysqlclient to use the
# client/server library
LDLIBS    = -L$(lib) -lmysqld -lz -lm -ldl -lcrypt

ifneq (,$(shell grep FreeBSD /COPYRIGHT 2>/dev/null))
# FreeBSD
LDFLAGS += -pthread
else
# Assume Linux
LDLIBS += -lpthread
endif

# This works for simple one-file test programs
sources := $(wildcard *.c)
objects := $(patsubst %c,%o,$(sources))
targets := $(basename $(sources))

all: $(targets)

clean:
        rm -f $(targets) $(objects) *.core
```

21.8 MySQL C API

The C API provides low-level access to the MySQL client/server protocol and enables C programs
to access database contents. The C API code is distributed with MySQL and implemented in the
`libmysqlclient` library. See Section 21.8.1, "MySQL C API Implementations".

Most client APIs use the `libmysqlclient` library to communicate with the MySQL server. (Exceptions
are Connector/J and Connector/Net) This means that, for example, you can take advantage of many of the
same environment variables that are used by other client programs because they are referenced from the
library. For a list of these variables, see Section 4.1, "Overview of MySQL Programs".

For instructions on building client programs using the C API, see Section 21.8.4.1, "Building C API
Client Programs". For programming with threads, see Section 21.8.4.2, "Writing C API Threaded Client
Programs". To create a standalone application which includes the "server" and "client" in the same
program (and does not communicate with an external MySQL server), see Section 21.7, "libmysqld, the
Embedded MySQL Server Library".

> **Note**
>
> If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, the programs were probably compiled using old header or library files. In this case, check the date of the `mysql.h` file and `libmysqlclient.a` library used for compilation to verify that they are from the new MySQL distribution. If not, recompile the programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.17` to `libmysqlclient.so.18`). For additional compatibility information, see Section 21.8.4.3, "Running C API Client Programs".

Clients have a maximum communication buffer size. The size of the buffer that is allocated initially (16KB) is automatically increased up to the maximum size (16MB by default). Because buffer sizes are increased only as demand warrants, simply increasing the maximum limit does not in itself cause more resources to be used. This size check is mostly a precaution against erroneous statements and communication packets.

The communication buffer must be large enough to contain a single SQL statement (for client-to-server traffic) and one row of returned data (for server-to-client traffic). Each session's communication buffer is dynamically enlarged to handle any query or row up to the maximum limit. For example, if you have `BLOB` values that contain up to 16MB of data, you must have a communication buffer limit of at least 16MB (in both server and client). The default maximum built into the client library is 1GB, but the default maximum in the server is 1MB. You can increase this by changing the value of the `max_allowed_packet` parameter at server startup. See Section 8.12.2, "Tuning Server Parameters".

The MySQL server shrinks each communication buffer to `net_buffer_length` bytes after each query. For clients, the size of the buffer associated with a connection is not decreased until the connection is closed, at which time client memory is reclaimed.

21.8.1 MySQL C API Implementations

The MySQL C API is a C-based API that client applications written in C can use to communicate with MySQL Server. Client programs refer to C API header files at compile time and link to a C API library file at link time. The library comes in two versions, depending on how the application is intended to communicate with the server:

- `libmysqlclient`: The client version of the library, used for applications that communicate over a network connection as a client of a standalone server process.

- `libmysqld`: The embedded server version of the library, used for applications intended to include an embedded MySQL server within the application itself. The application communicates with its own private server instance.

Both libraries have the same interface. In terms of C API calls, an application communicates with a standalone server the same way it communicates with an embedded server. A given client can be built to communicate with a standalone or embedded server, depending on whether it is linked against `libmysqlclient` or `libmysqld` at build time.

There are two ways to obtain the C API header and library files required to build C API client programs:

- Install a MySQL Server distribution. Server distributions include both `libmysqlclient` and `libmysqld`.

- Install a Connector/C distribution. Connector/C distributions include only `libmysqlclient`. They do not include `libmysqld`.

For both MySQL Server and Connector/C, you can install a binary distribution that contains the C API files pre-built, or you can use a source distribution and build the C API files yourself.

Normally, you install either a MySQL Server distribution or a Connector/C distribution, but not both. For information about issues involved with simultaneous MySQL Server and Connector/C installations, see Section 21.8.2, "Simultaneous MySQL Server and Connector/C Installations".

The names of the library files to use when linking C API client applications depend on the library type and platform for which a distribution is built:

- On Unix (and Unix-like) sytems, the static library is `libmysqlclient.a`. The dynamic library is `libmysqlclient.so` on most Unix systems and `libmysqlclient.dylib` on OS X.

  For distributions that include embedded server libraries, the corresponding library names begin with `libmysqld` rather than `libmysqlclient`.

- On Windows, the static library is `mysqlclient.lib` and the dynamic library is `libmysql.dll`. Windows distributions also include `libmysql.lib`, a static import library needed for using the dynamic library.

  For distributions that include embedded server libraries, the corresponding library names are `mysqlserver.lib`, `libmysqld.dll`, and `libmysqld.lib`.

  Windows distributions also include a set of debug libraries. These have the same names as the nondebug libraries, but are located in the `lib/debug` library. You must use the debug libraries when compiling clients built using the debug C runtime.

21.8.2 Simultaneous MySQL Server and Connector/C Installations

MySQL Server and Connector/C installation packages both provide the files needed to build and run MySQL C API client programs. This section discusses when it is possible to install both products on the same system. For some packaging formats, this is possible without conflict. For others, both products cannot be installed at the same time.

This discussion assumes the use of similar package types for both products (for example, RPM packages for both products). It does not try to describe coexistence between packaging types (for example, use of RPM packages for one product and a `tar` file package for the other). Nor does it describe coexistence of packages provided by Oracle and those provided by third-party vendors.

If you install both products, it may be necessary to adjust your development tools or runtime environment to choose one set of header files and libraries over the other. See Section 21.8.4.1, "Building C API Client Programs", and Section 21.8.4.3, "Running C API Client Programs".

`tar` and Zip file packages install under the directory into which you unpack them. For example, you can unpack MySQL Server and Connector/C `tar` packages under `/usr/local` and they will unpack into distinct directory names without conflict.

Windows MSI installers use their own installation directory, so MySQL Server and Connector/C installers do not conflict.

OS X DMG packages install under the same parent directory but in a different subdirectory, so there is no conflict. For example:

```
/usr/local/mysql-5.6.11-osx10.7-x86_64/
/usr/local/mysql-connector-c-6.1.0-osx10.7-x86/
```

Example C API Client Programs

Solaris PKG packages install under the same parent directory but in a different subdirectory, so there is no conflict. For example:

```
/opt/mysql/mysql
/opt/mysql/connector-c
```

The Solaris Connector/C installer does not create any symlinks from system directories such as `/usr/bin` or `/usr/lib` into the installation directory. That must be done manually if desired after installation.

For RPM installations, there are several types of RPM packages. MySQL Server `shared` and `devel` RPM packages are similar to the corresponding Connector/C RPM packages. These RPM package types cannot coexist because the MySQL Server and Connector/C RPM packages use the same installation locations for the client library-related files. This means the following conditions hold:

- If MySQL Server `shared` and `devel` RPM packages are installed, they provide the C API headers and libraries, and there is no need to install the Connector/C RPM packages. To install the Connector/C packages anyway, you must first remove the corresponding MySQL Server packages.

- To install MySQL Server RPM packages if you already have Connector/C RPM packages installed, you must first remove the Connector/C RPM packages.

MySQL Server RPM packages other than `shared` and `devel` do not conflict with Connector/C packages and can be installed if Connector/C is installed. This includes the main server RPM that includes the `mysqld` server itself.

21.8.3 Example C API Client Programs

Many of the clients in MySQL source distributions are written in C, such as `mysql`, `mysqladmin`, and `mysqlshow`. If you are looking for examples that demonstrate how to use the C API, take a look at these clients: Obtain a source distribution and look in its `client` directory. See Section 2.1.2, "How to Get MySQL".

21.8.4 Building and Running C API Client Programs

The following sections provide information on building client programs that use the C API. Topics include compiling and linking clients, writing threaded clients, and troubleshooting runtime problems.

21.8.4.1 Building C API Client Programs

This section provides guidelines for compiling C programs that use the MySQL C API.

Compiling MySQL Clients on Unix

You may need to specify an `-I` option when you compile client programs that use MySQL header files, so that the compiler can find them. For example, if the header files are installed in `/usr/local/mysql/include`, use this option in the compile command:

```
-I/usr/local/mysql/include
```

MySQL clients must be linked using the `-lmysqlclient -lz` options in the link command. You may also need to specify a `-L` option to tell the linker where to find the library. For example, if the library is installed in `/usr/local/mysql/lib`, use these options in the link command:

```
-L/usr/local/mysql/lib -lmysqlclient -lz
```

The path names may differ on your system. Adjust the `-I` and `-L` options as necessary.

To make it simpler to compile MySQL programs on Unix, use the `mysql_config` script. See
Section 4.7.2, "`mysql_config` — Display Options for Compiling Clients".

`mysql_config` displays the options needed for compiling or linking:

```
shell> mysql_config --cflags
shell> mysql_config --libs
```

You can run those commands to get the proper options and add them manually to compilation or link
commands. Alternatively, include the output from `mysql_config` directly within command lines using
backticks:

```
shell> gcc -c `mysql_config --cflags` progname.c
shell> gcc -o progname progname.o `mysql_config --libs`
```

Compiling MySQL Clients on Microsoft Windows

To specify header and library file locations, use the facilities provided by your development environment.

On Windows, you can link your code with either the dynamic or static C client library. The static library
is named `mysqlclient.lib` and the dynamic library is named `libmysql.dll`. In addition, the
`libmysql.lib` static import library is needed for using the dynamic library.

If you link with the static library, failure can occur unless these conditions are satisfied:

- The client application must be compiled with the same version of Visual Studio used to compile the
  library.

- The client application should link the C runtime statically by using the `/MT` compiler option.

If the client application is built in debug mode and uses the static debug C runtime (`/MTd` compiler option),
it can link to the `mysqlclient.lib` static library if that library was built using the same option. If the client
application uses the dynamic C runtime (`/MD` option, or `/MDd` option in debug mode), it must be linked to
the `libmysql.dll` dynamic library. It cannot link to the static client library.

The MSDN page describing the link options can be found here: http://msdn.microsoft.com/en-us/
library/2kzt1wy3.aspx

Troubleshooting Problems Linking to the MySQL Client Library

Linking with the single-threaded library (`libmysqlclient`) may lead to linker errors related
to `pthread` symbols. When using the single-threaded library, please compile your client with
`MYSQL_CLIENT_NO_THREADS` defined. This can be done on the command line by using the `-D` option to
the compiler, or in your source code before including the MySQL header files. This define should not be
used when building for use with the thread-safe client library (`libmysqlclient_r`).

If the linker cannot find the MySQL client library, you might get undefined-reference errors for symbols that
start with `mysql_`, such as those shown here:

```
/tmp/ccFKsdPa.o: In function `main':
/tmp/ccFKsdPa.o(.text+0xb): undefined reference to `mysql_init'
/tmp/ccFKsdPa.o(.text+0x31): undefined reference to `mysql_real_connect'
/tmp/ccFKsdPa.o(.text+0x69): undefined reference to `mysql_error'
/tmp/ccFKsdPa.o(.text+0x9a): undefined reference to `mysql_close'
```

You should be able to solve this problem by adding `-Ldir_path -lmysqlclient` at the end of your link
command, where `dir_path` represents the path name of the directory where the client library is located.
To determine the correct directory, try this command:

```
shell> mysql_config --libs
```

The output from `mysql_config` might indicate other libraries that should be specified on the link command as well. You can include `mysql_config` output directly in your compile or link command using backticks. For example:

```
shell> gcc -o progname progname.o `mysql_config --libs`
```

If an error occurs at link time that the `floor` symbol is undefined, link to the math library by adding `-lm` to the end of the compile/link line.

If you get `undefined reference` errors for the `uncompress` or `compress` function, add `-lz` to the end of your link command and try again.

Similarly, if you get undefined-reference errors for other functions that should exist on your system, such as `connect()`, check the manual page for the function in question to determine which libraries you should add to the link command.

If you get undefined-reference errors such as the following for functions that do not exist on your system, it usually means that your MySQL client library was compiled on a system that is not 100% compatible with yours:

```
mf_format.o(.text+0x201): undefined reference to `__lxstat'
```

In this case, you should download the latest MySQL or Connector/C source distribution and compile the MySQL client library yourself. See Section 2.11, "Installing MySQL from Source", and MySQL Connector/C Developer Guide.

21.8.4.2 Writing C API Threaded Client Programs

The client library is almost thread-safe. The biggest problem is that the subroutines in `sql/net_serv.cc` that read from sockets are not interrupt-safe. This was done with the thought that you might want to have your own alarm that can break a long read to a server. If you install interrupt handlers for the `SIGPIPE` interrupt, socket handling should be thread-safe.

To avoid aborting the program when a connection terminates, MySQL blocks `SIGPIPE` on the first call to `mysql_library_init()`, `mysql_init()`, or `mysql_connect()`. To use your own `SIGPIPE` handler, first call `mysql_library_init()`, then install your handler.

Current binary distributions should have both a normal client library, `libmysqlclient`, and a thread-safe library, `libmysqlclient_r`. For threaded clients, link against the latter library. If "undefined symbol" errors occur, in most cases this is because you have not included the thread libraries on the link/compile command.

The thread-safe client library, `libmysqlclient_r`, is thread-safe per connection. You can let two threads share the same connection with the following caveats:

• Multiple threads cannot send a query to the MySQL server at the same time on the same connection. In particular, you must ensure that between calls to `mysql_query()` and `mysql_store_result()` in one thread, no other thread uses the same connection. You must have a mutex lock around your pair of `mysql_query()` and `mysql_store_result()` calls. After `mysql_store_result()` returns, the lock can be released and other threads may query the same connection.

If you use POSIX threads, you can use `pthread_mutex_lock()` and `pthread_mutex_unlock()` to establish and release a mutex lock.

- Many threads can access different result sets that are retrieved with `mysql_store_result()`.

- To use `mysql_use_result()`, you must ensure that no other thread is using the same connection until the result set is closed. However, it really is best for threaded clients that share the same connection to use `mysql_store_result()`.

You need to know the following if you have a thread that did not create the connection to the MySQL database but is calling MySQL functions:

When you call `mysql_init()`, MySQL creates a thread-specific variable for the thread that is used by the debug library (among other things). If you call a MySQL function before the thread has called `mysql_init()`, the thread does not have the necessary thread-specific variables in place and you are likely to end up with a core dump sooner or later. To avoid problems, you must do the following:

1. Call `mysql_library_init()` before any other MySQL functions. It is not thread-safe, so call it before threads are created, or protect the call with a mutex.

2. Arrange for `mysql_thread_init()` to be called early in the thread handler before calling any MySQL function. If you call `mysql_init()`, it will call `mysql_thread_init()` for you.

3. In the thread, call `mysql_thread_end()` before calling `pthread_exit()`. This frees the memory used by MySQL thread-specific variables.

The preceding notes regarding `mysql_init()` also apply to `mysql_connect()`, which calls `mysql_init()`.

21.8.4.3 Running C API Client Programs

If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, the programs were probably compiled using old header or library files. In this case, check the date of the `mysql.h` file and `libmysqlclient.a` library used for compilation to verify that they are from the new MySQL distribution. If not, recompile the programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.17` to `libmysqlclient.so.18`).

The major client library version determines compatibility. (For example, for `libmysqlclient.so.18.1.0`, the major version is 18.) For this reason, the libraries shipped with newer versions of MySQL are drop-in replacements for older versions that have the same major number. As long as the major library version is the same, you can upgrade the library and old applications should continue to work with it.

Undefined-reference errors might occur at runtime when you try to execute a MySQL program. If these errors specify symbols that start with `mysql_` or indicate that the `libmysqlclient` library cannot be found, it means that your system cannot find the shared `libmysqlclient.so` library. The solution to this problem is to tell your system to search for shared libraries in the directory where that library is located. Use whichever of the following methods is appropriate for your system:

- Add the path of the directory where `libmysqlclient.so` is located to the `LD_LIBRARY_PATH` or `LD_LIBRARY` environment variable.

- On OS X, add the path of the directory where `libmysqlclient.dylib` is located to the `DYLD_LIBRARY_PATH` environment variable.

- Copy the shared-library files (such as `libmysqlclient.so`) to some directory that is searched by your system, such as `/lib`, and update the shared library information by executing `ldconfig`. Be sure to copy all related files. A shared library might exist under several names, using symlinks to provide the alternate names.

Another way to solve this problem is by linking your program statically with the `-static` option, or by removing the dynamic MySQL libraries before linking your code. Before trying the second method, you should be sure that no other programs are using the dynamic libraries.

21.8.4.4 C API Server and Client Library Versions

The string and numeric forms of the MySQL server version are available at compile time as the values of the `MYSQL_SERVER_VERSION` and `MYSQL_VERSION_ID` macros, and at runtime as the values of the `mysql_get_server_info()` and `mysql_get_server_version()` functions.

The client library version is the MySQL version. For Connector/C, this is the MySQL version on which the Connector/C distribution is based. The string and numeric forms of this version are available at compile time as the values of the `MYSQL_SERVER_VERSION` and `MYSQL_VERSION_ID` macros, and at runtime as the values of the `mysql_get_client_info()` and `mysql_get_client_version()` functions.

21.8.5 C API Data Structures

This section describes C API data structures other than those used for prepared statements. For information about the latter, see Section 21.8.9, "C API Prepared Statement Data Structures".

- `MYSQL`

  This structure represents a handle to one database connection. It is used for almost all MySQL functions. Do not try to make a copy of a `MYSQL` structure. There is no guarantee that such a copy will be usable.

- `MYSQL_RES`

  This structure represents the result of a query that returns rows (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`). The information returned from a query is called the *result set* in the remainder of this section.

- `MYSQL_ROW`

  This is a type-safe representation of one row of data. It is currently implemented as an array of counted byte strings. (You cannot treat these as null-terminated strings if field values may contain binary data, because such values may contain null bytes internally.) Rows are obtained by calling `mysql_fetch_row()`.

- `MYSQL_FIELD`

  This structure contains metadata: information about a field, such as the field's name, type, and size. Its members are described in more detail later in this section. You may obtain the `MYSQL_FIELD` structures for each field by calling `mysql_fetch_field()` repeatedly. Field values are not part of this structure; they are contained in a `MYSQL_ROW` structure.

- `MYSQL_FIELD_OFFSET`

  This is a type-safe representation of an offset into a MySQL field list. (Used by `mysql_field_seek()`.) Offsets are field numbers within a row, beginning at zero.

- `my_ulonglong`

  The type used for the number of rows and for `mysql_affected_rows()`, `mysql_num_rows()`, and `mysql_insert_id()`. This type provides a range of `0` to `1.84e19`.

  Some functions that return a row count using this type return -1 as an unsigned value to indicate an error or exceptional condition. You can check for -1 by comparing the return value to `(my_ulonglong)-1` (or to `(my_ulonglong)~0`, which is equivalent).

On some systems, attempting to print a value of type `my_ulonglong` does not work. To print such a value, convert it to `unsigned long` and use a `%lu` print format. Example:

```
printf ("Number of rows: %lu\n",
        (unsigned long) mysql_num_rows(result));
```

- `my_bool`

  A boolean type, for values that are true (nonzero) or false (zero).

The `MYSQL_FIELD` structure contains the members described in the following list:

- `char * name`

  The name of the field, as a null-terminated string. If the field was given an alias with an `AS` clause, the value of `name` is the alias.

- `char * org_name`

  The name of the field, as a null-terminated string. Aliases are ignored. For expressions, the value is an empty string.

- `char * table`

  The name of the table containing this field, if it is not a calculated field. For calculated fields, the `table` value is an empty string. If the column is selected from a view, `table` names the view. If the table or view was given an alias with an `AS` clause, the value of `table` is the alias. For a `UNION`, the value is the empty string.

- `char * org_table`

  The name of the table, as a null-terminated string. Aliases are ignored. If the column is selected from a view, `org_table` names the view. For a `UNION`, the value is the empty string.

- `char * db`

  The name of the database that the field comes from, as a null-terminated string. If the field is a calculated field, `db` is an empty string. For a `UNION`, the value is the empty string.

- `char * catalog`

  The catalog name. This value is always `"def"`.

- `char * def`

  The default value of this field, as a null-terminated string. This is set only if you use `mysql_list_fields()`.

- `unsigned long length`

  The width of the field. This corresponds to the display length, in bytes.

  The server determines the `length` value before it generates the result set, so this is the minimum length required for a data type capable of holding the largest possible value from the result column, without knowing in advance the actual values that will be produced by the query for the result set.

- `unsigned long max_length`

The maximum width of the field for the result set (the length in bytes of the longest field value for the rows actually in the result set). If you use `mysql_store_result()` or `mysql_list_fields()`, this contains the maximum length for the field. If you use `mysql_use_result()`, the value of this variable is zero.

The value of `max_length` is the length of the string representation of the values in the result set. For example, if you retrieve a `FLOAT` column and the "widest" value is `-12.345`, `max_length` is 7 (the length of `'-12.345'`).

If you are using prepared statements, `max_length` is not set by default because for the binary protocol the lengths of the values depend on the types of the values in the result set. (See Section 21.8.9, "C API Prepared Statement Data Structures".) If you want the `max_length` values anyway, enable the `STMT_ATTR_UPDATE_MAX_LENGTH` option with `mysql_stmt_attr_set()` and the lengths will be set when you call `mysql_stmt_store_result()`. (See Section 21.8.11.3, "mysql_stmt_attr_set()", and Section 21.8.11.27, "mysql_stmt_store_result()".)

- `unsigned int name_length`

  The length of `name`.

- `unsigned int org_name_length`

  The length of `org_name`.

- `unsigned int table_length`

  The length of `table`.

- `unsigned int org_table_length`

  The length of `org_table`.

- `unsigned int db_length`

  The length of `db`.

- `unsigned int catalog_length`

  The length of `catalog`.

- `unsigned int def_length`

  The length of `def`.

- `unsigned int flags`

  Bit-flags that describe the field. The `flags` value may have zero or more of the bits set that are shown in the following table.

Flag Value	Flag Description
`NOT_NULL_FLAG`	Field cannot be `NULL`
`PRI_KEY_FLAG`	Field is part of a primary key
`UNIQUE_KEY_FLAG`	Field is part of a unique key
`MULTIPLE_KEY_FLAG`	Field is part of a nonunique key
`UNSIGNED_FLAG`	Field has the `UNSIGNED` attribute

Flag Value	Flag Description
`ZEROFILL_FLAG`	Field has the `ZEROFILL` attribute
`BINARY_FLAG`	Field has the `BINARY` attribute
`AUTO_INCREMENT_FLAG`	Field has the `AUTO_INCREMENT` attribute
`ENUM_FLAG`	Field is an `ENUM`
`SET_FLAG`	Field is a `SET`
`BLOB_FLAG`	Field is a `BLOB` or `TEXT` (deprecated)
`TIMESTAMP_FLAG`	Field is a `TIMESTAMP` (deprecated)
`NUM_FLAG`	Field is numeric; see additional notes following table
`NO_DEFAULT_VALUE_FLAG`	Field has no default value; see additional notes following table

Some of these flags indicate data type information and are superseded by or used in conjunction with the `MYSQL_TYPE_xxx` value in the `field->type` member described later:

- To check for `BLOB` or `TIMESTAMP` values, check whether `type` is `MYSQL_TYPE_BLOB` or `MYSQL_TYPE_TIMESTAMP`. (The `BLOB_FLAG` and `TIMESTAMP_FLAG` flags are unneeded.)

- `ENUM` and `SET` values are returned as strings. For these, check that the `type` value is `MYSQL_TYPE_STRING` and that the `ENUM_FLAG` or `SET_FLAG` flag is set in the `flags` value.

`NUM_FLAG` indicates that a column is numeric. This includes columns with a type of `MYSQL_TYPE_DECIMAL`, `MYSQL_TYPE_TINY`, `MYSQL_TYPE_SHORT`, `MYSQL_TYPE_LONG`, `MYSQL_TYPE_FLOAT`, `MYSQL_TYPE_DOUBLE`, `MYSQL_TYPE_NULL`, `MYSQL_TYPE_LONGLONG`, `MYSQL_TYPE_INT24`, and `MYSQL_TYPE_YEAR`.

`NO_DEFAULT_VALUE_FLAG` indicates that a column has no `DEFAULT` clause in its definition. This does not apply to `NULL` columns (because such columns have a default of `NULL`), or to `AUTO_INCREMENT` columns (which have an implied default value).

The following example illustrates a typical use of the `flags` value:

```
if (field->flags & NOT_NULL_FLAG)
    printf("Field cannot be null\n");
```

You may use the convenience macros shown in the following table to determine the boolean status of the `flags` value.

Flag Status	Description
`IS_NOT_NULL(flags)`	True if this field is defined as `NOT NULL`
`IS_PRI_KEY(flags)`	True if this field is a primary key
`IS_BLOB(flags)`	True if this field is a `BLOB` or `TEXT` (deprecated; test `field->type` instead)

- `unsigned int decimals`

  The number of decimals for numeric fields.

- `unsigned int charsetnr`

An ID number that indicates the character set/collation pair for the field.

Normally, character values in result sets are converted to the character set indicated by the `character_set_results` system variable. In this case, `charsetnr` corresponds to the character set indicated by that variable. Character set conversion can be suppressed by setting `character_set_results` to `NULL`. In this case, `charsetnr` corresponds to the character set of the original table column or expression. See also Section 10.1.4, "Connection Character Sets and Collations".

To distinguish between binary and nonbinary data for string data types, check whether the `charsetnr` value is 63. If so, the character set is `binary`, which indicates binary rather than nonbinary data. This enables you to distinguish `BINARY` from `CHAR`, `VARBINARY` from `VARCHAR`, and the `BLOB` types from the `TEXT` types.

`charsetnr` values are the same as those displayed in the `Id` column of the `SHOW COLLATION` statement or the `ID` column of the `INFORMATION_SCHEMA COLLATIONS` table. You can use those information sources to see which character set and collation specific `charsetnr` values indicate:

```
mysql> SHOW COLLATION WHERE Id = 63;
+-----------+---------+----+---------+----------+---------+
| Collation | Charset | Id | Default | Compiled | Sortlen |
+-----------+---------+----+---------+----------+---------+
| binary    | binary  | 63 | Yes     | Yes      |       1 |
+-----------+---------+----+---------+----------+---------+

mysql> SELECT COLLATION_NAME, CHARACTER_SET_NAME
    -> FROM INFORMATION_SCHEMA.COLLATIONS WHERE ID = 33;
+-----------------+--------------------+
| COLLATION_NAME  | CHARACTER_SET_NAME |
+-----------------+--------------------+
| utf8_general_ci | utf8               |
+-----------------+--------------------+
```

- `enum enum_field_types type`

  The type of the field. The `type` value may be one of the `MYSQL_TYPE_` symbols shown in the following table.

Type Value	Type Description
`MYSQL_TYPE_TINY`	`TINYINT` field
`MYSQL_TYPE_SHORT`	`SMALLINT` field
`MYSQL_TYPE_LONG`	`INTEGER` field
`MYSQL_TYPE_INT24`	`MEDIUMINT` field
`MYSQL_TYPE_LONGLONG`	`BIGINT` field
`MYSQL_TYPE_DECIMAL`	`DECIMAL` or `NUMERIC` field
`MYSQL_TYPE_NEWDECIMAL`	Precision math `DECIMAL` or `NUMERIC`
`MYSQL_TYPE_FLOAT`	`FLOAT` field
`MYSQL_TYPE_DOUBLE`	`DOUBLE` or `REAL` field
`MYSQL_TYPE_BIT`	`BIT` field
`MYSQL_TYPE_TIMESTAMP`	`TIMESTAMP` field
`MYSQL_TYPE_DATE`	`DATE` field

Type Value	Type Description
MYSQL_TYPE_TIME	TIME field
MYSQL_TYPE_DATETIME	DATETIME field
MYSQL_TYPE_YEAR	YEAR field
MYSQL_TYPE_STRING	CHAR or BINARY field
MYSQL_TYPE_VAR_STRING	VARCHAR or VARBINARY field
MYSQL_TYPE_BLOB	BLOB or TEXT field (use max_length to determine the maximum length)
MYSQL_TYPE_SET	SET field
MYSQL_TYPE_ENUM	ENUM field
MYSQL_TYPE_GEOMETRY	Spatial field
MYSQL_TYPE_NULL	NULL-type field

You can use the IS_NUM() macro to test whether a field has a numeric type. Pass the type value to IS_NUM() and it evaluates to TRUE if the field is numeric:

```
if (IS_NUM(field->type))
    printf("Field is numeric\n");
```

ENUM and SET values are returned as strings. For these, check that the type value is MYSQL_TYPE_STRING and that the ENUM_FLAG or SET_FLAG flag is set in the flags value.

21.8.6 C API Function Overview

The functions available in the C API are summarized here and described in greater detail in a later section. See Section 21.8.7, "C API Function Descriptions".

Table 21.4 C API Function Names and Descriptions

Function	Description
my_init()	Initialize global variables, and thread handler in thread-safe programs
mysql_affected_rows()	Returns the number of rows changed/deleted/inserted by the last UPDATE, DELETE, or INSERT query
mysql_autocommit()	Toggles autocommit mode on/off
mysql_change_user()	Changes user and database on an open connection
mysql_character_set_name(	Return default character set name for current connection
mysql_close()	Closes a server connection
mysql_commit()	Commits the transaction
mysql_connect()	Connects to a MySQL server (this function is deprecated; use mysql_real_connect() instead)
mysql_create_db()	Creates a database (this function is deprecated; use the SQL statement CREATE DATABASE instead)
mysql_data_seek()	Seeks to an arbitrary row number in a query result set
mysql_debug()	Does a DBUG_PUSH with the given string
mysql_drop_db()	Drops a database (this function is deprecated; use the SQL statement DROP DATABASE instead)

Function	Description
`mysql_dump_debug_info()`	Makes the server write debug information to the log
`mysql_eof()`	Determines whether the last row of a result set has been read (this function is deprecated; `mysql_errno()` or `mysql_error()` may be used instead)
`mysql_errno()`	Returns the error number for the most recently invoked MySQL function
`mysql_error()`	Returns the error message for the most recently invoked MySQL function
`mysql_escape_string()`	Escapes special characters in a string for use in an SQL statement
`mysql_fetch_field()`	Returns the type of the next table field
`mysql_fetch_field_direct(`	Returns the type of a table field, given a field number
`mysql_fetch_fields()`	Returns an array of all field structures
`mysql_fetch_lengths()`	Returns the lengths of all columns in the current row
`mysql_fetch_row()`	Fetches the next row from the result set
`mysql_field_count()`	Returns the number of result columns for the most recent statement
`mysql_field_seek()`	Puts the column cursor on a specified column
`mysql_field_tell()`	Returns the position of the field cursor used for the last `mysql_fetch_field()`
`mysql_free_result()`	Frees memory used by a result set
`mysql_get_character_set_i`n`f`o``	Return information about default character set
`mysql_get_client_info()`	Returns client version information as a string
`mysql_get_client_version(`	Returns client version information as an integer
`mysql_get_host_info()`	Returns a string describing the connection
`mysql_get_proto_info()`	Returns the protocol version used by the connection
`mysql_get_server_info()`	Returns the server version number
`mysql_get_server_version(`	Returns version number of server as an integer
`mysql_get_ssl_cipher()`	Return current SSL cipher
`mysql_hex_string()`	Encode string in hexadecimal format
`mysql_info()`	Returns information about the most recently executed query
`mysql_init()`	Gets or initializes a `MYSQL` structure
`mysql_insert_id()`	Returns the ID generated for an `AUTO_INCREMENT` column by the previous query
`mysql_kill()`	Kills a given thread
`mysql_library_end()`	Finalize the MySQL C API library
`mysql_library_init()`	Initialize the MySQL C API library
`mysql_list_dbs()`	Returns database names matching a simple regular expression
`mysql_list_fields()`	Returns field names matching a simple regular expression
`mysql_list_processes()`	Returns a list of the current server threads
`mysql_list_tables()`	Returns table names matching a simple regular expression
`mysql_more_results()`	Checks whether any more results exist

Function	Description
`mysql_next_result()`	Returns/initiates the next result in multiple-result executions
`mysql_num_fields()`	Returns the number of columns in a result set
`mysql_num_rows()`	Returns the number of rows in a result set
`mysql_options()`	Sets connect options for `mysql_real_connect()`
`mysql_ping()`	Checks whether the connection to the server is working, reconnecting as necessary
`mysql_query()`	Executes an SQL query specified as a null-terminated string
`mysql_real_connect()`	Connects to a MySQL server
`mysql_real_escape_string(`	Escapes special characters in a string for use in an SQL statement, taking into account the current character set of the connection
`mysql_real_query()`	Executes an SQL query specified as a counted string
`mysql_refresh()`	Flush or reset tables and caches
`mysql_reload()`	Tells the server to reload the grant tables
`mysql_rollback()`	Rolls back the transaction
`mysql_row_seek()`	Seeks to a row offset in a result set, using value returned from `mysql_row_tell()`
`mysql_row_tell()`	Returns the row cursor position
`mysql_select_db()`	Selects a database
`mysql_server_end()`	Finalize the MySQL C API library
`mysql_server_init()`	Initialize the MySQL C API library
`mysql_set_character_set()`	Set default character set for current connection
`mysql_set_local_infile_default()`	Set the `LOAD DATA LOCAL INFILE` handler callbacks to their default values
`mysql_set_local_infile_handler`	Install application-specific `LOAD DATA LOCAL INFILE` handler callbacks
`mysql_set_server_option()`	Sets an option for the connection (like `multi-statements`)
`mysql_sqlstate()`	Returns the SQLSTATE error code for the last error
`mysql_shutdown()`	Shuts down the database server
`mysql_ssl_set()`	Prepare to establish SSL connection to server
`mysql_stat()`	Returns the server status as a string
`mysql_store_result()`	Retrieves a complete result set to the client
`mysql_thread_end()`	Finalize thread handler
`mysql_thread_id()`	Returns the current thread ID
`mysql_thread_init()`	Initialize thread handler
`mysql_thread_safe()`	Returns 1 if the clients are compiled as thread-safe
`mysql_use_result()`	Initiates a row-by-row result set retrieval
`mysql_warning_count()`	Returns the warning count for the previous SQL statement

Application programs should use this general outline for interacting with MySQL:

1. Initialize the MySQL library by calling `mysql_library_init()`. This function exists in both the `libmysqlclient` C client library and the `libmysqld` embedded server library, so it is used whether you build a regular client program by linking with the `-libmysqlclient` flag, or an embedded server application by linking with the `-libmysqld` flag.

2. Initialize a connection handler by calling `mysql_init()` and connect to the server by calling `mysql_real_connect()`.

3. Issue SQL statements and process their results. (The following discussion provides more information about how to do this.)

4. Close the connection to the MySQL server by calling `mysql_close()`.

5. End use of the MySQL library by calling `mysql_library_end()`.

The purpose of calling `mysql_library_init()` and `mysql_library_end()` is to provide proper initialization and finalization of the MySQL library. For applications that are linked with the client library, they provide improved memory management. If you do not call `mysql_library_end()`, a block of memory remains allocated. (This does not increase the amount of memory used by the application, but some memory leak detectors will complain about it.) For applications that are linked with the embedded server, these calls start and stop the server.

In a nonmulti-threaded environment, the call to `mysql_library_init()` may be omitted, because `mysql_init()` will invoke it automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multi-threaded environment, and thus neither is `mysql_init()`, which calls `mysql_library_init()`. You must either call `mysql_library_init()` prior to spawning any threads, or else use a mutex to protect the call, whether you invoke `mysql_library_init()` or indirectly through `mysql_init()`. This should be done prior to any other client library call.

To connect to the server, call `mysql_init()` to initialize a connection handler, then call `mysql_real_connect()` with that handler (along with other information such as the host name, user name, and password). Upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the `MYSQL` structure) to a value of `1` in versions of the API older than 5.0.3, or `0` in newer versions. A value of `1` for this flag indicates that if a statement cannot be performed because of a lost connection, to try reconnecting to the server before giving up. You can use the `MYSQL_OPT_RECONNECT` option to `mysql_options()` to control reconnection behavior. When you are done with the connection, call `mysql_close()` to terminate it.

While a connection is active, the client may send SQL statements to the server using `mysql_query()` or `mysql_real_query()`. The difference between the two is that `mysql_query()` expects the query to be specified as a null-terminated string whereas `mysql_real_query()` expects a counted string. If the string contains binary data (which may include null bytes), you must use `mysql_real_query()`.

For each non-`SELECT` query (for example, `INSERT`, `UPDATE`, `DELETE`), you can find out how many rows were changed (affected) by calling `mysql_affected_rows()`.

For `SELECT` queries, you retrieve the selected rows as a result set. (Note that some statements are `SELECT`-like in that they return rows. These include `SHOW`, `DESCRIBE`, and `EXPLAIN`. Treat these statements the same way as `SELECT` statements.)

There are two ways for a client to process result sets. One way is to retrieve the entire result set all at once by calling `mysql_store_result()`. This function acquires from the server all the rows returned by the query and stores them in the client. The second way is for the client to initiate a row-by-row result set retrieval by calling `mysql_use_result()`. This function initializes the retrieval, but does not actually get any rows from the server.

In both cases, you access rows by calling `mysql_fetch_row()`. With `mysql_store_result()`, `mysql_fetch_row()` accesses rows that have previously been fetched from the server. With `mysql_use_result()`, `mysql_fetch_row()` actually retrieves the row from the server. Information about the size of the data in each row is available by calling `mysql_fetch_lengths()`.

After you are done with a result set, call `mysql_free_result()` to free the memory used for it.

The two retrieval mechanisms are complementary. Choose the approach that is most appropriate for each client application. In practice, clients tend to use `mysql_store_result()` more commonly.

An advantage of `mysql_store_result()` is that because the rows have all been fetched to the client, you not only can access rows sequentially, you can move back and forth in the result set using `mysql_data_seek()` or `mysql_row_seek()` to change the current row position within the result set. You can also find out how many rows there are by calling `mysql_num_rows()`. On the other hand, the memory requirements for `mysql_store_result()` may be very high for large result sets and you are more likely to encounter out-of-memory conditions.

An advantage of `mysql_use_result()` is that the client requires less memory for the result set because it maintains only one row at a time (and because there is less allocation overhead, `mysql_use_result()` can be faster). Disadvantages are that you must process each row quickly to avoid tying up the server, you do not have random access to rows within the result set (you can only access rows sequentially), and the number of rows in the result set is unknown until you have retrieved them all. Furthermore, you *must* retrieve all the rows even if you determine in mid-retrieval that you've found the information you were looking for.

The API makes it possible for clients to respond appropriately to statements (retrieving rows only as necessary) without knowing whether the statement is a `SELECT`. You can do this by calling `mysql_store_result()` after each `mysql_query()` (or `mysql_real_query()`). If the result set call succeeds, the statement was a `SELECT` and you can read the rows. If the result set call fails, call `mysql_field_count()` to determine whether a result was actually to be expected. If `mysql_field_count()` returns zero, the statement returned no data (indicating that it was an `INSERT`, `UPDATE`, `DELETE`, and so forth), and was not expected to return rows. If `mysql_field_count()` is nonzero, the statement should have returned rows, but did not. This indicates that the statement was a `SELECT` that failed. See the description for `mysql_field_count()` for an example of how this can be done.

Both `mysql_store_result()` and `mysql_use_result()` enable you to obtain information about the fields that make up the result set (the number of fields, their names and types, and so forth). You can access field information sequentially within the row by calling `mysql_fetch_field()` repeatedly, or by field number within the row by calling `mysql_fetch_field_direct()`. The current field cursor position may be changed by calling `mysql_field_seek()`. Setting the field cursor affects subsequent calls to `mysql_fetch_field()`. You can also get information for fields all at once by calling `mysql_fetch_fields()`.

For detecting and reporting errors, MySQL provides access to error information by means of the `mysql_errno()` and `mysql_error()` functions. These return the error code or error message for the most recently invoked function that can succeed or fail, enabling you to determine when an error occurred and what it was.

21.8.7 C API Function Descriptions

In the descriptions here, a parameter or return value of `NULL` means `NULL` in the sense of the C programming language, not a MySQL `NULL` value.

Functions that return a value generally return a pointer or an integer. Unless specified otherwise, functions returning a pointer return a non-`NULL` value to indicate success or a `NULL` value to indicate an error, and

functions returning an integer return zero to indicate success or nonzero to indicate an error. Note that "nonzero" means just that. Unless the function description says otherwise, do not test against a value other than zero:

```
if (result)                   /* correct */
    ... error ...

if (result < 0)               /* incorrect */
    ... error ...

if (result == -1)             /* incorrect */
    ... error ...
```

When a function returns an error, the **Errors** subsection of the function description lists the possible types of errors. You can find out which of these occurred by calling `mysql_errno()`. A string representation of the error may be obtained by calling `mysql_error()`.

21.8.7.1 mysql_affected_rows()

```
my_ulonglong mysql_affected_rows(MYSQL *mysql)
```

Description

`mysql_affected_rows()` may be called immediately after executing a statement with `mysql_query()` or `mysql_real_query()`. It returns the number of rows changed, deleted, or inserted by the last statement if it was an `UPDATE`, `DELETE`, or `INSERT`. For `SELECT` statements, `mysql_affected_rows()` works like `mysql_num_rows()`.

For `UPDATE` statements, the affected-rows value by default is the number of rows actually changed. If you specify the `CLIENT_FOUND_ROWS` flag to `mysql_real_connect()` when connecting to `mysqld`, the affected-rows value is the number of rows "found"; that is, matched by the `WHERE` clause.

For `REPLACE` statements, the affected-rows value is 2 if the new row replaced an old row, because in this case, one row was inserted after the duplicate was deleted.

For `INSERT ... ON DUPLICATE KEY UPDATE` statements, the affected-rows value is 1 if the row is inserted as a new row and 2 if an existing row is updated.

Following a `CALL` statement for a stored procedure, `mysql_affected_rows()` returns the value that it would return for the last statement executed within the procedure, or 0 if that statement would return `-1`. Within the procedure, you can use `ROW_COUNT()` at the SQL level to obtain the affected-rows value for individual statements.

Return Values

An integer greater than zero indicates the number of rows affected or retrieved. Zero indicates that no records were updated for an `UPDATE` statement, no rows matched the `WHERE` clause in the query or that no query has yet been executed. -1 indicates that the query returned an error or that, for a `SELECT` query, `mysql_affected_rows()` was called prior to calling `mysql_store_result()`.

Because `mysql_affected_rows()` returns an unsigned value, you can check for -1 by comparing the return value to `(my_ulonglong)-1` (or to `(my_ulonglong)~0`, which is equivalent).

Errors

None.

Example

```
char *stmt = "UPDATE products SET cost=cost*1.25
                WHERE group=10";
mysql_query(&mysql,stmt);
printf("%ld products updated",
        (long) mysql_affected_rows(&mysql));
```

21.8.7.2 mysql_autocommit()

```
my_bool mysql_autocommit(MYSQL *mysql, my_bool mode)
```

Description

Sets autocommit mode on if `mode` is 1, off if `mode` is 0.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

None.

21.8.7.3 mysql_change_user()

```
my_bool mysql_change_user(MYSQL *mysql, const char *user, const char *password,
const char *db)
```

Description

Changes the user and causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that include no explicit database specifier.

`mysql_change_user()` fails if the connected user cannot be authenticated or does not have permission to use the database. In this case, the user and database are not changed.

Pass a `db` parameter of `NULL` if you do not want to have a default database.

This function resets the session state as if one had done a new connect and reauthenticated. (See Section 21.8.15, "Controlling Automatic Reconnection Behavior".) It always performs a `ROLLBACK` of any active transactions, closes and drops all temporary tables, and unlocks all locked tables. Session system variables are reset to the values of the corresponding global system variables. Prepared statements are released and `HANDLER` variables are closed. Locks acquired with `GET_LOCK()` are released. These effects occur even if the user did not change.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

The same that you can get from `mysql_real_connect()`, plus:

- `CR_COMMANDS_OUT_OF_SYNC`

Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_SERVER_LOST

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

- ER_UNKNOWN_COM_ERROR

  The MySQL server does not implement this command (probably an old server).

- ER_ACCESS_DENIED_ERROR

  The user or password was wrong.

- ER_BAD_DB_ERROR

  The database did not exist.

- ER_DBACCESS_DENIED_ERROR

  The user did not have access rights to the database.

- ER_WRONG_DB_NAME

  The database name was too long.

Example

```
if (mysql_change_user(&mysql, "user", "password", "new_database"))
{
   fprintf(stderr, "Failed to change user.  Error: %s\n",
           mysql_error(&mysql));
}
```

21.8.7.4 mysql_character_set_name()

```
const char *mysql_character_set_name(MYSQL *mysql)
```

Description

Returns the default character set name for the current connection.

Return Values

The default character set name

Errors

None.

21.8.7.5 mysql_close()

```
void mysql_close(MYSQL *mysql)
```

Description

Closes a previously opened connection. `mysql_close()` also deallocates the connection handle pointed to by `mysql` if the handle was allocated automatically by `mysql_init()` or `mysql_connect()`.

Return Values

None.

Errors

None.

21.8.7.6 mysql_commit()

```
my_bool mysql_commit(MYSQL *mysql)
```

Description

Commits the current transaction.

The action of this function is subject to the value of the `completion_type` system variable. In particular, if the value of `completion_type` is 2, the server performs a release after terminating a transaction and closes the client connection. The client program should call `mysql_close()` to close the connection from the client side.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

None.

21.8.7.7 mysql_connect()

```
MYSQL *mysql_connect(MYSQL *mysql, const char *host, const char *user, const
char *passwd)
```

Description

This function is deprecated. Use `mysql_real_connect()` instead.

`mysql_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_connect()` must complete successfully before you can execute any of the other API functions, with the exception of `mysql_get_client_info()`.

The meanings of the parameters are the same as for the corresponding parameters for `mysql_real_connect()` with the difference that the connection parameter may be `NULL`. In this case, the C API allocates memory for the connection structure automatically and frees it when you call `mysql_close()`. The disadvantage of this approach is that you cannot retrieve an error message if the connection fails. (To get error information from `mysql_errno()` or `mysql_error()`, you must provide a valid `MYSQL` pointer.)

Return Values

Same as for `mysql_real_connect()`.

Errors

Same as for `mysql_real_connect()`.

21.8.7.8 mysql_create_db()

```
int mysql_create_db(MYSQL *mysql, const char *db)
```

Description

Creates the database named by the `db` parameter.

This function is deprecated. It is preferable to use `mysql_query()` to issue an SQL `CREATE DATABASE` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
if(mysql_create_db(&mysql, "my_database"))
{
   fprintf(stderr, "Failed to create new database.  Error: %s\n",
          mysql_error(&mysql));
}
```

21.8.7.9 mysql_data_seek()

```
void mysql_data_seek(MYSQL_RES *result, my_ulonglong offset)
```

Description

Seeks to an arbitrary row in a query result set. The `offset` value is a row number. Specify a value in the range from `0` to `mysql_num_rows(result)-1`.

This function requires that the result set structure contains the entire result of the query, so `mysql_data_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

Return Values

None.

Errors

None.

21.8.7.10 mysql_debug()

```
void mysql_debug(const char *debug)
```

Description

Does a `DBUG_PUSH` with the given string. `mysql_debug()` uses the Fred Fish debug library. To use this function, you must compile the client library to support debugging. See Section 22.4.3, "The DBUG Package".

Return Values

None.

Errors

None.

Example

The call shown here causes the client library to generate a trace file in `/tmp/client.trace` on the client machine:

```
mysql_debug("d:t:O,/tmp/client.trace");
```

21.8.7.11 mysql_drop_db()

```
int mysql_drop_db(MYSQL *mysql, const char *db)
```

Description

Drops the database named by the `db` parameter.

This function is deprecated. It is preferable to use `mysql_query()` to issue an SQL `DROP DATABASE` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_SERVER_LOST

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

Example

```
if(mysql_drop_db(&mysql, "my_database"))
  fprintf(stderr, "Failed to drop the database: Error: %s\n",
          mysql_error(&mysql));
```

21.8.7.12 mysql_dump_debug_info()

```
int mysql_dump_debug_info(MYSQL *mysql)
```

Description

Instructs the server to write debugging information to the error log. The connected user must have the SUPER privilege.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC

  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_SERVER_LOST

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

21.8.7.13 mysql_eof()

```
my_bool mysql_eof(MYSQL_RES *result)
```

Description

This function is deprecated. mysql_errno() or mysql_error() may be used instead.

`mysql_eof()` determines whether the last row of a result set has been read.

If you acquire a result set from a successful call to `mysql_store_result()`, the client receives the entire set in one operation. In this case, a `NULL` return from `mysql_fetch_row()` always means the end of the result set has been reached and it is unnecessary to call `mysql_eof()`. When used with `mysql_store_result()`, `mysql_eof()` always returns true.

On the other hand, if you use `mysql_use_result()` to initiate a result set retrieval, the rows of the set are obtained from the server one by one as you call `mysql_fetch_row()` repeatedly. Because an error may occur on the connection during this process, a `NULL` return value from `mysql_fetch_row()` does not necessarily mean the end of the result set was reached normally. In this case, you can use `mysql_eof()` to determine what happened. `mysql_eof()` returns a nonzero value if the end of the result set was reached and zero if an error occurred.

Historically, `mysql_eof()` predates the standard MySQL error functions `mysql_errno()` and `mysql_error()`. Because those error functions provide the same information, their use is preferred over `mysql_eof()`, which is deprecated. (In fact, they provide more information, because `mysql_eof()` returns only a boolean value whereas the error functions indicate a reason for the error when one occurs.)

Return Values

Zero for success. Nonzero if the end of the result set has been reached.

Errors

None.

Example

The following example shows how you might use `mysql_eof()`:

```
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(!mysql_eof(result))  // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

However, you can achieve the same effect with the standard MySQL error functions:

```
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(mysql_errno(&mysql))  // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

21.8.7.14 mysql_errno()

```
unsigned int mysql_errno(MYSQL *mysql)
```

Description

For the connection specified by `mysql`, `mysql_errno()` returns the error code for the most recently invoked API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL `errmsg.h` header file. Server error message numbers are listed in `mysqld_error.h`. Errors also are listed at Appendix B, *Errors, Error Codes, and Common Problems*.

> **Note**
>
> Some functions such as `mysql_fetch_row()` do not set `mysql_errno()` if they succeed. A rule of thumb is that all functions that have to ask the server for information reset `mysql_errno()` if they succeed.

MySQL-specific error numbers returned by `mysql_errno()` differ from SQLSTATE values returned by `mysql_sqlstate()`. For example, the `mysql` client program displays errors using the following format, where `1146` is the `mysql_errno()` value and `'42S02'` is the corresponding `mysql_sqlstate()` value:

```
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

Return Values

An error code value for the last `mysql_xxx()` call, if it failed. zero means no error occurred.

Errors

None.

21.8.7.15 mysql_error()

```
const char *mysql_error(MYSQL *mysql)
```

Description

For the connection specified by `mysql`, `mysql_error()` returns a null-terminated string containing the error message for the most recently invoked API function that failed. If a function did not fail, the return value of `mysql_error()` may be the previous error or an empty string to indicate no error.

A rule of thumb is that all functions that have to ask the server for information reset `mysql_error()` if they succeed.

For functions that reset `mysql_error()`, either of these two tests can be used to check for an error:

```
if(*mysql_error(&mysql))
{
  // an error occurred
}

if(mysql_error(&mysql)[0])
{
  // an error occurred
}
```

The language of the client error messages may be changed by recompiling the MySQL client library. You can choose error messages in several different languages. See Section 10.2, "Setting the Error Message Language".

Return Values

A null-terminated character string that describes the error. An empty string if no error occurred.

Errors

None.

21.8.7.16 mysql_escape_string()

> **Note**
>
> This function should not be used. Use `mysql_real_escape_string()` instead.

`mysql_escape_string()` is identical to `mysql_real_escape_string()` except that `mysql_real_escape_string()` takes a connection handler as its first argument and escapes the string according to the current character set. `mysql_escape_string()` does not take a connection argument and does not respect the current character set.

21.8.7.17 mysql_fetch_field()

```
MYSQL_FIELD *mysql_fetch_field(MYSQL_RES *result)
```

Description

Returns the definition of one column of a result set as a `MYSQL_FIELD` structure. Call this function repeatedly to retrieve information about all columns in the result set. `mysql_fetch_field()` returns `NULL` when no more fields are left.

`mysql_fetch_field()` is reset to return information about the first field each time you execute a new `SELECT` query. The field returned by `mysql_fetch_field()` is also affected by calls to `mysql_field_seek()`.

If you've called `mysql_query()` to perform a `SELECT` on a table but have not called `mysql_store_result()`, MySQL returns the default blob length (8KB) if you call `mysql_fetch_field()` to ask for the length of a `BLOB` field. (The 8KB size is chosen because MySQL does not know the maximum length for the `BLOB`. This should be made configurable sometime.) Once you've retrieved the result set, `field->max_length` contains the length of the largest value for this column in the specific query.

Return Values

The `MYSQL_FIELD` structure for the current column. `NULL` if no columns are left.

Errors

None.

Example

```
MYSQL_FIELD *field;

while((field = mysql_fetch_field(result)))
{
    printf("field name %s\n", field->name);
}
```

21.8.7.18 mysql_fetch_field_direct()

```
MYSQL_FIELD *mysql_fetch_field_direct(MYSQL_RES *result, unsigned int fieldnr)
```

Description

Given a field number `fieldnr` for a column within a result set, returns that column's field definition as a `MYSQL_FIELD` structure. Use this function to retrieve the definition for an arbitrary column. Specify a value for `fieldnr` in the range from 0 to `mysql_num_fields(result)-1`.

Return Values

The `MYSQL_FIELD` structure for the specified column.

Errors

None.

Example

```
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *field;

num_fields = mysql_num_fields(result);
for(i = 0; i < num_fields; i++)
{
    field = mysql_fetch_field_direct(result, i);
    printf("Field %u is %s\n", i, field->name);
}
```

21.8.7.19 mysql_fetch_fields()

```
MYSQL_FIELD *mysql_fetch_fields(MYSQL_RES *result)
```

Description

Returns an array of all `MYSQL_FIELD` structures for a result set. Each structure provides the field definition for one column of the result set.

Return Values

An array of `MYSQL_FIELD` structures for all columns of a result set.

Errors

None.

Example

```
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *fields;

num_fields = mysql_num_fields(result);
fields = mysql_fetch_fields(result);
for(i = 0; i < num_fields; i++)
{
```

```
    printf("Field %u is %s\n", i, fields[i].name);
}
```

21.8.7.20 mysql_fetch_lengths()

```
unsigned long *mysql_fetch_lengths(MYSQL_RES *result)
```

Description

Returns the lengths of the columns of the current row within a result set. If you plan to copy field values, this length information is also useful for optimization, because you can avoid calling `strlen()`. In addition, if the result set contains binary data, you **must** use this function to determine the size of the data, because `strlen()` returns incorrect results for any field containing null characters.

The length for empty columns and for columns containing `NULL` values is zero. To see how to distinguish these two cases, see the description for `mysql_fetch_row()`.

Return Values

An array of unsigned long integers representing the size of each column (not including any terminating null bytes). `NULL` if an error occurred.

Errors

`mysql_fetch_lengths()` is valid only for the current row of the result set. It returns `NULL` if you call it before calling `mysql_fetch_row()` or after retrieving all rows in the result.

Example

```
MYSQL_ROW row;
unsigned long *lengths;
unsigned int num_fields;
unsigned int i;

row = mysql_fetch_row(result);
if (row)
{
    num_fields = mysql_num_fields(result);
    lengths = mysql_fetch_lengths(result);
    for(i = 0; i < num_fields; i++)
    {
        printf("Column %u is %lu bytes in length.\n",
                i, lengths[i]);
    }
}
```

21.8.7.21 mysql_fetch_row()

```
MYSQL_ROW mysql_fetch_row(MYSQL_RES *result)
```

Description

Retrieves the next row of a result set. When used after `mysql_store_result()`, `mysql_fetch_row()` returns `NULL` when there are no more rows to retrieve. When used after `mysql_use_result()`, `mysql_fetch_row()` returns `NULL` when there are no more rows to retrieve or if an error occurred.

The number of values in the row is given by `mysql_num_fields(result)`. If `row` holds the return value from a call to `mysql_fetch_row()`, pointers to the values are accessed as `row[0]` to `row[mysql_num_fields(result)-1]`. `NULL` values in the row are indicated by `NULL` pointers.

The lengths of the field values in the row may be obtained by calling `mysql_fetch_lengths()`. Empty fields and fields containing `NULL` both have length 0; you can distinguish these by checking the pointer for the field value. If the pointer is `NULL`, the field is `NULL`; otherwise, the field is empty.

Return Values

A `MYSQL_ROW` structure for the next row. `NULL` if there are no more rows to retrieve or if an error occurred.

Errors

Errors are not reset between calls to `mysql_fetch_row()`

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
MYSQL_ROW row;
unsigned int num_fields;
unsigned int i;

num_fields = mysql_num_fields(result);
while ((row = mysql_fetch_row(result)))
{
   unsigned long *lengths;
   lengths = mysql_fetch_lengths(result);
   for(i = 0; i < num_fields; i++)
   {
       printf("[%.*s] ", (int) lengths[i],
              row[i] ? row[i] : "NULL");
   }
   printf("\n");
}
```

21.8.7.22 mysql_field_count()

```
unsigned int mysql_field_count(MYSQL *mysql)
```

Description

Returns the number of columns for the most recent query on the connection.

The normal use of this function is when `mysql_store_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a nonempty result. This enables the client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 21.8.14.1, "Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success".

Return Values

An unsigned integer representing the number of columns in a result set.

Errors

> None.

Example

```
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result)  // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
    else  // mysql_store_result() returned nothing; should it have?
    {
        if(mysql_field_count(&mysql) == 0)
        {
            // query does not return data
            // (it was not a SELECT)
            num_rows = mysql_affected_rows(&mysql);
        }
        else // mysql_store_result() should have returned data
        {
            fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
        }
    }
}
```

An alternative is to replace the `mysql_field_count(&mysql)` call with `mysql_errno(&mysql)`. In this case, you are checking directly for an error from `mysql_store_result()` rather than inferring from the value of `mysql_field_count()` whether the statement was a `SELECT`.

21.8.7.23 mysql_field_seek()

`MYSQL_FIELD_OFFSET mysql_field_seek(MYSQL_RES *result, MYSQL_FIELD_OFFSET offset)`

Description

Sets the field cursor to the given offset. The next call to `mysql_fetch_field()` retrieves the field definition of the column associated with that offset.

To seek to the beginning of a row, pass an `offset` value of zero.

Return Values

The previous value of the field cursor.

Errors

None.

21.8.7.24 mysql_field_tell()

```
MYSQL_FIELD_OFFSET mysql_field_tell(MYSQL_RES *result)
```

Description

Returns the position of the field cursor used for the last `mysql_fetch_field()`. This value can be used as an argument to `mysql_field_seek()`.

Return Values

The current offset of the field cursor.

Errors

None.

21.8.7.25 mysql_free_result()

```
void mysql_free_result(MYSQL_RES *result)
```

Description

Frees the memory allocated for a result set by `mysql_store_result()`, `mysql_use_result()`, `mysql_list_dbs()`, and so forth. When you are done with a result set, you must free the memory it uses by calling `mysql_free_result()`.

Do not attempt to access a result set after freeing it.

Return Values

None.

Errors

None.

21.8.7.26 mysql_get_character_set_info()

```
void mysql_get_character_set_info(MYSQL *mysql, MY_CHARSET_INFO *cs)
```

Description

This function provides information about the default client character set. The default character set may be changed with the `mysql_set_character_set()` function.

Example

This example shows the fields that are available in the `MY_CHARSET_INFO` structure:

```
if (!mysql_set_character_set(&mysql, "utf8"))
{
    MY_CHARSET_INFO cs;
    mysql_get_character_set_info(&mysql, &cs);
    printf("character set information:\n");
    printf("character set+collation number: %d\n", cs.number);
```

```
    printf("character set name: %s\n", cs.name);
    printf("collation name: %s\n", cs.csname);
    printf("comment: %s\n", cs.comment);
    printf("directory: %s\n", cs.dir);
    printf("multi byte character min. length: %d\n", cs.mbminlen);
    printf("multi byte character max. length: %d\n", cs.mbmaxlen);
}
```

21.8.7.27 mysql_get_client_info()

```
const char *mysql_get_client_info(void)
```

Description

Returns a string that represents the MySQL client library version; for example, `"5.1.73"`.

The function value is the MySQL version. For Connector/C, this is the MySQL version on which the Connector/C distribution is based. For more information, see Section 21.8.4.4, "C API Server and Client Library Versions".

Return Values

A character string that represents the MySQL client library version.

Errors

None.

21.8.7.28 mysql_get_client_version()

```
unsigned long mysql_get_client_version(void)
```

Description

Returns an integer that represents the MySQL client library version. The value has the format `XYYZZ` where `X` is the major version, `YY` is the release level (or minor version), and `ZZ` is the sub-version within the release level:

```
major_version*10000 + release_level*100 + sub_version
```

For example, `"5.1.73"` is returned as `50173`.

The function value is the MySQL version. For Connector/C, this is the MySQL version on which the Connector/C distribution is based. For more information, see Section 21.8.4.4, "C API Server and Client Library Versions".

Return Values

An integer that represents the MySQL client library version.

Errors

None.

21.8.7.29 mysql_get_host_info()

```
const char *mysql_get_host_info(MYSQL *mysql)
```

Description

Returns a string describing the type of connection in use, including the server host name.

Return Values

A character string representing the server host name and the connection type.

Errors

None.

21.8.7.30 mysql_get_proto_info()

```
unsigned int mysql_get_proto_info(MYSQL *mysql)
```

Description

Returns the protocol version used by current connection.

Return Values

An unsigned integer representing the protocol version used by the current connection.

Errors

None.

21.8.7.31 mysql_get_server_info()

```
const char *mysql_get_server_info(MYSQL *mysql)
```

Description

Returns a string that represents the MySQL server version; for example, `"5.1.73"`.

Return Values

A character string that represents the MySQL server version.

Errors

None.

21.8.7.32 mysql_get_server_version()

```
unsigned long mysql_get_server_version(MYSQL *mysql)
```

Description

Returns an integer that represents the MySQL server version. The value has the format `XYYZZ` where `X` is the major version, `YY` is the release level (or minor version), and `ZZ` is the sub-version within the release level:

```
major_version*10000 + release_level*100 + sub_version
```

For example, `"5.1.73"` is returned as `50173`.

This function is useful in client programs for determining whether some version-specific server capability exists.

Return Values

An integer that represents the MySQL server version.

Errors

None.

21.8.7.33 mysql_get_ssl_cipher()

```
const char *mysql_get_ssl_cipher(MYSQL *mysql)
```

Description

`mysql_get_ssl_cipher()` returns the encryption cipher used for the given connection to the server. `mysql` is the connection handler returned from `mysql_init()`.

This function was added in MySQL 5.1.11.

Return Values

A string naming the encryption cipher used for the connection, or `NULL` if no cipher is being used.

21.8.7.34 mysql_hex_string()

```
unsigned long mysql_hex_string(char *to, const char *from, unsigned long
length)
```

Description

This function creates a legal SQL string for use in an SQL statement. See Section 9.1.1, "String Literals".

The string in the `from` argument is encoded in hexadecimal format, with each character encoded as two hexadecimal digits. The result is placed in the `to` argument, followed by a terminating null byte.

The string pointed to by `from` must be `length` bytes long. You must allocate the `to` buffer to be at least `length*2+1` bytes long. When `mysql_hex_string()` returns, the contents of `to` is a null-terminated string. The return value is the length of the encoded string, not including the terminating null byte.

The return value can be placed into an SQL statement using either `X'value'` or `0xvalue` format. However, the return value does not include the `X'...'` or `0x`. The caller must supply whichever of those is desired.

Example

```
char query[1000],*end;

end = strmov(query,"INSERT INTO test_table values(");
end = strmov(end,"X'");
end += mysql_hex_string(end,"What is this",12);
end = strmov(end,"',X'");
end += mysql_hex_string(end,"binary data: \0\r\n",16);
end = strmov(end,"')");

if (mysql_real_query(&mysql,query,(unsigned int) (end - query)))
```

```
{
  fprintf(stderr, "Failed to insert row, Error: %s\n",
          mysql_error(&mysql));
}
```

The `strmov()` function used in the example is included in the `libmysqlclient` library and works like `strcpy()` but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the encoded string that is placed into `to`, not including the terminating null character.

Errors

None.

21.8.7.35 mysql_info()

```
const char *mysql_info(MYSQL *mysql)
```

Description

Retrieves a string providing information about the most recently executed statement, but only for the statements listed here. For other statements, `mysql_info()` returns `NULL`. The format of the string varies depending on the type of statement, as described here. The numbers are illustrative only; the string contains values appropriate for the statement.

- `INSERT INTO ... SELECT ...`

  String format: `Records: 100 Duplicates: 0 Warnings: 0`

- `INSERT INTO ... VALUES (...),(...),(...)...`

  String format: `Records: 3 Duplicates: 0 Warnings: 0`

- `LOAD DATA INFILE ...`

  String format: `Records: 1 Deleted: 0 Skipped: 0 Warnings: 0`

- `ALTER TABLE`

  String format: `Records: 3 Duplicates: 0 Warnings: 0`

- `UPDATE`

  String format: `Rows matched: 40 Changed: 40 Warnings: 0`

`mysql_info()` returns a non-`NULL` value for `INSERT ... VALUES` only for the multiple-row form of the statement (that is, only if multiple value lists are specified).

Return Values

A character string representing additional information about the most recently executed statement. `NULL` if no information is available for the statement.

Errors

None.

21.8.7.36 mysql_init()

```
MYSQL *mysql_init(MYSQL *mysql)
```

Description

Allocates or initializes a `MYSQL` object suitable for `mysql_real_connect()`. If `mysql` is a `NULL` pointer, the function allocates, initializes, and returns a new object. Otherwise, the object is initialized and the address of the object is returned. If `mysql_init()` allocates a new object, it is freed when `mysql_close()` is called to close the connection.

In a nonmulti-threaded environment, `mysql_init()` invokes `mysql_library_init()` automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multi-threaded environment, and thus neither is `mysql_init()`. Before calling `mysql_init()`, either call `mysql_library_init()` prior to spawning any threads, or use a mutex to protect the `mysql_library_init()` call. This should be done prior to any other client library call.

Return Values

An initialized `MYSQL*` handle. `NULL` if there was insufficient memory to allocate a new object.

Errors

In case of insufficient memory, `NULL` is returned.

21.8.7.37 mysql_insert_id()

```
my_ulonglong mysql_insert_id(MYSQL *mysql)
```

Description

Returns the value generated for an `AUTO_INCREMENT` column by the previous `INSERT` or `UPDATE` statement. Use this function after you have performed an `INSERT` statement into a table that contains an `AUTO_INCREMENT` field, or have used `INSERT` or `UPDATE` to set a column value with `LAST_INSERT_ID(expr)`.

The return value of `mysql_insert_id()` is always zero unless explicitly updated under one of the following conditions:

- `INSERT` statements that store a value into an `AUTO_INCREMENT` column. This is true whether the value is automatically generated by storing the special values `NULL` or `0` into the column, or is an explicit nonspecial value.

- In the case of a multiple-row `INSERT` statement, the return value of `mysql_insert_id()` depends on the MySQL server version.

  In MySQL 5.1.12 and later, `mysql_insert_id()` returns the first automatically generated `AUTO_INCREMENT` value that was successfully inserted. In MySQL 5.1.11 and earlier, `mysql_insert_id()` returns the first automatically generated `AUTO_INCREMENT` value, regardless of whether insertion of that value was successful.

  If no rows are successfully inserted, `mysql_insert_id()` returns 0.

- Starting in MySQL 5.1.12, if an `INSERT ... SELECT` statement is executed, and no automatically generated value is successfully inserted, `mysql_insert_id()` returns the ID of the last inserted row.

- Starting in MySQL 5.1.12, if an `INSERT ... SELECT` statement uses `LAST_INSERT_ID(expr)`, `mysql_insert_id()` returns *expr*.

- `INSERT` statements that generate an `AUTO_INCREMENT` value by inserting `LAST_INSERT_ID(expr)` into any column or by updating any column to `LAST_INSERT_ID(expr)`.

- If the previous statement returned an error, the value of `mysql_insert_id()` is undefined.

For 5.1.12 and later, the return value of `mysql_insert_id()` can be simplified to the following sequence:

1. If there is an `AUTO_INCREMENT` column, and an automatically generated value was successfully inserted, return the first such value.

2. If `LAST_INSERT_ID(expr)` occurred in the statement, return *expr*, even if there was an `AUTO_INCREMENT` column in the affected table.

3. The return value varies depending on the statement used. When called after an `INSERT` statement:

   - If there is an `AUTO_INCREMENT` column in the table, and there were some explicit values for this column that were successfully inserted into the table, return the last of the explicit values.

   When called after an `INSERT ... ON DUPLICATE KEY UPDATE` statement:

   - If there is an `AUTO_INCREMENT` column in the table and there were some explicit successfully inserted values or some updated values, return the last of the inserted or updated values.

`mysql_insert_id()` returns 0 if the previous statement does not use an `AUTO_INCREMENT` value. If you need to save the value for later, be sure to call `mysql_insert_id()` immediately after the statement that generates the value.

The value of `mysql_insert_id()` is affected only by statements issued within the current client connection. It is not affected by statements issued by other clients.

The `LAST_INSERT_ID()` SQL function returns the value of the first automatically generated value that was successfully inserted (starting from 5.1.12) or the first automatically generated value if any rows were successfully inserted (before 5.1.12). `LAST_INSERT_ID()` is not reset between statements because the value of that function is maintained in the server. Another difference from `mysql_insert_id()` is that `LAST_INSERT_ID()` is not updated if you set an `AUTO_INCREMENT` column to a specific nonspecial value. See Section 12.14, "Information Functions".

`mysql_insert_id()` returns 0 following a `CALL` statement for a stored procedure that generates an `AUTO_INCREMENT` value because in this case `mysql_insert_id()` applies to `CALL` and not the statement within the procedure. Within the procedure, you can use `LAST_INSERT_ID()` at the SQL level to obtain the `AUTO_INCREMENT` value.

The reason for the differences between `LAST_INSERT_ID()` and `mysql_insert_id()` is that `LAST_INSERT_ID()` is made easy to use in scripts while `mysql_insert_id()` tries to provide more exact information about what happens to the `AUTO_INCREMENT` column.

Return Values

Described in the preceding discussion.

Errors

None.

21.8.7.38 mysql_kill()

```
int mysql_kill(MYSQL *mysql, unsigned long pid)
```

Description

Asks the server to kill the thread specified by `pid`.

This function is deprecated. It is preferable to use `mysql_query()` to issue an SQL `KILL` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.39 mysql_library_end()

```
void mysql_library_end(void)
```

Description

This function finalizes the MySQL library. Call it when you are done using the library (for example, after disconnecting from the server). The action taken by the call depends on whether your application is linked to the MySQL client library or the MySQL embedded server library. For a client program linked against the `libmysqlclient` library by using the `-lmysqlclient` flag, `mysql_library_end()` performs some memory management to clean up. For an embedded server application linked against the `libmysqld` library by using the `-lmysqld` flag, `mysql_library_end()` shuts down the embedded server and then cleans up.

For usage information, see Section 21.8.6, "C API Function Overview", and Section 21.8.7.40, "mysql_library_init()".

21.8.7.40 mysql_library_init()

```
int mysql_library_init(int argc, char **argv, char **groups)
```

Description

Call this function to initialize the MySQL library before you call any other MySQL function, whether your application is a regular client program or uses the embedded server. If the application uses the embedded

server, this call starts the server and initializes any subsystems (`mysys`, `InnoDB`, and so forth) that the server uses.

After your application is done using the MySQL library, call `mysql_library_end()` to clean up. See Section 21.8.7.39, "mysql_library_end()".

The choice of whether the application operates as a regular client or uses the embedded server depends on whether you use the `libmysqlclient` or `libmysqld` library at link time to produce the final executable. For additional information, see Section 21.8.6, "C API Function Overview".

In a nonmulti-threaded environment, the call to `mysql_library_init()` may be omitted, because `mysql_init()` will invoke it automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multi-threaded environment, and thus neither is `mysql_init()`, which calls `mysql_library_init()`. You must either call `mysql_library_init()` prior to spawning any threads, or else use a mutex to protect the call, whether you invoke `mysql_library_init()` or indirectly through `mysql_init()`. Do this prior to any other client library call.

The `argc` and `argv` arguments are analogous to the arguments to `main()`, and enable passing of options to the embedded server. For convenience, `argc` may be `0` (zero) if there are no command-line arguments for the server. This is the usual case for applications intended for use only as regular (nonembedded) clients, and the call typically is written as `mysql_library_init(0, NULL, NULL)`.

```
#include <mysql.h>
#include <stdlib.h>

int main(void) {
  if (mysql_library_init(0, NULL, NULL)) {
    fprintf(stderr, "could not initialize MySQL library\n");
    exit(1);
  }

  /* Use any MySQL API functions here */

  mysql_library_end();

  return EXIT_SUCCESS;
}
```

When arguments are to be passed (`argc` is greater than `0`), the first element of `argv` is ignored (it typically contains the program name). `mysql_library_init()` makes a copy of the arguments so it is safe to destroy `argv` or `groups` after the call.

For embedded applications, if you want to connect to an external server without starting the embedded server, you have to specify a negative value for `argc`.

The `groups` argument is an array of strings that indicate the groups in option files from which to read options. See Section 4.2.6, "Using Option Files". Make the final entry in the array `NULL`. For convenience, if the `groups` argument itself is `NULL`, the `[server]` and `[embedded]` groups are used by default.

```
#include <mysql.h>
#include <stdlib.h>

static char *server_args[] = {
  "this_program",       /* this string is not used */
  "--datadir=.",
  "--key_buffer_size=32M"
};
static char *server_groups[] = {
```

```
  "embedded",
  "server",
  "this_program_SERVER",
  (char *)NULL
};

int main(void) {
  if (mysql_library_init(sizeof(server_args) / sizeof(char *),
                         server_args, server_groups)) {
    fprintf(stderr, "could not initialize MySQL library\n");
    exit(1);
  }

  /* Use any MySQL API functions here */

  mysql_library_end();

  return EXIT_SUCCESS;
}
```

Return Values

Zero for success. Nonzero if an error occurred.

21.8.7.41 mysql_list_dbs()

```
MYSQL_RES *mysql_list_dbs(MYSQL *mysql, const char *wild)
```

Description

Returns a result set consisting of database names on the server that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters "`%`" or "`_`", or may be a `NULL` pointer to match all databases. Calling `mysql_list_dbs()` is similar to executing the query `SHOW DATABASES [LIKE wild]`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

An unknown error occurred.

21.8.7.42 mysql_list_fields()

```
MYSQL_RES *mysql_list_fields(MYSQL *mysql, const char *table, const char *wild)
```

Description

Returns an empty result set for which the metadata provides information about the columns in the given table that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters "`%`" or "`_`", or may be a `NULL` pointer to match all fields. Calling `mysql_list_fields()` is similar to executing the query `SHOW COLUMNS FROM` `tbl_name` `[LIKE` `wild]`.

It is preferable to use `SHOW COLUMNS FROM` `tbl_name` instead of `mysql_list_fields()`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
int i;
MYSQL_RES *tbl_cols = mysql_list_fields(mysql, "mytbl", "f%");

unsigned int field_cnt = mysql_num_fields(tbl_cols);
printf("Number of columns: %d\n", field_cnt);

for (i=0; i < field_cnt; ++i)
{
  /* col describes i-th column of the table */
  MYSQL_FIELD *col = mysql_fetch_field_direct(tbl_cols, i);
  printf ("Column %d: %s\n", i, col->name);
}
mysql_free_result(tbl_cols);
```

21.8.7.43 mysql_list_processes()

```
MYSQL_RES *mysql_list_processes(MYSQL *mysql)
```

Description

Returns a result set describing the current server threads. This is the same kind of information as that reported by `mysqladmin processlist` or a `SHOW PROCESSLIST` query.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.44 mysql_list_tables()

```
MYSQL_RES *mysql_list_tables(MYSQL *mysql, const char *wild)
```

Description

Returns a result set consisting of table names in the current database that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters "`%`" or "`_`", or may be a `NULL` pointer to match all tables. Calling `mysql_list_tables()` is similar to executing the query `SHOW TABLES [LIKE wild]`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.45 mysql_more_results()

```
my_bool mysql_more_results(MYSQL *mysql)
```

Description

This function is used when you execute multiple statements specified as a single statement string, or when you execute `CALL` statements, which can return multiple result sets.

`mysql_more_results()` true if more results exist from the currently executed statement, in which case the application must call `mysql_next_result()` to fetch the results.

Return Values

`TRUE` (1) if more results exist. `FALSE` (0) if no more results exist.

In most cases, you can call `mysql_next_result()` instead to test whether more results exist and initiate retrieval if so.

See Section 21.8.16, "C API Support for Multiple Statement Execution", and Section 21.8.7.46, "mysql_next_result()".

Errors

None.

21.8.7.46 mysql_next_result()

```
int mysql_next_result(MYSQL *mysql)
```

Description

This function is used when you execute multiple statements specified as a single statement string, or when you use `CALL` statements to execute stored procedures, which can return multiple result sets.

`mysql_next_result()` reads the next statement result and returns a status to indicate whether more results exist. If `mysql_next_result()` returns an error, there are no more results.

Before each call to `mysql_next_result()`, you must call `mysql_free_result()` for the current statement if it is a statement that returned a result set (rather than just a result status).

After calling `mysql_next_result()` the state of the connection is as if you had called `mysql_real_query()` or `mysql_query()` for the next statement. This means that you can call `mysql_store_result()`, `mysql_warning_count()`, `mysql_affected_rows()`, and so forth.

If your program uses `CALL` statements to execute stored procedures, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. Because `CALL` can return

multiple results, process them using a loop that calls `mysql_next_result()` to determine whether there are more results.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`).

It is also possible to test whether there are more results by calling `mysql_more_results()`. However, this function does not change the connection state, so if it returns true, you must still call `mysql_next_result()` to advance to the next result.

For an example that shows how to use `mysql_next_result()`, see Section 21.8.16, "C API Support for Multiple Statement Execution".

Return Values

Return Value	Description
0	Successful and there are more results
-1	Successful and there are no more results
>0	An error occurred

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order. For example, if you did not call `mysql_use_result()` for a previous result set.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.47 mysql_num_fields()

```
unsigned int mysql_num_fields(MYSQL_RES *result)
```

To pass a `MYSQL*` argument instead, use `unsigned int mysql_field_count(MYSQL *mysql)`.

Description

Returns the number of columns in a result set.

You can get the number of columns either from a pointer to a result set or to a connection handle. You would use the connection handle if `mysql_store_result()` or `mysql_use_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a nonempty result. This enables the

client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 21.8.14.1, "Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success".

Return Values

An unsigned integer representing the number of columns in a result set.

Errors

None.

Example

```
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result)  // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
    else  // mysql_store_result() returned nothing; should it have?
    {
        if (mysql_errno(&mysql))
        {
            fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
        }
        else if (mysql_field_count(&mysql) == 0)
        {
            // query does not return data
            // (it was not a SELECT)
            num_rows = mysql_affected_rows(&mysql);
        }
    }
}
```

An alternative (if you know that your query should have returned a result set) is to replace the `mysql_errno(&mysql)` call with a check whether `mysql_field_count(&mysql)` returns 0. This happens only if something went wrong.

21.8.7.48 mysql_num_rows()

```
my_ulonglong mysql_num_rows(MYSQL_RES *result)
```

Description

Returns the number of rows in the result set.

The use of `mysql_num_rows()` depends on whether you use `mysql_store_result()` or `mysql_use_result()` to return the result set. If you use `mysql_store_result()`,

`mysql_num_rows()` may be called immediately. If you use `mysql_use_result()`, `mysql_num_rows()` does not return the correct value until all the rows in the result set have been retrieved.

`mysql_num_rows()` is intended for use with statements that return a result set, such as `SELECT`. For statements such as `INSERT`, `UPDATE`, or `DELETE`, the number of affected rows can be obtained with `mysql_affected_rows()`.

Return Values

The number of rows in the result set.

Errors

None.

21.8.7.49 mysql_options()

```
int mysql_options(MYSQL *mysql, enum mysql_option option, const void *arg)
```

Description

Can be used to set extra connect options and affect behavior for a connection. This function may be called multiple times to set several options.

Call `mysql_options()` after `mysql_init()` and before `mysql_connect()` or `mysql_real_connect()`.

The `option` argument is the option that you want to set; the `arg` argument is the value for the option. If the option is an integer, specify a pointer to the value of the integer as the `arg` argument.

The following list describes the possible options, their effect, and how `arg` is used for each option. Several of the options apply only when the application is linked against the `libmysqld` embedded server library and are unused for applications linked against the `libmysqlclient` client library. For option descriptions that indicate `arg` is unused, its value is irrelevant; it is conventional to pass 0.

- `MYSQL_INIT_COMMAND` (argument type: `char *`)

  SQL statement to execute when connecting to the MySQL server. Automatically re-executed if reconnection occurs.

- `MYSQL_OPT_COMPRESS` (argument: not used)

  Use the compressed client/server protocol.

- `MYSQL_OPT_CONNECT_TIMEOUT` (argument type: `unsigned int *`)

  The connect timeout in seconds.

- `MYSQL_OPT_GUESS_CONNECTION` (argument: not used)

  For an application linked against the `libmysqld` embedded server library, this enables the library to guess whether to use the embedded server or a remote server. "Guess" means that if the host name is set and is not `localhost`, it uses a remote server. This behavior is the default. `MYSQL_OPT_USE_EMBEDDED_CONNECTION` and `MYSQL_OPT_USE_REMOTE_CONNECTION` can be used to override it. This option is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_OPT_LOCAL_INFILE` (argument type: optional pointer to `unsigned int`)

If no pointer is given or if pointer points to an `unsigned int` that has a nonzero value, the `LOAD DATA LOCAL INFILE` statement is enabled.

- `MYSQL_OPT_NAMED_PIPE` (argument: not used)

  Use a named pipe to connect to the MySQL server on Windows, if the server permits named-pipe connections.

- `MYSQL_OPT_PROTOCOL` (argument type: `unsigned int *`)

  Type of protocol to use. Specify one of the enum values of `mysql_protocol_type` defined in `mysql.h`.

- `MYSQL_OPT_READ_TIMEOUT` (argument type: `unsigned int *`)

  The timeout in seconds for each attempt to read from the server. There are retries if necessary, so the total effective timeout value is three times the option value. You can set the value so that a lost connection can be detected earlier than the TCP/IP `Close_Wait_Timeout` value of 10 minutes. Before MySQL 5.1.41, this option applies only to TCP/IP connections and, prior to MySQL 5.1.12, only for Windows.

  Implementation of this timeout uses mechanisms that may not be available on all platforms. On such a platform, a client that issues a read call might under certain circumstances wait without timing out. For example, a client might not time out if the server is not responding because it is waiting for a "disk full" condition to clear.

- `MYSQL_OPT_RECONNECT` (argument type: `my_bool *`)

  Enable or disable automatic reconnection to the server if the connection is found to have been lost. Reconnect is off by default; this option provides a way to set reconnection behavior explicitly.

  Note: `mysql_real_connect()` incorrectly reset the `MYSQL_OPT_RECONNECT` option to its default value before MySQL 5.1.6. Therefore, prior to that version, if you want reconnect to be enabled for each connection, you must call `mysql_options()` with the `MYSQL_OPT_RECONNECT` option after each call to `mysql_real_connect()`. This is not necessary as of 5.1.6: Call `mysql_options()` only before `mysql_real_connect()` as usual.

- `MYSQL_OPT_SSL_VERIFY_SERVER_CERT` (argument type: `my_bool *`)

  Enable or disable verification of the server's Common Name value in its certificate against the host name used when connecting to the server. The connection is rejected if there is a mismatch. For encrypted connections, this feature can be used to prevent man-in-the-middle attacks. Verification is disabled by default. Added in MySQL 5.1.11.

- `MYSQL_OPT_USE_EMBEDDED_CONNECTION` (argument: not used)

  For an application linked against the `libmysqld` embedded server library, this forces the use of the embedded server for the connection. This option is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_OPT_USE_REMOTE_CONNECTION` (argument: not used)

  For an application linked against the `libmysqld` embedded server library, this forces the use of a remote server for the connection. This option is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_OPT_USE_RESULT` (argument: not used)

This option is unused.

- `MYSQL_OPT_WRITE_TIMEOUT` (argument type: `unsigned int *`)

  The timeout in seconds for each attempt to write to the server. There is a retry if necessary, so the total effective timeout value is two times the option value. Before MySQL 5.1.41, this option applies only to TCP/IP connections and, prior to MySQL 5.1.12, only for Windows.

- `MYSQL_READ_DEFAULT_FILE` (argument type: `char *`)

  Read options from the named option file instead of from `my.cnf`.

- `MYSQL_READ_DEFAULT_GROUP` (argument type: `char *`)

  Read options from the named group from `my.cnf` or the file specified with `MYSQL_READ_DEFAULT_FILE`.

- `MYSQL_REPORT_DATA_TRUNCATION` (argument type: `my_bool *`)

  Enable or disable reporting of data truncation errors for prepared statements using the `error` member of `MYSQL_BIND` structures. (Default: enabled.)

- `MYSQL_SECURE_AUTH` (argument type: `my_bool *`)

  Whether to connect to a server that does not support the password hashing used in MySQL 4.1.1 and later.

- `MYSQL_SET_CHARSET_DIR` (argument type: `char *`)

  The path name to the directory that contains character set definition files.

- `MYSQL_SET_CHARSET_NAME` (argument type: `char *`)

  The name of the character set to use as the default character set.

- `MYSQL_SET_CLIENT_IP` (argument type: `char *`)

  For an application linked against the `libmysqld` embedded server library (when `libmysqld` is compiled with authentication support), this means that the user is considered to have connected from the specified IP address (specified as a string) for authentication purposes. This option is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_SHARED_MEMORY_BASE_NAME` (argument type: `char *`)

  The name of the shared-memory object for communication to the server on Windows, if the server supports shared-memory connections. Specify the same value as the `--shared-memory-base-name` option used for the `mysqld` server you want to connect to.

The `client` group is always read if you use `MYSQL_READ_DEFAULT_FILE` or `MYSQL_READ_DEFAULT_GROUP`.

The specified group in the option file may contain the following options.

Option	Description
`character-sets-dir=`*`dir_name`*	The directory where character sets are installed.
`compress`	Use the compressed client/server protocol.

Option	Description
`connect-timeout=seconds`	The connect timeout in seconds. On Linux this timeout is also used for waiting for the first answer from the server.
`database=db_name`	Connect to this database if no database was specified in the connect command.
`debug`	Debug options.
`default-character-set=charset_name`	The default character set to use.
`disable-local-infile`	Disable use of `LOAD DATA LOCAL INFILE`.
`host=host_name`	Default host name.
`init-command=stmt`	Statement to execute when connecting to MySQL server. Automatically re-executed if reconnection occurs.
`interactive-timeout=seconds`	Same as specifying `CLIENT_INTERACTIVE` to `mysql_real_connect()`. See Section 21.8.7.52, "mysql_real_connect()".
`local-infile[={0|1}]`	If no argument or nonzero argument, enable use of `LOAD DATA LOCAL`; otherwise disable.
`max_allowed_packet=bytes`	Maximum size of packet that client can read from server.
`multi-queries`, `multi-results`	Enable multiple result sets from multiple-statement executions or stored procedures.
`multi-statements`	Enable the client to send multiple statements in a single string (separated by `;` characters).
`password=password`	Default password.
`pipe`	Use named pipes to connect to a MySQL server on Windows.
`port=port_num`	Default port number.
`protocol={TCP|SOCKET|PIPE|MEMORY}`	The protocol to use when connecting to the server.
`return-found-rows`	Tell `mysql_info()` to return found rows instead of updated rows when using `UPDATE`.
`shared-memory-base-name=name`	Shared-memory name to use to connect to server.
`socket={file_name|pipe_name}`	Default socket file.
`ssl-ca=file_name`	Certificate Authority file.
`ssl-capath=dir_name`	Certificate Authority directory.
`ssl-cert=file_name`	Certificate file.
`ssl-cipher=cipher_list`	Permissible SSL ciphers.
`ssl-key=file_name`	Key file.
`timeout=seconds`	Like `connect-timeout`.
`user`	Default user.

`timeout` has been replaced by `connect-timeout`, but `timeout` is still supported for backward compatibility.

For more information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Before MySQL 5.1.18, the `arg` argument was declared as `char *`.

Return Values

Zero for success. Nonzero if you specify an unknown option.

Example

The following `mysql_options()` calls request the use of compression in the client/server protocol, cause options to be read from the `[odbc]` group of option files, and disable transaction autocommit mode:

```
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_OPT_COMPRESS,0);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"odbc");
mysql_options(&mysql,MYSQL_INIT_COMMAND,"SET autocommit=0");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
        mysql_error(&mysql));
}
```

This code requests that the client use the compressed client/server protocol and read the additional options from the `odbc` section in the `my.cnf` file.

21.8.7.50 mysql_ping()

```
int mysql_ping(MYSQL *mysql)
```

Description

Checks whether the connection to the server is working. If the connection has gone down and auto-reconnect is enabled an attempt to reconnect is made. If the connection is down and auto-reconnect is disabled, `mysql_ping()` returns an error.

Auto-reconnect is disabled by default. To enable it, call `mysql_options()` with the `MYSQL_OPT_RECONNECT` option. For details, see Section 21.8.7.49, "mysql_options()".

`mysql_ping()` can be used by clients that remain idle for a long while, to check whether the server has closed the connection and reconnect if necessary.

If `mysql_ping()`) does cause a reconnect, there is no explicit indication of it. To determine whether a reconnect occurs, call `mysql_thread_id()` to get the original connection identifier before calling `mysql_ping()`, then call `mysql_thread_id()` again to see whether the identifier has changed.

If reconnect occurs, some characteristics of the connection will have been reset. For details about these characteristics, see Section 21.8.15, "Controlling Automatic Reconnection Behavior".

Return Values

Zero if the connection to the server is active. Nonzero if an error occurred. A nonzero return does not indicate whether the MySQL server itself is down; the connection might be broken for other reasons such as network problems.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

21.8.7.51 mysql_query()

```
int mysql_query(MYSQL *mysql, const char *stmt_str)
```

Description

Executes the SQL statement pointed to by the null-terminated string `stmt_str`. Normally, the string must consist of a single SQL statement without a terminating semicolon ("`;`") or `\g`. If multiple-statement execution has been enabled, the string can contain several statements separated by semicolons. See Section 21.8.16, "C API Support for Multiple Statement Execution".

`mysql_query()` cannot be used for statements that contain binary data; you must use `mysql_real_query()` instead. (Binary data may contain the "`\0`" character, which `mysql_query()` interprets as the end of the statement string.)

If you want to know whether the statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 21.8.7.22, "mysql_field_count()".

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC

  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_SERVER_LOST

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

21.8.7.52 mysql_real_connect()

```
MYSQL *mysql_real_connect(MYSQL *mysql, const char *host, const char *user,
const char *passwd, const char *db, unsigned int port, const char *unix_socket,
unsigned long client_flag)
```

Description

mysql_real_connect() attempts to establish a connection to a MySQL database engine running on host. mysql_real_connect() must complete successfully before you can execute any other API functions that require a valid MYSQL connection handle structure.

The parameters are specified as follows:

- For the first parameter, specify the address of an existing MYSQL structure. Before calling mysql_real_connect(), call mysql_init() to initialize the MYSQL structure. You can change a lot of connect options with the mysql_options() call. See Section 21.8.7.49, "mysql_options()".

- The value of host may be either a host name or an IP address. If host is NULL or the string "localhost", a connection to the local host is assumed. For Windows, the client connects using a shared-memory connection, if the server has shared-memory connections enabled. Otherwise, TCP/IP is used. For Unix, the client connects using a Unix socket file. For local connections, you can also influence the type of connection to use with the MYSQL_OPT_PROTOCOL or MYSQL_OPT_NAMED_PIPE options to mysql_options(). The type of connection must be supported by the server. For a host value of "." on Windows, the client connects using a named pipe, if the server has named-pipe connections enabled. If named-pipe connections are not enabled, an error occurs.

- The user parameter contains the user's MySQL login ID. If user is NULL or the empty string "", the current user is assumed. Under Unix, this is the current login name. Under Windows ODBC, the current user name must be specified explicitly. See the Connector/ODBC section of Chapter 21, *Connectors and APIs*.

- The passwd parameter contains the password for user. If passwd is NULL, only entries in the user table for the user that have a blank (empty) password field are checked for a match. This enables the database administrator to set up the MySQL privilege system in such a way that users get different privileges depending on whether they have specified a password.

> **Note**
>
> Do not attempt to encrypt the password before calling mysql_real_connect(); password encryption is handled automatically by the client API.

- The user and passwd parameters use whatever character set has been configured for the MYSQL object. By default, this is latin1, but can be changed by calling mysql_options(mysql, MYSQL_SET_CHARSET_NAME, "charset_name") prior to connecting.

- db is the database name. If db is not NULL, the connection sets the default database to this value.

- If port is not 0, the value is used as the port number for the TCP/IP connection. Note that the host parameter determines the type of the connection.

- If unix_socket is not NULL, the string specifies the socket or named pipe to use. Note that the host parameter determines the type of the connection.

- The value of client_flag is usually 0, but can be set to a combination of the following flags to enable certain features.

Flag Name	Flag Description
CLIENT_COMPRESS	Use compression in the client/server protocol.
CLIENT_FOUND_ROWS	Return the number of found (matched) rows, not the number of changed rows.

Flag Name	Flag Description
CLIENT_IGNORE_SIGPIPE	Prevents the client library from installing a SIGPIPE signal handler. This can be used to avoid conflicts with a handler that the application has already installed.
CLIENT_IGNORE_SPACE	Permit spaces after function names. Makes all functions names reserved words.
CLIENT_INTERACTIVE	Permit interactive_timeout seconds of inactivity (rather than wait_timeout seconds) before closing the connection. The client's session wait_timeout variable is set to the value of the session interactive_timeout variable.
CLIENT_LOCAL_FILES	Enable LOAD DATA LOCAL handling.
CLIENT_MULTI_RESULTS	Tell the server that the client can handle multiple result sets from multiple-statement executions or stored procedures. This flag is automatically enabled if CLIENT_MULTI_STATEMENTS is enabled. See the note following this table for more information about this flag.
CLIENT_MULTI_STATEMENTS	Tell the server that the client may send multiple statements in a single string (separated by ; characters). If this flag is not set, multiple-statement execution is disabled. See the note following this table for more information about this flag.
CLIENT_NO_SCHEMA	Do not permit db_name.tbl_name.col_name syntax. This is for ODBC. It causes the parser to generate an error if you use that syntax, which is useful for trapping bugs in some ODBC programs.
CLIENT_ODBC	Unused.
CLIENT_SSL	Use SSL (encrypted protocol). Do not set this option within an application program; it is set internally in the client library. Instead, use mysql_ssl_set() before calling mysql_real_connect().
CLIENT_REMEMBER_OPTIONS	Remember options specified by calls to mysql_options(). Without this option, if mysql_real_connect() fails, you must repeat the mysql_options() calls before trying to connect again. With this option, the mysql_options() calls need not be repeated.

If your program uses CALL statements to execute stored procedures, the CLIENT_MULTI_RESULTS flag must be enabled. This is because each CALL returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. Because CALL can return multiple results, process them using a loop that calls mysql_next_result() to determine whether there are more results.

CLIENT_MULTI_RESULTS can be enabled when you call mysql_real_connect(), either explicitly by passing the CLIENT_MULTI_RESULTS flag itself, or implicitly by passing CLIENT_MULTI_STATEMENTS (which also enables CLIENT_MULTI_RESULTS).

If you enable CLIENT_MULTI_STATEMENTS or CLIENT_MULTI_RESULTS, you should process the result for every call to mysql_query() or mysql_real_query() by using a loop that calls mysql_next_result() to determine whether there are more results. For an example, see Section 21.8.16, "C API Support for Multiple Statement Execution".

For some parameters, it is possible to have the value taken from an option file rather than from an explicit value in the mysql_real_connect() call. To do this, call mysql_options() with the MYSQL_READ_DEFAULT_FILE or MYSQL_READ_DEFAULT_GROUP option before calling

`mysql_real_connect()`. Then, in the `mysql_real_connect()` call, specify the "no-value" value for each parameter to be read from an option file:

- For `host`, specify a value of `NULL` or the empty string (`""`).

- For `user`, specify a value of `NULL` or the empty string.

- For `passwd`, specify a value of `NULL`. (For the password, a value of the empty string in the `mysql_real_connect()` call cannot be overridden in an option file, because the empty string indicates explicitly that the MySQL account must have an empty password.)

- For `db`, specify a value of `NULL` or the empty string.

- For `port`, specify a value of 0.

- For `unix_socket`, specify a value of `NULL`.

If no value is found in an option file for a parameter, its default value is used as indicated in the descriptions given earlier in this section.

Return Values

A `MYSQL*` connection handle if the connection was successful, `NULL` if the connection was unsuccessful. For a successful connection, the return value is the same as the value of the first parameter.

Errors

- `CR_CONN_HOST_ERROR`

  Failed to connect to the MySQL server.

- `CR_CONNECTION_ERROR`

  Failed to connect to the local MySQL server.

- `CR_IPSOCK_ERROR`

  Failed to create an IP socket.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SOCKET_CREATE_ERROR`

  Failed to create a Unix socket.

- `CR_UNKNOWN_HOST`

  Failed to find the IP address for the host name.

- `CR_VERSION_ERROR`

  A protocol mismatch resulted from attempting to connect to a server with a client library that uses a different protocol version.

- `CR_NAMEDPIPEOPEN_ERROR`

  Failed to create a named pipe on Windows.

- `CR_NAMEDPIPEWAIT_ERROR`

  Failed to wait for a named pipe on Windows.

- `CR_NAMEDPIPESETSTATE_ERROR`

  Failed to get a pipe handler on Windows.

- `CR_SERVER_LOST`

  If `connect_timeout` > 0 and it took longer than `connect_timeout` seconds to connect to the server or if the server died while executing the `init-command`.

Example

```
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"your_prog_name");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
        mysql_error(&mysql));
}
```

By using `mysql_options()` the MySQL library reads the `[client]` and `[your_prog_name]` sections in the `my.cnf` file which ensures that your program works, even if someone has set up MySQL in some nonstandard way.

Upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the `MYSQL` structure) to a value of `1` in versions of the API older than 5.0.3, or `0` in newer versions. A value of `1` for this flag indicates that if a statement cannot be performed because of a lost connection, to try reconnecting to the server before giving up. You can use the `MYSQL_OPT_RECONNECT` option to `mysql_options()` to control reconnection behavior.

21.8.7.53 mysql_real_escape_string()

```
unsigned long mysql_real_escape_string(MYSQL *mysql, char *to, const char
*from, unsigned long length)
```

Description

This function creates a legal SQL string for use in an SQL statement. See Section 9.1.1, "String Literals".

The `mysql` argument must be a valid, open connection because character escaping depends on the character set in use by the server.

The string in the `from` argument is encoded to produce an escaped SQL string, taking into account the current character set of the connection. The result is placed in the `to` argument, followed by a terminating null byte.

Characters encoded are "`\`", "`'`", "`"`", `NUL` (ASCII 0), "`\n`", "`\r`", and Control+Z. Strictly speaking, MySQL requires only that backslash and the quote character used to quote the string in the query be escaped. `mysql_real_escape_string()` quotes the other characters to make them easier to read in log files. For comparison, see the quoting rules for literal strings and the `QUOTE()` SQL function in Section 9.1.1, "String Literals", and Section 12.5, "String Functions".

The string pointed to by `from` must be `length` bytes long. You must allocate the `to` buffer to be at least `length*2+1` bytes long. (In the worst case, each character may need to be encoded as using two bytes,

and there must be room for the terminating null byte.) When `mysql_real_escape_string()` returns, the contents of `to` is a null-terminated string. The return value is the length of the encoded string, not including the terminating null byte.

If you must change the character set of the connection, use the `mysql_set_character_set()` function rather than executing a `SET NAMES` (or `SET CHARACTER SET`) statement. `mysql_set_character_set()` works like `SET NAMES` but also affects the character set used by `mysql_real_escape_string()`, which `SET NAMES` does not.

Example

The following example inserts two escaped strings into an `INSERT` statement, each within single quote characters:

```
char query[1000],*end;

end = strmov(query,"INSERT INTO test_table VALUES(");
*end++ = '\'';
end += mysql_real_escape_string(&mysql,end,"What is this",12);
*end++ = '\'';
*end++ = ',';
*end++ = '\'';
end += mysql_real_escape_string(&mysql,end,"binary data: \0\r\n",16);
*end++ = '\'';
*end++ = ')';

if (mysql_real_query(&mysql,query,(unsigned int) (end - query)))
{
    fprintf(stderr, "Failed to insert row, Error: %s\n",
            mysql_error(&mysql));
}
```

The `strmov()` function used in the example is included in the `libmysqlclient` library and works like `strcpy()` but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the encoded string that is placed into the `to` argument, not including the terminating null character.

Errors

None.

21.8.7.54 mysql_real_query()

```
int mysql_real_query(MYSQL *mysql, const char *stmt_str, unsigned long length)
```

Description

Executes the SQL statement pointed to by `stmt_str`, a string `length` bytes long. Normally, the string must consist of a single SQL statement without a terminating semicolon ("`;`") or `\g`. If multiple-statement execution has been enabled, the string can contain several statements separated by semicolons. See Section 21.8.16, "C API Support for Multiple Statement Execution".

`mysql_query()` cannot be used for statements that contain binary data; you must use `mysql_real_query()` instead. (Binary data may contain the "`\0`" character, which `mysql_query()` interprets as the end of the statement string.) In addition, `mysql_real_query()` is faster than `mysql_query()` because it does not call `strlen()` on the statement string.

If you want to know whether the statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 21.8.7.22, "mysql_field_count()".

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.55 mysql_refresh()

```
int mysql_refresh(MYSQL *mysql, unsigned int options)
```

Description

This function flushes tables or caches, or resets replication server information. The connected user must have the `RELOAD` privilege.

The `options` argument is a bit mask composed from any combination of the following values. Multiple values can be OR'ed together to perform multiple operations with a single call.

- `REFRESH_GRANT`

  Refresh the grant tables, like `FLUSH PRIVILEGES`.

- `REFRESH_LOG`

  Flush the logs, like `FLUSH LOGS`.

- `REFRESH_TABLES`

  Flush the table cache, like `FLUSH TABLES`.

- `REFRESH_HOSTS`

  Flush the host cache, like `FLUSH HOSTS`.

- `REFRESH_STATUS`

  Reset status variables, like `FLUSH STATUS`.

- `REFRESH_THREADS`

Flush the thread cache.

- REFRESH_SLAVE

  On a slave replication server, reset the master server information and restart the slave, like RESET SLAVE.

- REFRESH_MASTER

  On a master replication server, remove the binary log files listed in the binary log index and truncate the index file, like RESET MASTER.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC

  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_SERVER_LOST

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

21.8.7.56 mysql_reload()

```
int mysql_reload(MYSQL *mysql)
```

Description

Asks the MySQL server to reload the grant tables. The connected user must have the RELOAD privilege.

This function is deprecated. It is preferable to use mysql_query() to issue an SQL FLUSH PRIVILEGES statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC

  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

The MySQL server has gone away.

- `CR_SERVER_LOST`

The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

An unknown error occurred.

21.8.7.57 mysql_rollback()

```
my_bool mysql_rollback(MYSQL *mysql)
```

Description

Rolls back the current transaction.

The action of this function is subject to the value of the `completion_type` system variable. In particular, if the value of `completion_type` is 2, the server performs a release after terminating a transaction and closes the client connection. The client program should call `mysql_close()` to close the connection from the client side.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

None.

21.8.7.58 mysql_row_seek()

```
MYSQL_ROW_OFFSET mysql_row_seek(MYSQL_RES *result, MYSQL_ROW_OFFSET offset)
```

Description

Sets the row cursor to an arbitrary row in a query result set. The `offset` value is a row offset, typically a value returned from `mysql_row_tell()` or from `mysql_row_seek()`. This value is not a row number; to seek to a row within a result set by number, use `mysql_data_seek()` instead.

This function requires that the result set structure contains the entire result of the query, so `mysql_row_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_row_seek()`.

Errors

None.

21.8.7.59 mysql_row_tell()

```
MYSQL_ROW_OFFSET mysql_row_tell(MYSQL_RES *result)
```

Description

Returns the current position of the row cursor for the last `mysql_fetch_row()`. This value can be used as an argument to `mysql_row_seek()`.

Use `mysql_row_tell()` only after `mysql_store_result()`, not after `mysql_use_result()`.

Return Values

The current offset of the row cursor.

Errors

None.

21.8.7.60 mysql_select_db()

```
int mysql_select_db(MYSQL *mysql, const char *db)
```

Description

Causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that include no explicit database specifier.

`mysql_select_db()` fails unless the connected user can be authenticated as having permission to use the database.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.61 mysql_set_character_set()

```
int mysql_set_character_set(MYSQL *mysql, const char *csname)
```

Description

This function is used to set the default character set for the current connection. The string `csname` specifies a valid character set name. The connection collation becomes the default collation of the

character set. This function works like the `SET NAMES` statement, but also sets the value of `mysql->charset`, and thus affects the character set used by `mysql_real_escape_string()`

Return Values

Zero for success. Nonzero if an error occurred.

Example

```
MYSQL mysql;

mysql_init(&mysql);
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
        mysql_error(&mysql));
}

if (!mysql_set_character_set(&mysql, "utf8"))
{
    printf("New client character set: %s\n",
        mysql_character_set_name(&mysql));
}
```

21.8.7.62 mysql_set_local_infile_default()

```
void mysql_set_local_infile_default(MYSQL *mysql);
```

Description

Sets the `LOAD DATA LOCAL INFILE` callback functions to the defaults used internally by the C client library. The library calls this function automatically if `mysql_set_local_infile_handler()` has not been called or does not supply valid functions for each of its callbacks.

Return Values

None.

Errors

None.

21.8.7.63 mysql_set_local_infile_handler()

```
void mysql_set_local_infile_handler(MYSQL *mysql, int (*local_infile_init)(void
**, const char *, void *), int (*local_infile_read)(void *, char *, unsigned
int), void (*local_infile_end)(void *), int (*local_infile_error)(void *,
char*, unsigned int), void *userdata);
```

Description

This function installs callbacks to be used during the execution of `LOAD DATA LOCAL INFILE` statements. It enables application programs to exert control over local (client-side) data file reading. The arguments are the connection handler, a set of pointers to callback functions, and a pointer to a data area that the callbacks can use to share information.

To use `mysql_set_local_infile_handler()`, you must write the following callback functions:

```
int
local_infile_init(void **ptr, const char *filename, void *userdata);
```

The initialization function. This is called once to do any setup necessary, open the data file, allocate data structures, and so forth. The first `void**` argument is a pointer to a pointer. You can set the pointer (that is, `*ptr`) to a value that will be passed to each of the other callbacks (as a `void*`). The callbacks can use this pointed-to value to maintain state information. The `userdata` argument is the same value that is passed to `mysql_set_local_infile_handler()`.

The initialization function should return zero for success, nonzero for an error.

```
int
local_infile_read(void *ptr, char *buf, unsigned int buf_len);
```

The data-reading function. This is called repeatedly to read the data file. `buf` points to the buffer where the read data is stored, and `buf_len` is the maximum number of bytes that the callback can read and store in the buffer. (It can read fewer bytes, but should not read more.)

The return value is the number of bytes read, or zero when no more data could be read (this indicates EOF). Return a value less than zero if an error occurs.

```
void
local_infile_end(void *ptr)
```

The termination function. This is called once after `local_infile_read()` has returned zero (EOF) or an error. Within this function, deallocate any memory allocated by `local_infile_init()` and perform any other cleanup necessary. It is invoked even if the initialization function returns an error.

```
int
local_infile_error(void *ptr,
                   char *error_msg,
                   unsigned int error_msg_len);
```

The error-handling function. This is called to get a textual error message to return to the user in case any of your other functions returns an error. `error_msg` points to the buffer into which the message is written, and `error_msg_len` is the length of the buffer. Write the message as a null-terminated string, at most `error_msg_len`−1 bytes long.

The return value is the error number.

Typically, the other callbacks store the error message in the data structure pointed to by `ptr`, so that `local_infile_error()` can copy the message from there into `error_msg`.

After calling `mysql_set_local_infile_handler()` in your C code and passing pointers to your callback functions, you can then issue a `LOAD DATA LOCAL INFILE` statement (for example, by using `mysql_query()`). The client library automatically invokes your callbacks. The file name specified in `LOAD DATA LOCAL INFILE` will be passed as the second parameter to the `local_infile_init()` callback.

Return Values

None.

Errors

None.

21.8.7.64 mysql_set_server_option()

```
int mysql_set_server_option(MYSQL *mysql, enum enum_mysql_set_option option)
```

Description

Enables or disables an option for the connection. `option` can have one of the following values.

Option	Description
`MYSQL_OPTION_MULTI_STATEMENTS_ON`	Enable multiple-statement support
`MYSQL_OPTION_MULTI_STATEMENTS_OFF`	Disable multiple-statement support

If you enable multiple-statement support, you should retrieve results from calls to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 21.8.16, "C API Support for Multiple Statement Execution".

Enabling multiple-statement support with `MYSQL_OPTION_MULTI_STATEMENTS_ON` does not have quite the same effect as enabling it by passing the `CLIENT_MULTI_STATEMENTS` flag to `mysql_real_connect()`: `CLIENT_MULTI_STATEMENTS` also enables `CLIENT_MULTI_RESULTS`. If you are using the `CALL` SQL statement in your programs, multiple-result support must be enabled; this means that `MYSQL_OPTION_MULTI_STATEMENTS_ON` by itself is insufficient to permit the use of `CALL`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `ER_UNKNOWN_COM_ERROR`

  The server did not support `mysql_set_server_option()` (which is the case that the server is older than 4.1.1) or the server did not support the option one tried to set.

21.8.7.65 mysql_shutdown()

```
int mysql_shutdown(MYSQL *mysql, enum mysql_enum_shutdown_level shutdown_level)
```

Description

Asks the database server to shut down. The connected user must have the `SHUTDOWN` privilege. MySQL servers support only one type of shutdown; `shutdown_level` must be equal to `SHUTDOWN_DEFAULT`. Dynamically linked executables which have been compiled with older versions of the `libmysqlclient` headers and call `mysql_shutdown()` need to be used with the old `libmysqlclient` dynamic library.

The shutdown process is described in Section 5.1.11, "The Server Shutdown Process".

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC

  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- CR_SERVER_LOST

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

  An unknown error occurred.

21.8.7.66 mysql_sqlstate()

```
const char *mysql_sqlstate(MYSQL *mysql)
```

Description

Returns a null-terminated string containing the SQLSTATE error code for the most recently executed SQL statement. The error code consists of five characters. `'00000'` means "no error." The values are specified by ANSI SQL and ODBC. For a list of possible values, see Appendix B, *Errors, Error Codes, and Common Problems*.

SQLSTATE values returned by `mysql_sqlstate()` differ from MySQL-specific error numbers returned by `mysql_errno()`. For example, the `mysql` client program displays errors using the following format, where `1146` is the `mysql_errno()` value and `'42S02'` is the corresponding `mysql_sqlstate()` value:

```
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

Not all MySQL error numbers are mapped to SQLSTATE error codes. The value `'HY000'` (general error) is used for unmapped error numbers.

If you call `mysql_sqlstate()` after `mysql_real_connect()` fails, `mysql_sqlstate()` might not return a useful value. For example, this happens if a host is blocked by the server and the connection is closed without any SQLSTATE value being sent to the client.

Return Values

A null-terminated character string containing the SQLSTATE error code.

See Also

See Section 21.8.7.14, "mysql_errno()", Section 21.8.7.15, "mysql_error()", and Section 21.8.11.26, "mysql_stmt_sqlstate()".

21.8.7.67 mysql_ssl_set()

```
my_bool mysql_ssl_set(MYSQL *mysql, const char *key, const char *cert, const
char *ca, const char *capath, const char *cipher)
```

Description

`mysql_ssl_set()` is used for establishing secure connections using SSL. It must be called before `mysql_real_connect()`.

`mysql_ssl_set()` does nothing unless SSL support is enabled in the client library.

`mysql` is the connection handler returned from `mysql_init()`. The other parameters are specified as follows:

- `key` is the path name to the key file.

- `cert` is the path name to the certificate file.

- `ca` is the path name to the certificate authority file.

- `capath` is the path name to a directory that contains trusted SSL CA certificates in PEM format.

- `cipher` is a list of permissible ciphers to use for SSL encryption.

Any unused SSL parameters may be given as `NULL`.

Return Values

This function always returns `0`. If SSL setup is incorrect, `mysql_real_connect()` returns an error when you attempt to connect.

21.8.7.68 mysql_stat()

```
const char *mysql_stat(MYSQL *mysql)
```

Description

Returns a character string containing information similar to that provided by the `mysqladmin status` command. This includes uptime in seconds and the number of running threads, questions, reloads, and open tables.

Return Values

A character string describing the server status. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

    An unknown error occurred.

21.8.7.69 mysql_store_result()

```
MYSQL_RES *mysql_store_result(MYSQL *mysql)
```

Description

After invoking `mysql_query()` or `mysql_real_query()`, you must call `mysql_store_result()` or `mysql_use_result()` for every statement that successfully produces a result set (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`, `CHECK TABLE`, and so forth). You must also call `mysql_free_result()` after you are done with the result set.

You need not call `mysql_store_result()` or `mysql_use_result()` for other statements, but it does not do any harm or cause any notable performance degradation if you call `mysql_store_result()` in all cases. You can detect whether the statement has a result set by checking whether `mysql_store_result()` returns a nonzero value (more about this later).

If you enable multiple-statement support, you should retrieve results from calls to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 21.8.16, "C API Support for Multiple Statement Execution".

If you want to know whether a statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 21.8.7.22, "mysql_field_count()".

`mysql_store_result()` reads the entire result of a query to the client, allocates a `MYSQL_RES` structure, and places the result into this structure.

`mysql_store_result()` returns a null pointer if the statement did not return a result set (for example, if it was an `INSERT` statement).

`mysql_store_result()` also returns a null pointer if reading of the result set failed. You can check whether an error occurred by checking whether `mysql_error()` returns a nonempty string, `mysql_errno()` returns nonzero, or `mysql_field_count()` returns zero.

An empty result set is returned if there are no rows returned. (An empty result set differs from a null pointer as a return value.)

After you have called `mysql_store_result()` and gotten back a result that is not a null pointer, you can call `mysql_num_rows()` to find out how many rows are in the result set.

You can call `mysql_fetch_row()` to fetch rows from the result set, or `mysql_row_seek()` and `mysql_row_tell()` to obtain or set the current row position within the result set.

See Section 21.8.14.1, "Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success".

Return Values

A `MYSQL_RES` result structure with the results. `NULL` (0) if an error occurred.

Errors

`mysql_store_result()` resets `mysql_error()` and `mysql_errno()` if it succeeds.

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.70 mysql_thread_id()

`unsigned long mysql_thread_id(MYSQL *mysql)`

Description

Returns the thread ID of the current connection. This value can be used as an argument to `mysql_kill()` to kill the thread.

If the connection is lost and you reconnect with `mysql_ping()`, the thread ID changes. This means you should not get the thread ID and store it for later. You should get it when you need it.

> **Note**
>
> This function does not work correctly if thread IDs become larger than 32 bits, which can occur on some systems. To avoid problems with `mysql_thread_id()`, do not use it. To get the connection ID, execute a `SELECT CONNECTION_ID()` query and retrieve the result.

Return Values

The thread ID of the current connection.

Errors

None.

21.8.7.71 mysql_use_result()

`MYSQL_RES *mysql_use_result(MYSQL *mysql)`

Description

After invoking `mysql_query()` or `mysql_real_query()`, you must call `mysql_store_result()` or `mysql_use_result()` for every statement that successfully produces a result set (`SELECT`, `SHOW`,

`DESCRIBE`, `EXPLAIN`, `CHECK TABLE`, and so forth). You must also call `mysql_free_result()` after you are done with the result set.

`mysql_use_result()` initiates a result set retrieval but does not actually read the result set into the client like `mysql_store_result()` does. Instead, each row must be retrieved individually by making calls to `mysql_fetch_row()`. This reads the result of a query directly from the server without storing it in a temporary table or local buffer, which is somewhat faster and uses much less memory than `mysql_store_result()`. The client allocates memory only for the current row and a communication buffer that may grow up to `max_allowed_packet` bytes.

On the other hand, you should not use `mysql_use_result()` for locking reads if you are doing a lot of processing for each row on the client side, or if the output is sent to a screen on which the user may type a `^S` (stop scroll). This ties up the server and prevent other threads from updating any tables from which the data is being fetched.

When using `mysql_use_result()`, you must execute `mysql_fetch_row()` until a `NULL` value is returned, otherwise, the unfetched rows are returned as part of the result set for your next query. The C API gives the error `Commands out of sync; you can't run this command now` if you forget to do this!

You may not use `mysql_data_seek()`, `mysql_row_seek()`, `mysql_row_tell()`, `mysql_num_rows()`, or `mysql_affected_rows()` with a result returned from `mysql_use_result()`, nor may you issue other queries until `mysql_use_result()` has finished. (However, after you have fetched all the rows, `mysql_num_rows()` accurately returns the number of rows fetched.)

You must call `mysql_free_result()` once you are done with the result set.

When using the `libmysqld` embedded server, the memory benefits are essentially lost because memory usage incrementally increases with each row retrieved until `mysql_free_result()` is called.

Return Values

A `MYSQL_RES` result structure. `NULL` if an error occurred.

Errors

`mysql_use_result()` resets `mysql_error()` and `mysql_errno()` if it succeeds.

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.7.72 mysql_warning_count()

```
unsigned int mysql_warning_count(MYSQL *mysql)
```

Description

Returns the number of errors, warnings, and notes generated during execution of the previous SQL statement.

Return Values

The warning count.

Errors

None.

21.8.8 C API Prepared Statements

The MySQL client/server protocol provides for the use of prepared statements. This capability uses the `MYSQL_STMT` statement handler data structure returned by the `mysql_stmt_init()` initialization function. Prepared execution is an efficient way to execute a statement more than once. The statement is first parsed to prepare it for execution. Then it is executed one or more times at a later time, using the statement handle returned by the initialization function.

Prepared execution is faster than direct execution for statements executed more than once, primarily because the query is parsed only once. In the case of direct execution, the query is parsed every time it is executed. Prepared execution also can provide a reduction of network traffic because for each execution of the prepared statement, it is necessary only to send the data for the parameters.

Prepared statements might not provide a performance increase in some situations. For best results, test your application both with prepared and nonprepared statements and choose whichever yields best performance.

Another advantage of prepared statements is that it uses a binary protocol that makes data transfer between client and server more efficient.

For a list of SQL statements that can be used as prepared statements, see Section 13.5, "SQL Syntax for Prepared Statements".

As of MySQL 5.1.25, metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, "Automatic Prepared Statement Repreparation".

21.8.9 C API Prepared Statement Data Structures

Prepared statements use several data structures:

- To obtain a statement handle, pass a `MYSQL` connection handler to `mysql_stmt_init()`, which returns a pointer to a `MYSQL_STMT` data structure. This structure is used for further operations with the statement. To specify the statement to prepare, pass the `MYSQL_STMT` pointer and the statement string to `mysql_stmt_prepare()`.

- To provide input parameters for a prepared statement, set up `MYSQL_BIND` structures and pass them to `mysql_stmt_bind_param()`. To receive output column values, set up `MYSQL_BIND` structures and pass them to `mysql_stmt_bind_result()`.

- The `MYSQL_TIME` structure is used to transfer temporal data in both directions.

The following discussion describes the prepared statement data types in detail. For examples that show how to use them, see Section 21.8.11.10, "mysql_stmt_execute()", and Section 21.8.11.11, "mysql_stmt_fetch()".

- `MYSQL_STMT`

  This structure is a handle for a prepared statement. A handle is created by calling `mysql_stmt_init()`, which returns a pointer to a `MYSQL_STMT`. The handle is used for all subsequent operations with the statement until you close it with `mysql_stmt_close()`, at which point the handle becomes invalid.

  The `MYSQL_STMT` structure has no members intended for application use. Applications should not try to copy a `MYSQL_STMT` structure. There is no guarantee that such a copy will be usable.

  Multiple statement handles can be associated with a single connection. The limit on the number of handles depends on the available system resources.

- `MYSQL_BIND`

  This structure is used both for statement input (data values sent to the server) and output (result values returned from the server):

  - For input, use `MYSQL_BIND` structures with `mysql_stmt_bind_param()` to bind parameter data values to buffers for use by `mysql_stmt_execute()`.

  - For output, use `MYSQL_BIND` structures with `mysql_stmt_bind_result()` to bind buffers to result set columns, for use in fetching rows with `mysql_stmt_fetch()`.

  To use a `MYSQL_BIND` structure, zero its contents to initialize it, then set its members appropriately. For example, to declare and initialize an array of three `MYSQL_BIND` structures, use this code:

  ```
  MYSQL_BIND bind[3];
  memset(bind, 0, sizeof(bind));
  ```

  The `MYSQL_BIND` structure contains the following members for use by application programs. For several of the members, the manner of use depends on whether the structure is used for input or output.

  - `enum enum_field_types buffer_type`

    The type of the buffer. This member indicates the data type of the C language variable bound to a statement parameter or result set column. For input, `buffer_type` indicates the type of the variable containing the value to be sent to the server. For output, it indicates the type of the variable into which a value received from the server should be stored. For permissible `buffer_type` values, see Section 21.8.9.1, "C API Prepared Statement Type Codes".

  - `void *buffer`

    A pointer to the buffer to be used for data transfer. This is the address of a C language variable.

    For input, `buffer` is a pointer to the variable in which you store the data value for a statement parameter. When you call `mysql_stmt_execute()`, MySQL use the value stored in the variable in place of the corresponding parameter marker in the statement (specified with `?` in the statement string).

For output, `buffer` is a pointer to the variable in which to return a result set column value. When you call `mysql_stmt_fetch()`, MySQL stores a column value from the current row of the result set in this variable. You can access the value when the call returns.

To minimize the need for MySQL to perform type conversions between C language values on the client side and SQL values on the server side, use C variables that have types similar to those of the corresponding SQL values:

- For numeric data types, `buffer` should point to a variable of the proper numeric C type. For integer variables (which can be `char` for single-byte values or an integer type for larger values), you should also indicate whether the variable has the `unsigned` attribute by setting the `is_unsigned` member, described later.

- For character (nonbinary) and binary string data types, `buffer` should point to a character buffer.

- For date and time data types, `buffer` should point to a `MYSQL_TIME` structure.

For guidelines about mapping between C types and SQL types and notes about type conversions, see Section 21.8.9.1, "C API Prepared Statement Type Codes", and Section 21.8.9.2, "C API Prepared Statement Type Conversions".

- `unsigned long buffer_length`

  The actual size of `*buffer` in bytes. This indicates the maximum amount of data that can be stored in the buffer. For character and binary C data, the `buffer_length` value specifies the length of `*buffer` when used with `mysql_stmt_bind_param()` to specify input values, or the maximum number of output data bytes that can be fetched into the buffer when used with `mysql_stmt_bind_result()`.

- `unsigned long *length`

  A pointer to an `unsigned long` variable that indicates the actual number of bytes of data stored in `*buffer`. `length` is used for character or binary C data.

  For input parameter data binding, set `*length` to indicate the actual length of the parameter value stored in `*buffer`. This is used by `mysql_stmt_execute()`.

  For output value binding, MySQL sets `*length` when you call `mysql_stmt_fetch()`. The `mysql_stmt_fetch()` return value determines how to interpret the length:

  - If the return value is 0, `*length` indicates the actual length of the parameter value.

  - If the return value is `MYSQL_DATA_TRUNCATED`, `*length` indicates the nontruncated length of the parameter value. In this case, the minimum of `*length` and `buffer_length` indicates the actual length of the value.

  `length` is ignored for numeric and temporal data types because the `buffer_type` value determines the length of the data value.

  If you must determine the length of a returned value before fetching it, see Section 21.8.11.11, "mysql_stmt_fetch()", for some strategies.

- `my_bool *is_null`

  This member points to a `my_bool` variable that is true if a value is `NULL`, false if it is not `NULL`. For input, set `*is_null` to true to indicate that you are passing a `NULL` value as a statement parameter.

`is_null` is a *pointer* to a boolean scalar, not a boolean scalar, to provide flexibility in how you specify `NULL` values:

- If your data values are always `NULL`, use `MYSQL_TYPE_NULL` as the `buffer_type` value when you bind the column. The other `MYSQL_BIND` members, including `is_null`, do not matter.

- If your data values are always `NOT NULL`, set `is_null = (my_bool*) 0`, and set the other members appropriately for the variable you are binding.

- In all other cases, set the other members appropriately and set `is_null` to the address of a `my_bool` variable. Set that variable's value to true or false appropriately between executions to indicate whether the corresponding data value is `NULL` or `NOT NULL`, respectively.

For output, when you fetch a row, MySQL sets the value pointed to by `is_null` to true or false according to whether the result set column value returned from the statement is or is not `NULL`.

- `my_bool is_unsigned`

  This member applies for C variables with data types that can be `unsigned` (`char`, `short int`, `int`, `long long int`). Set `is_unsigned` to true if the variable pointed to by `buffer` is `unsigned` and false otherwise. For example, if you bind a `signed char` variable to `buffer`, specify a type code of `MYSQL_TYPE_TINY` and set `is_unsigned` to false. If you bind an `unsigned char` instead, the type code is the same but `is_unsigned` should be true. (For `char`, it is not defined whether it is signed or unsigned, so it is best to be explicit about signedness by using `signed char` or `unsigned char`.)

  `is_unsigned` applies only to the C language variable on the client side. It indicates nothing about the signedness of the corresponding SQL value on the server side. For example, if you use an `int` variable to supply a value for a `BIGINT UNSIGNED` column, `is_unsigned` should be false because `int` is a signed type. If you use an `unsigned int` variable to supply a value for a `BIGINT` column, `is_unsigned` should be true because `unsigned int` is an unsigned type. MySQL performs the proper conversion between signed and unsigned values in both directions, although a warning occurs if truncation results.

- `my_bool *error`

  For output, set this member to point to a `my_bool` variable to have truncation information for the parameter stored there after a row fetching operation. When truncation reporting is enabled, `mysql_stmt_fetch()` returns `MYSQL_DATA_TRUNCATED` and `*error` is true in the `MYSQL_BIND` structures for parameters in which truncation occurred. Truncation indicates loss of sign or significant digits, or that a string was too long to fit in a column. Truncation reporting is enabled by default, but can be controlled by calling `mysql_options()` with the `MYSQL_REPORT_DATA_TRUNCATION` option.

- `MYSQL_TIME`

This structure is used to send and receive `DATE`, `TIME`, `DATETIME`, and `TIMESTAMP` data directly to and from the server. Set the `buffer` member to point to a `MYSQL_TIME` structure, and set the `buffer_type` member of a `MYSQL_BIND` structure to one of the temporal types (`MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATE`, `MYSQL_TYPE_DATETIME`, `MYSQL_TYPE_TIMESTAMP`).

The `MYSQL_TIME` structure contains the members listed in the following table.

Member	Description
`unsigned int year`	The year

Member	Description
`unsigned int month`	The month of the year
`unsigned int day`	The day of the month
`unsigned int hour`	The hour of the day
`unsigned int minute`	The minute of the hour
`unsigned int second`	The second of the minute
`my_bool neg`	A boolean flag indicating whether the time is negative
`unsigned long second_part`	The fractional part of the second in microseconds; currently unused

Only those parts of a `MYSQL_TIME` structure that apply to a given type of temporal value are used. The `year`, `month`, and `day` elements are used for `DATE`, `DATETIME`, and `TIMESTAMP` values. The `hour`, `minute`, and `second` elements are used for `TIME`, `DATETIME`, and `TIMESTAMP` values. See Section 21.8.18, "C API Prepared Statement Handling of Date and Time Values".

21.8.9.1 C API Prepared Statement Type Codes

The `buffer_type` member of `MYSQL_BIND` structures indicates the data type of the C language variable bound to a statement parameter or result set column. For input, `buffer_type` indicates the type of the variable containing the value to be sent to the server. For output, it indicates the type of the variable into which a value received from the server should be stored.

The following table shows the permissible values for the `buffer_type` member of `MYSQL_BIND` structures for input values sent to the server. The table shows the C variable types that you can use, the corresponding type codes, and the SQL data types for which the supplied value can be used without conversion. Choose the `buffer_type` value according to the data type of the C language variable that you are binding. For the integer types, you should also set the `is_unsigned` member to indicate whether the variable is signed or unsigned.

Input Variable C Type	`buffer_type` Value	SQL Type of Destination Value
`signed char`	MYSQL_TYPE_TINY	`TINYINT`
`short int`	MYSQL_TYPE_SHORT	`SMALLINT`
`int`	MYSQL_TYPE_LONG	`INT`
`long long int`	MYSQL_TYPE_LONGLONG	`BIGINT`
`float`	MYSQL_TYPE_FLOAT	`FLOAT`
`double`	MYSQL_TYPE_DOUBLE	`DOUBLE`
`MYSQL_TIME`	MYSQL_TYPE_TIME	`TIME`
`MYSQL_TIME`	MYSQL_TYPE_DATE	`DATE`
`MYSQL_TIME`	MYSQL_TYPE_DATETIME	`DATETIME`
`MYSQL_TIME`	MYSQL_TYPE_TIMESTAMP	`TIMESTAMP`
`char[]`	MYSQL_TYPE_STRING	`TEXT`, `CHAR`, `VARCHAR`
`char[]`	MYSQL_TYPE_BLOB	`BLOB`, `BINARY`, `VARBINARY`
	MYSQL_TYPE_NULL	`NULL`

Use `MYSQL_TYPE_NULL` as indicated in the description for the `is_null` member in Section 21.8.9, "C API Prepared Statement Data Structures".

For input string data, use `MYSQL_TYPE_STRING` or `MYSQL_TYPE_BLOB` depending on whether the value is a character (nonbinary) or binary string:

- `MYSQL_TYPE_STRING` indicates character input string data. The value is assumed to be in the character set indicated by the `character_set_client` system variable. If the server stores the value into a column with a different character set, it converts the value to that character set.

- `MYSQL_TYPE_BLOB` indicates binary input string data. The value is treated as having the `binary` character set. That is, it is treated as a byte string and no conversion occurs.

The following table shows the permissible values for the `buffer_type` member of `MYSQL_BIND` structures for output values received from the server. The table shows the SQL types of received values, the corresponding type codes that such values have in result set metadata, and the recommended C language data types to bind to the `MYSQL_BIND` structure to receive the SQL values without conversion. Choose the `buffer_type` value according to the data type of the C language variable that you are binding. For the integer types, you should also set the `is_unsigned` member to indicate whether the variable is signed or unsigned.

SQL Type of Received Value	`buffer_type` Value	Output Variable C Type
`TINYINT`	`MYSQL_TYPE_TINY`	`signed char`
`SMALLINT`	`MYSQL_TYPE_SHORT`	`short int`
`MEDIUMINT`	`MYSQL_TYPE_INT24`	`int`
`INT`	`MYSQL_TYPE_LONG`	`int`
`BIGINT`	`MYSQL_TYPE_LONGLONG`	`long long int`
`FLOAT`	`MYSQL_TYPE_FLOAT`	`float`
`DOUBLE`	`MYSQL_TYPE_DOUBLE`	`double`
`DECIMAL`	`MYSQL_TYPE_NEWDECIMAL`	`char[]`
`YEAR`	`MYSQL_TYPE_SHORT`	`short int`
`TIME`	`MYSQL_TYPE_TIME`	`MYSQL_TIME`
`DATE`	`MYSQL_TYPE_DATE`	`MYSQL_TIME`
`DATETIME`	`MYSQL_TYPE_DATETIME`	`MYSQL_TIME`
`TIMESTAMP`	`MYSQL_TYPE_TIMESTAMP`	`MYSQL_TIME`
`CHAR`, `BINARY`	`MYSQL_TYPE_STRING`	`char[]`
`VARCHAR`, `VARBINARY`	`MYSQL_TYPE_VAR_STRING`	`char[]`
`TINYBLOB`, `TINYTEXT`	`MYSQL_TYPE_TINY_BLOB`	`char[]`
`BLOB`, `TEXT`	`MYSQL_TYPE_BLOB`	`char[]`
`MEDIUMBLOB`, `MEDIUMTEXT`	`MYSQL_TYPE_MEDIUM_BLOB`	`char[]`
`LONGBLOB`, `LONGTEXT`	`MYSQL_TYPE_LONG_BLOB`	`char[]`
`BIT`	`MYSQL_TYPE_BIT`	`char[]`

21.8.9.2 C API Prepared Statement Type Conversions

Prepared statements transmit data between the client and server using C language variables on the client side that correspond to SQL values on the server side. If there is a mismatch between the C variable type on the client side and the corresponding SQL value type on the server side, MySQL performs implicit type conversions in both directions.

MySQL knows the type code for the SQL value on the server side. The `buffer_type` value in the `MYSQL_BIND` structure indicates the type code of the C variable that holds the value on the client side. The two codes together tell MySQL what conversion must be performed, if any. Here are some examples:

- If you use `MYSQL_TYPE_LONG` with an `int` variable to pass an integer value to the server that is to be stored into a `FLOAT` column, MySQL converts the value to floating-point format before storing it.

- If you fetch an SQL `MEDIUMINT` column value, but specify a `buffer_type` value of `MYSQL_TYPE_LONGLONG` and use a C variable of type `long long int` as the destination buffer, MySQL converts the `MEDIUMINT` value (which requires less than 8 bytes) for storage into the `long long int` (an 8-byte variable).

- If you fetch a numeric column with a value of 255 into a `char[4]` character array and specify a `buffer_type` value of `MYSQL_TYPE_STRING`, the resulting value in the array is a 4-byte string `'255\0'`.

- MySQL returns `DECIMAL` values as the string representation of the original server-side value, which is why the corresponding C type is `char[]`. For example, `12.345` is returned to the client as `'12.345'`. If you specify `MYSQL_TYPE_NEWDECIMAL` and bind a string buffer to the `MYSQL_BIND` structure, `mysql_stmt_fetch()` stores the value in the buffer as a string without conversion. If instead you specify a numeric variable and type code, `mysql_stmt_fetch()` converts the string-format `DECIMAL` value to numeric form.

- For the `MYSQL_TYPE_BIT` type code, `BIT` values are returned into a string buffer, which is why the corresponding C type is `char[]`. The value represents a bit string that requires interpretation on the client side. To return the value as a type that is easier to deal with, you can cause the value to be cast to integer using either of the following types of expressions:

```
SELECT bit_col + 0 FROM t
SELECT CAST(bit_col AS UNSIGNED) FROM t
```

  To retrieve the value, bind an integer variable large enough to hold the value and specify the appropriate corresponding integer type code.

Before binding variables to the `MYSQL_BIND` structures that are to be used for fetching column values, you can check the type codes for each column of the result set. This might be desirable if you want to determine which variable types would be best to use to avoid type conversions. To get the type codes, call `mysql_stmt_result_metadata()` after executing the prepared statement with `mysql_stmt_execute()`. The metadata provides access to the type codes for the result set as described in Section 21.8.11.22, "mysql_stmt_result_metadata()", and Section 21.8.5, "C API Data Structures".

To determine whether output string values in a result set returned from the server contain binary or nonbinary data, check whether the `charsetnr` value of the result set metadata is 63 (see Section 21.8.5, "C API Data Structures"). If so, the character set is `binary`, which indicates binary rather than nonbinary data. This enables you to distinguish `BINARY` from `CHAR`, `VARBINARY` from `VARCHAR`, and the `BLOB` types from the `TEXT` types.

If you cause the `max_length` member of the `MYSQL_FIELD` column metadata structures to be set (by calling `mysql_stmt_attr_set()`), be aware that the `max_length` values for the result set indicate the lengths of the longest string representation of the result values, not the lengths of the binary representation. That is, `max_length` does not necessarily correspond to the size of the buffers needed to fetch the values with the binary protocol used for prepared statements. Choose the size of the buffers according to the types of the variables into which you fetch the values. For example, a `TINYINT` column containing the value -128 might have a `max_length` value of 4. But the binary representation of any

`TINYINT` value requires only 1 byte for storage, so you can supply a `signed char` variable in which to store the value and set `is_unsigned` to indicate that values are signed.

As of MySQL 5.1.25, metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, "Automatic Prepared Statement Repreparation".

21.8.10 C API Prepared Statement Function Overview

The functions available for prepared statement processing are summarized here and described in greater detail in a later section. See Section 21.8.11, "C API Prepared Statement Function Descriptions".

Function	Description
`mysql_stmt_affected_rows()`	Returns the number of rows changed, deleted, or inserted by prepared `UPDATE`, `DELETE`, or `INSERT` statement
`mysql_stmt_attr_get()`	Gets value of an attribute for a prepared statement
`mysql_stmt_attr_set()`	Sets an attribute for a prepared statement
`mysql_stmt_bind_param()`	Associates application data buffers with the parameter markers in a prepared SQL statement
`mysql_stmt_bind_result()`	Associates application data buffers with columns in a result set
`mysql_stmt_close()`	Frees memory used by a prepared statement
`mysql_stmt_data_seek()`	Seeks to an arbitrary row number in a statement result set
`mysql_stmt_errno()`	Returns the error number for the last statement execution
`mysql_stmt_error()`	Returns the error message for the last statement execution
`mysql_stmt_execute()`	Executes a prepared statement
`mysql_stmt_fetch()`	Fetches the next row of data from a result set and returns data for all bound columns
`mysql_stmt_fetch_column()`	Fetch data for one column of the current row of a result set
`mysql_stmt_field_count()`	Returns the number of result columns for the most recent statement
`mysql_stmt_free_result()`	Free the resources allocated to a statement handle
`mysql_stmt_init()`	Allocates memory for a `MYSQL_STMT` structure and initializes it
`mysql_stmt_insert_id()`	Returns the ID generated for an `AUTO_INCREMENT` column by a prepared statement
`mysql_stmt_num_rows()`	Returns the row count from a buffered statement result set
`mysql_stmt_param_count()`	Returns the number of parameters in a prepared statement
`mysql_stmt_param_metadata()`	(Return parameter metadata in the form of a result set) This function does nothing
`mysql_stmt_prepare()`	Prepares an SQL statement string for execution
`mysql_stmt_reset()`	Resets the statement buffers in the server
`mysql_stmt_result_metadata()`	Returns prepared statement metadata in the form of a result set
`mysql_stmt_row_seek()`	Seeks to a row offset in a statement result set, using value returned from `mysql_stmt_row_tell()`
`mysql_stmt_row_tell()`	Returns the statement row cursor position
`mysql_stmt_send_long_data()`	Sends long data in chunks to server
`mysql_stmt_sqlstate()`	Returns the SQLSTATE error code for the last statement execution

Function	Description
`mysql_stmt_store_result()`	Retrieves a complete result set to the client

Call `mysql_stmt_init()` to create a statement handle, then `mysql_stmt_prepare()` to prepare the statement string, `mysql_stmt_bind_param()` to supply the parameter data, and `mysql_stmt_execute()` to execute the statement. You can repeat the `mysql_stmt_execute()` by changing parameter values in the respective buffers supplied through `mysql_stmt_bind_param()`.

You can send text or binary data in chunks to server using `mysql_stmt_send_long_data()`. See Section 21.8.11.25, "mysql_stmt_send_long_data()".

If the statement is a `SELECT` or any other statement that produces a result set, `mysql_stmt_prepare()` also returns the result set metadata information in the form of a `MYSQL_RES` result set through `mysql_stmt_result_metadata()`.

You can supply the result buffers using `mysql_stmt_bind_result()`, so that the `mysql_stmt_fetch()` automatically returns data to these buffers. This is row-by-row fetching.

When statement execution has been completed, close the statement handle using `mysql_stmt_close()` so that all resources associated with it can be freed.

If you obtained a `SELECT` statement's result set metadata by calling `mysql_stmt_result_metadata()`, you should also free the metadata using `mysql_free_result()`.

Execution Steps

To prepare and execute a statement, an application follows these steps:

1. Create a prepared statement handle with `mysql_stmt_init()`. To prepare the statement on the server, call `mysql_stmt_prepare()` and pass it a string containing the SQL statement.

2. If the statement will produce a result set, call `mysql_stmt_result_metadata()` to obtain the result set metadata. This metadata is itself in the form of result set, albeit a separate one from the one that contains the rows returned by the query. The metadata result set indicates how many columns are in the result and contains information about each column.

3. Set the values of any parameters using `mysql_stmt_bind_param()`. All parameters must be set. Otherwise, statement execution returns an error or produces unexpected results.

4. Call `mysql_stmt_execute()` to execute the statement.

5. If the statement produces a result set, bind the data buffers to use for retrieving the row values by calling `mysql_stmt_bind_result()`.

6. Fetch the data into the buffers row by row by calling `mysql_stmt_fetch()` repeatedly until no more rows are found.

7. Repeat steps 3 through 6 as necessary, by changing the parameter values and re-executing the statement.

When `mysql_stmt_prepare()` is called, the MySQL client/server protocol performs these actions:

- The server parses the statement and sends the okay status back to the client by assigning a statement ID. It also sends total number of parameters, a column count, and its metadata if it is a result set oriented statement. All syntax and semantics of the statement are checked by the server during this call.

- The client uses this statement ID for the further operations, so that the server can identify the statement from among its pool of statements.

When `mysql_stmt_execute()` is called, the MySQL client/server protocol performs these actions:

- The client uses the statement handle and sends the parameter data to the server.

- The server identifies the statement using the ID provided by the client, replaces the parameter markers with the newly supplied data, and executes the statement. If the statement produces a result set, the server sends the data back to the client. Otherwise, it sends an okay status and the number of rows changed, deleted, or inserted.

When `mysql_stmt_fetch()` is called, the MySQL client/server protocol performs these actions:

- The client reads the data from the current row of the result set and places it into the application data buffers by doing the necessary conversions. If the application buffer type is same as that of the field type returned from the server, the conversions are straightforward.

If an error occurs, you can get the statement error number, error message, and SQLSTATE code using `mysql_stmt_errno()`, `mysql_stmt_error()`, and `mysql_stmt_sqlstate()`, respectively.

Prepared Statement Logging

For prepared statements that are executed with the `mysql_stmt_prepare()` and `mysql_stmt_execute()` C API functions, the server writes `Prepare` and `Execute` lines to the general query log so that you can tell when statements are prepared and executed.

Suppose that you prepare and execute a statement as follows:

1. Call `mysql_stmt_prepare()` to prepare the statement string `"SELECT ?"`.

2. Call `mysql_stmt_bind_param()` to bind the value `3` to the parameter in the prepared statement.

3. Call `mysql_stmt_execute()` to execute the prepared statement.

As a result of the preceding calls, the server writes the following lines to the general query log:

```
Prepare  [1] SELECT ?
Execute  [1] SELECT 3
```

Each `Prepare` and `Execute` line in the log is tagged with a `[N]` statement identifier so that you can keep track of which prepared statement is being logged. `N` is a positive integer. If there are multiple prepared statements active simultaneously for the client, `N` may be greater than 1. Each `Execute` lines shows a prepared statement after substitution of data values for `?` parameters.

21.8.11 C API Prepared Statement Function Descriptions

To prepare and execute queries, use the functions described in detail in the following sections.

All functions that operate with a `MYSQL_STMT` structure begin with the prefix `mysql_stmt_`.

To create a `MYSQL_STMT` handle, use the `mysql_stmt_init()` function.

21.8.11.1 mysql_stmt_affected_rows()

`my_ulonglong mysql_stmt_affected_rows(MYSQL_STMT *stmt)`

Description

`mysql_stmt_affected_rows()` may be called immediately after executing a statement with `mysql_stmt_execute()`. It is like `mysql_affected_rows()` but for prepared statements. For a description of what the affected-rows value returned by this function means, See Section 21.8.7.1, "mysql_affected_rows()".

Errors

None.

Example

See the Example in Section 21.8.11.10, "mysql_stmt_execute()".

21.8.11.2 mysql_stmt_attr_get()

```
my_bool mysql_stmt_attr_get(MYSQL_STMT *stmt, enum enum_stmt_attr_type option,
void *arg)
```

Description

Can be used to get the current value for a statement attribute.

The `option` argument is the option that you want to get; the `arg` should point to a variable that should contain the option value. If the option is an integer, `arg` should point to the value of the integer.

See Section 21.8.11.3, "mysql_stmt_attr_set()", for a list of options and option types.

> **Note**
>
> In MySQL 5.1, `mysql_stmt_attr_get()` originally used `unsigned long *`, not `my_bool *`, for `STMT_ATTR_UPDATE_MAX_LENGTH`. This was corrected in MySQL 5.1.7.

Return Values

Zero for success. Nonzero if `option` is unknown.

Errors

None.

21.8.11.3 mysql_stmt_attr_set()

```
my_bool mysql_stmt_attr_set(MYSQL_STMT *stmt, enum enum_stmt_attr_type option,
const void *arg)
```

Description

Can be used to affect behavior for a prepared statement. This function may be called multiple times to set several options.

The `option` argument is the option that you want to set. The `arg` argument is the value for the option. `arg` should point to a variable that is set to the desired attribute value. The variable type is as indicated in the following table.

The following table shows the possible `option` values.

Option	Argument Type	Function
STMT_ATTR_UPDATE_MAX_LENGTH	my_bool *	If set to 1, causes `mysql_stmt_store_result()` to update the metadata `MYSQL_FIELD->max_length` value.
STMT_ATTR_CURSOR_TYPE	unsigned long *	Type of cursor to open for statement when `mysql_stmt_execute()`

Option	Argument Type	Function
		is invoked. `*arg` can be `CURSOR_TYPE_NO_CURSOR` (the default) or `CURSOR_TYPE_READ_ONLY`.
`STMT_ATTR_PREFETCH_ROWS`	`unsigned long *`	Number of rows to fetch from server at a time when using a cursor. `*arg` can be in the range from 1 to the maximum value of `unsigned long`. The default is 1.

If you use the `STMT_ATTR_CURSOR_TYPE` option with `CURSOR_TYPE_READ_ONLY`, a cursor is opened for the statement when you invoke `mysql_stmt_execute()`. If there is already an open cursor from a previous `mysql_stmt_execute()` call, it closes the cursor before opening a new one. `mysql_stmt_reset()` also closes any open cursor before preparing the statement for re-execution. `mysql_stmt_free_result()` closes any open cursor.

If you open a cursor for a prepared statement, `mysql_stmt_store_result()` is unnecessary, because that function causes the result set to be buffered on the client side.

Return Values

Zero for success. Nonzero if `option` is unknown.

Errors

None.

Example

The following example opens a cursor for a prepared statement and sets the number of rows to fetch at a time to 5:

```
MYSQL_STMT *stmt;
int rc;
unsigned long type;
unsigned long prefetch_rows = 5;

stmt = mysql_stmt_init(mysql);
type = (unsigned long) CURSOR_TYPE_READ_ONLY;
rc = mysql_stmt_attr_set(stmt, STMT_ATTR_CURSOR_TYPE, (void*) &type);
/* ... check return value ... */
rc = mysql_stmt_attr_set(stmt, STMT_ATTR_PREFETCH_ROWS,
                         (void*) &prefetch_rows);
/* ... check return value ... */
```

21.8.11.4 mysql_stmt_bind_param()

```
my_bool mysql_stmt_bind_param(MYSQL_STMT *stmt, MYSQL_BIND *bind)
```

Description

`mysql_stmt_bind_param()` is used to bind input data for the parameter markers in the SQL statement that was passed to `mysql_stmt_prepare()`. It uses `MYSQL_BIND` structures to supply the data. `bind` is the address of an array of `MYSQL_BIND` structures. The client library expects the array to contain one element for each `?` parameter marker that is present in the query.

Suppose that you prepare the following statement:

```
INSERT INTO mytbl VALUES(?,?,?)
```

When you bind the parameters, the array of `MYSQL_BIND` structures must contain three elements, and can be declared like this:

```
MYSQL_BIND bind[3];
```

Section 21.8.9, "C API Prepared Statement Data Structures", describes the members of each `MYSQL_BIND` element and how they should be set to provide input values.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_UNSUPPORTED_PARAM_TYPE`

  The conversion is not supported. Possibly the `buffer_type` value is invalid or is not one of the supported types.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 21.8.11.10, "mysql_stmt_execute()".

21.8.11.5 mysql_stmt_bind_result()

```
my_bool mysql_stmt_bind_result(MYSQL_STMT *stmt, MYSQL_BIND *bind)
```

Description

`mysql_stmt_bind_result()` is used to associate (that is, bind) output columns in the result set to data buffers and length buffers. When `mysql_stmt_fetch()` is called to fetch data, the MySQL client/server protocol places the data for the bound columns into the specified buffers.

All columns must be bound to buffers prior to calling `mysql_stmt_fetch()`. `bind` is the address of an array of `MYSQL_BIND` structures. The client library expects the array to contain one element for each column of the result set. If you do not bind columns to `MYSQL_BIND` structures, `mysql_stmt_fetch()` simply ignores the data fetch. The buffers should be large enough to hold the data values, because the protocol does not return data values in chunks.

A column can be bound or rebound at any time, even after a result set has been partially retrieved. The new binding takes effect the next time `mysql_stmt_fetch()` is called. Suppose that an application binds the columns in a result set and calls `mysql_stmt_fetch()`. The client/server protocol returns data in the bound buffers. Then suppose that the application binds the columns to a different set of buffers. The protocol places data into the newly bound buffers when the next call to `mysql_stmt_fetch()` occurs.

To bind a column, an application calls `mysql_stmt_bind_result()` and passes the type, address, and length of the output buffer into which the value should be stored. Section 21.8.9, "C API Prepared

Statement Data Structures", describes the members of each `MYSQL_BIND` element and how they should be set to receive output values.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_UNSUPPORTED_PARAM_TYPE`

  The conversion is not supported. Possibly the `buffer_type` value is invalid or is not one of the supported types.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 21.8.11.11, "mysql_stmt_fetch()".

21.8.11.6 mysql_stmt_close()

```
my_bool mysql_stmt_close(MYSQL_STMT *)
```

Description

Closes the prepared statement. `mysql_stmt_close()` also deallocates the statement handle pointed to by `stmt`.

If the current statement has pending or unread results, this function cancels them so that the next query can be executed.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 21.8.11.10, "mysql_stmt_execute()".

21.8.11.7 mysql_stmt_data_seek()

```
void mysql_stmt_data_seek(MYSQL_STMT *stmt, my_ulonglong offset)
```

Description

Seeks to an arbitrary row in a statement result set. The `offset` value is a row number and should be in the range from `0` to `mysql_stmt_num_rows(stmt)-1`.

This function requires that the statement result set structure contains the entire result of the last executed query, so `mysql_stmt_data_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

Return Values

None.

Errors

None.

21.8.11.8 mysql_stmt_errno()

```
unsigned int mysql_stmt_errno(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_errno()` returns the error code for the most recently invoked statement API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL `errmsg.h` header file. Server error message numbers are listed in `mysqld_error.h`. Errors also are listed at Appendix B, *Errors, Error Codes, and Common Problems*.

Return Values

An error code value. Zero if no error occurred.

Errors

None.

21.8.11.9 mysql_stmt_error()

```
const char *mysql_stmt_error(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_error()` returns a null-terminated string containing the error message for the most recently invoked statement API function that can succeed or fail. An empty string (`""`) is returned if no error occurred. Either of these two tests can be used to check for an error:

```
if(*mysql_stmt_errno(stmt))
{
  // an error occurred
}

if (mysql_stmt_error(stmt)[0])
{
  // an error occurred
}
```

The language of the client error messages may be changed by recompiling the MySQL client library. You can choose error messages in several different languages.

Return Values

A character string that describes the error. An empty string if no error occurred.

Errors

None.

21.8.11.10 mysql_stmt_execute()

```
int mysql_stmt_execute(MYSQL_STMT *stmt)
```

Description

`mysql_stmt_execute()` executes the prepared query associated with the statement handle. The currently bound parameter marker values are sent to server during this call, and the server replaces the markers with this newly supplied data.

Statement processing following `mysql_stmt_execute()` depends on the type of statement:

- For an `UPDATE`, `DELETE`, or `INSERT`, the number of changed, deleted, or inserted rows can be found by calling `mysql_stmt_affected_rows()`.

- For a statement such as `SELECT` that generates a result set, you must call `mysql_stmt_fetch()` to fetch the data prior to calling any other functions that result in query processing. For more information on how to fetch the results, refer to Section 21.8.11.11, "mysql_stmt_fetch()".

  Do not following invocation of `mysql_stmt_execute()` with a call to `mysql_store_result()` or `mysql_use_result()`. Those functions are not intended for processing results from prepared statements.

For statements that generate a result set, you can request that `mysql_stmt_execute()` open a cursor for the statement by calling `mysql_stmt_attr_set()` before executing the statement. If you execute a statement multiple times, `mysql_stmt_execute()` closes any open cursor before opening a new one.

As of MySQL 5.1.25, metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, "Automatic Prepared Statement Repreparation".

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- CR_UNKNOWN_ERROR

    An unknown error occurred.

Example

The following example demonstrates how to create and populate a table using mysql_stmt_init(), mysql_stmt_prepare(), mysql_stmt_param_count(), mysql_stmt_bind_param(), mysql_stmt_execute(), and mysql_stmt_affected_rows(). The mysql variable is assumed to be a valid connection handle. For an example that shows how to retrieve data, see Section 21.8.11.11, "mysql_stmt_fetch()".

```
#define STRING_SIZE 50

#define DROP_SAMPLE_TABLE "DROP TABLE IF EXISTS test_table"
#define CREATE_SAMPLE_TABLE "CREATE TABLE test_table(col1 INT,\
                                                     col2 VARCHAR(40),\
                                                     col3 SMALLINT,\
                                                     col4 TIMESTAMP)"
#define INSERT_SAMPLE "INSERT INTO \
                       test_table(col1,col2,col3) \
                       VALUES(?,?,?)"

MYSQL_STMT    *stmt;
MYSQL_BIND    bind[3];
my_ulonglong  affected_rows;
int           param_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
unsigned long str_length;
my_bool       is_null;

if (mysql_query(mysql, DROP_SAMPLE_TABLE))
{
  fprintf(stderr, " DROP TABLE failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

if (mysql_query(mysql, CREATE_SAMPLE_TABLE))
{
  fprintf(stderr, " CREATE TABLE failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

/* Prepare an INSERT query with 3 parameters */
/* (the TIMESTAMP column is not named; the server */
/*  sets it to the current date and time) */
stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(stmt, INSERT_SAMPLE, strlen(INSERT_SAMPLE)))
{
  fprintf(stderr, " mysql_stmt_prepare(), INSERT failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
fprintf(stdout, " prepare, INSERT successful\n");
```

```
/* Get the parameter count from the statement */
param_count= mysql_stmt_param_count(stmt);
fprintf(stdout, " total parameters in INSERT: %d\n", param_count);

if (param_count != 3) /* validate parameter count */
{
  fprintf(stderr, " invalid parameter count returned by MySQL\n");
  exit(0);
}

/* Bind the data for all 3 parameters */

memset(bind, 0, sizeof(bind));

/* INTEGER PARAM */
/* This is a number type, so there is no need
   to specify buffer_length */
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *)&int_data;
bind[0].is_null= 0;
bind[0].length= 0;

/* STRING PARAM */
bind[1].buffer_type= MYSQL_TYPE_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= 0;
bind[1].length= &str_length;

/* SMALLINT PARAM */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null;
bind[2].length= 0;

/* Bind the buffers */
if (mysql_stmt_bind_param(stmt, bind))
{
  fprintf(stderr, " mysql_stmt_bind_param() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Specify the data values for the first row */
int_data= 10;             /* integer */
strncpy(str_data, "MySQL", STRING_SIZE); /* string  */
str_length= strlen(str_data);

/* INSERT SMALLINT data as NULL */
is_null= 1;

/* Execute the INSERT statement - 1*/
if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, " mysql_stmt_execute(), 1 failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get the number of affected rows */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 1): %lu\n",
                (unsigned long) affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
  fprintf(stderr, " invalid affected rows by MySQL\n");
```

```
    exit(0);
}

/* Specify data values for second row,
   then re-execute the statement */
int_data= 1000;
strncpy(str_data, "
        The most popular Open Source database",
        STRING_SIZE);
str_length= strlen(str_data);
small_data= 1000;          /* smallint */
is_null= 0;                /* reset */

/* Execute the INSERT statement - 2*/
if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, " mysql_stmt_execute, 2 failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get the total rows affected */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 2): %lu\n",
                (unsigned long) affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
  fprintf(stderr, " invalid affected rows by MySQL\n");
  exit(0);
}

/* Close the statement */
if (mysql_stmt_close(stmt))
{
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
```

Note

For complete examples on the use of prepared statement functions, refer to the file `tests/mysql_client_test.c`. This file can be obtained from a MySQL source distribution or from the source repository (see Section 2.11, "Installing MySQL from Source").

21.8.11.11 mysql_stmt_fetch()

```
int mysql_stmt_fetch(MYSQL_STMT *stmt)
```

Description

`mysql_stmt_fetch()` returns the next row in the result set. It can be called only while the result set exists; that is, after a call to `mysql_stmt_execute()` for a statement such as `SELECT` that produces a result set.

`mysql_stmt_fetch()` returns row data using the buffers bound by `mysql_stmt_bind_result()`. It returns the data in those buffers for all the columns in the current row set and the lengths are returned to the `length` pointer. All columns must be bound by the application before it calls `mysql_stmt_fetch()`.

By default, result sets are fetched unbuffered a row at a time from the server. To buffer the entire result set on the client, call `mysql_stmt_store_result()` after binding the data buffers and before calling `mysql_stmt_fetch()`.

If a fetched data value is a `NULL` value, the `*is_null` value of the corresponding `MYSQL_BIND` structure contains TRUE (1). Otherwise, the data and its length are returned in the `*buffer` and `*length` elements based on the buffer type specified by the application. Each numeric and temporal type has a fixed length, as listed in the following table. The length of the string types depends on the length of the actual data value, as indicated by `data_length`.

Type	Length
`MYSQL_TYPE_TINY`	1
`MYSQL_TYPE_SHORT`	2
`MYSQL_TYPE_LONG`	4
`MYSQL_TYPE_LONGLONG`	8
`MYSQL_TYPE_FLOAT`	4
`MYSQL_TYPE_DOUBLE`	8
`MYSQL_TYPE_TIME`	`sizeof(MYSQL_TIME)`
`MYSQL_TYPE_DATE`	`sizeof(MYSQL_TIME)`
`MYSQL_TYPE_DATETIME`	`sizeof(MYSQL_TIME)`
`MYSQL_TYPE_STRING`	`data length`
`MYSQL_TYPE_BLOB`	`data_length`

In some cases you might want to determine the length of a column value before fetching it with `mysql_stmt_fetch()`. For example, the value might be a long string or `BLOB` value for which you want to know how much space must be allocated. To accomplish this, you can use these strategies:

- Before invoking `mysql_stmt_fetch()` to retrieve individual rows, pass `STMT_ATTR_UPDATE_MAX_LENGTH` to `mysql_stmt_attr_set()`, then invoke `mysql_stmt_store_result()` to buffer the entire result on the client side. Setting the `STMT_ATTR_UPDATE_MAX_LENGTH` attribute causes the maximal length of column values to be indicated by the `max_length` member of the result set metadata returned by `mysql_stmt_result_metadata()`.

- Invoke `mysql_stmt_fetch()` with a zero-length buffer for the column in question and a pointer in which the real length can be stored. Then use the real length with `mysql_stmt_fetch_column()`.

```
real_length= 0;

bind[0].buffer= 0;
bind[0].buffer_length= 0;
bind[0].length= &real_length
mysql_stmt_bind_result(stmt, bind);

mysql_stmt_fetch(stmt);
if (real_length > 0)
{
  data= malloc(real_length);
  bind[0].buffer= data;
  bind[0].buffer_length= real_length;
  mysql_stmt_fetch_column(stmt, bind, 0, 0);
}
```

Return Values

Return Value	Description
0	Successful, the data has been fetched to application data buffers.
1	Error occurred. Error code and message can be obtained by calling `mysql_stmt_errno()` and `mysql_stmt_error()`.
MYSQL_NO_DATA	No more rows/data exists
MYSQL_DATA_TRUNCATED	Data truncation occurred

`MYSQL_DATA_TRUNCATED` is returned when truncation reporting is enabled. To determine which column values were truncated when this value is returned, check the `error` members of the `MYSQL_BIND` structures used for fetching values. Truncation reporting is enabled by default, but can be controlled by calling `mysql_options()` with the `MYSQL_REPORT_DATA_TRUNCATION` option.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

- `CR_UNSUPPORTED_PARAM_TYPE`

  The buffer type is `MYSQL_TYPE_DATE`, `MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATETIME`, or `MYSQL_TYPE_TIMESTAMP`, but the data type is not `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP`.

- All other unsupported conversion errors are returned from `mysql_stmt_bind_result()`.

Example

The following example demonstrates how to fetch data from a table using `mysql_stmt_result_metadata()`, `mysql_stmt_bind_result()`, and `mysql_stmt_fetch()`. (This example expects to retrieve the two rows inserted by the example shown in Section 21.8.11.10, "mysql_stmt_execute()".) The `mysql` variable is assumed to be a valid connection handle.

```
#define STRING_SIZE 50

#define SELECT_SAMPLE "SELECT col1, col2, col3, col4 \
                      FROM test_table"

MYSQL_STMT    *stmt;
MYSQL_BIND    bind[4];
MYSQL_RES     *prepare_meta_result;
```

```
MYSQL_TIME    ts;
unsigned long length[4];
int           param_count, column_count, row_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
my_bool       is_null[4];
my_bool       error[4];

/* Prepare a SELECT query to fetch data from test_table */
stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(stmt, SELECT_SAMPLE, strlen(SELECT_SAMPLE)))
{
  fprintf(stderr, " mysql_stmt_prepare(), SELECT failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
fprintf(stdout, " prepare, SELECT successful\n");

/* Get the parameter count from the statement */
param_count= mysql_stmt_param_count(stmt);
fprintf(stdout, " total parameters in SELECT: %d\n", param_count);

if (param_count != 0) /* validate parameter count */
{
  fprintf(stderr, " invalid parameter count returned by MySQL\n");
  exit(0);
}

/* Fetch result set meta information */
prepare_meta_result = mysql_stmt_result_metadata(stmt);
if (!prepare_meta_result)
{
  fprintf(stderr,
          " mysql_stmt_result_metadata(), \
            returned no meta information\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get total columns in the query */
column_count= mysql_num_fields(prepare_meta_result);
fprintf(stdout,
        " total columns in SELECT statement: %d\n",
        column_count);

if (column_count != 4) /* validate column count */
{
  fprintf(stderr, " invalid column count returned by MySQL\n");
  exit(0);
}

/* Execute the SELECT query */
if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, " mysql_stmt_execute(), failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Bind the result buffers for all 4 columns before fetching them */
```

```
memset(bind, 0, sizeof(bind));

/* INTEGER COLUMN */
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *)&int_data;
bind[0].is_null= &is_null[0];
bind[0].length= &length[0];
bind[0].error= &error[0];

/* STRING COLUMN */
bind[1].buffer_type= MYSQL_TYPE_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= &is_null[1];
bind[1].length= &length[1];
bind[1].error= &error[1];

/* SMALLINT COLUMN */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null[2];
bind[2].length= &length[2];
bind[2].error= &error[2];

/* TIMESTAMP COLUMN */
bind[3].buffer_type= MYSQL_TYPE_TIMESTAMP;
bind[3].buffer= (char *)&ts;
bind[3].is_null= &is_null[3];
bind[3].length= &length[3];
bind[3].error= &error[3];

/* Bind the result buffers */
if (mysql_stmt_bind_result(stmt, bind))
{
  fprintf(stderr, " mysql_stmt_bind_result() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Now buffer all results to client (optional step) */
if (mysql_stmt_store_result(stmt))
{
  fprintf(stderr, " mysql_stmt_store_result() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Fetch all rows */
row_count= 0;
fprintf(stdout, "Fetching results ...\n");
while (!mysql_stmt_fetch(stmt))
{
  row_count++;
  fprintf(stdout, "  row %d\n", row_count);

  /* column 1 */
  fprintf(stdout, "   column1 (integer)  : ");
  if (is_null[0])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %d(%ld)\n", int_data, length[0]);

  /* column 2 */
  fprintf(stdout, "   column2 (string)   : ");
  if (is_null[1])
    fprintf(stdout, " NULL\n");
  else
```

```
      fprintf(stdout, " %s(%ld)\n", str_data, length[1]);

  /* column 3 */
  fprintf(stdout, "   column3 (smallint) : ");
  if (is_null[2])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %d(%ld)\n", small_data, length[2]);

  /* column 4 */
  fprintf(stdout, "   column4 (timestamp): ");
  if (is_null[3])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %04d-%02d-%02d %02d:%02d:%02d (%ld)\n",
                    ts.year, ts.month, ts.day,
                    ts.hour, ts.minute, ts.second,
                    length[3]);
  fprintf(stdout, "\n");
}

/* Validate rows fetched */
fprintf(stdout, " total rows fetched: %d\n", row_count);
if (row_count != 2)
{
  fprintf(stderr, " MySQL failed to return all rows\n");
  exit(0);
}

/* Free the prepared result metadata */
mysql_free_result(prepare_meta_result);


/* Close the statement */
if (mysql_stmt_close(stmt))
{
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
```

21.8.11.12 mysql_stmt_fetch_column()

```
int mysql_stmt_fetch_column(MYSQL_STMT *stmt, MYSQL_BIND *bind, unsigned int
column, unsigned long offset)
```

Description

Fetch one column from the current result set row. `bind` provides the buffer where data should be placed.
It should be set up the same way as for `mysql_stmt_bind_result()`. `column` indicates which column
to fetch. The first column is numbered 0. `offset` is the offset within the data value at which to begin
retrieving data. This can be used for fetching the data value in pieces. The beginning of the value is offset
0.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_INVALID_PARAMETER_NO`

  Invalid column number.

- `CR_NO_DATA`

  The end of the result set has already been reached.

21.8.11.13 mysql_stmt_field_count()

```
unsigned int mysql_stmt_field_count(MYSQL_STMT *stmt)
```

Description

Returns the number of columns for the most recent statement for the statement handler. This value is zero for statements such as `INSERT` or `DELETE` that do not produce result sets.

`mysql_stmt_field_count()` can be called after you have prepared a statement by invoking `mysql_stmt_prepare()`.

Return Values

An unsigned integer representing the number of columns in a result set.

Errors

None.

21.8.11.14 mysql_stmt_free_result()

```
my_bool mysql_stmt_free_result(MYSQL_STMT *stmt)
```

Description

Releases memory associated with the result set produced by execution of the prepared statement. If there is a cursor open for the statement, `mysql_stmt_free_result()` closes it.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

21.8.11.15 mysql_stmt_init()

```
MYSQL_STMT *mysql_stmt_init(MYSQL *mysql)
```

Description

Create a `MYSQL_STMT` handle. The handle should be freed with `mysql_stmt_close(MYSQL_STMT *)`.

See also Section 21.8.9, "C API Prepared Statement Data Structures", for more information.

Return Values

A pointer to a `MYSQL_STMT` structure in case of success. `NULL` if out of memory.

Errors

- `CR_OUT_OF_MEMORY`

  Out of memory.

21.8.11.16 mysql_stmt_insert_id()

```
my_ulonglong mysql_stmt_insert_id(MYSQL_STMT *stmt)
```

Description

Returns the value generated for an `AUTO_INCREMENT` column by the prepared `INSERT` or `UPDATE` statement. Use this function after you have executed a prepared `INSERT` statement on a table which contains an `AUTO_INCREMENT` field.

See Section 21.8.7.37, "mysql_insert_id()", for more information.

Return Values

Value for `AUTO_INCREMENT` column which was automatically generated or explicitly set during execution of prepared statement, or value generated by `LAST_INSERT_ID(expr)` function. Return value is undefined if statement does not set `AUTO_INCREMENT` value.

Errors

None.

21.8.11.17 mysql_stmt_num_rows()

```
my_ulonglong mysql_stmt_num_rows(MYSQL_STMT *stmt)
```

Description

Returns the number of rows in the result set.

The use of `mysql_stmt_num_rows()` depends on whether you used `mysql_stmt_store_result()` to buffer the entire result set in the statement handle. If you use `mysql_stmt_store_result()`, `mysql_stmt_num_rows()` may be called immediately. Otherwise, the row count is unavailable unless you count the rows as you fetch them.

`mysql_stmt_num_rows()` is intended for use with statements that return a result set, such as `SELECT`. For statements such as `INSERT`, `UPDATE`, or `DELETE`, the number of affected rows can be obtained with `mysql_stmt_affected_rows()`.

Return Values

The number of rows in the result set.

Errors

None.

21.8.11.18 mysql_stmt_param_count()

```
unsigned long mysql_stmt_param_count(MYSQL_STMT *stmt)
```

Description

Returns the number of parameter markers present in the prepared statement.

Return Values

An unsigned long integer representing the number of parameters in a statement.

Errors

None.

Example

See the Example in Section 21.8.11.10, "mysql_stmt_execute()".

21.8.11.19 mysql_stmt_param_metadata()

```
MYSQL_RES *mysql_stmt_param_metadata(MYSQL_STMT *stmt)
```

This function currently does nothing.

Description

Return Values

Errors

21.8.11.20 mysql_stmt_prepare()

```
int mysql_stmt_prepare(MYSQL_STMT *stmt, const char *stmt_str, unsigned long
length)
```

Description

Given the statement handle returned by `mysql_stmt_init()`, prepares the SQL statement pointed to by the string `stmt_str` and returns a status value. The string length should be given by the `length` argument. The string must consist of a single SQL statement. You should not add a terminating semicolon (";") or `\g` to the statement.

The application can include one or more parameter markers in the SQL statement by embedding question mark (`?`) characters into the SQL string at the appropriate positions.

The markers are legal only in certain places in SQL statements. For example, they are permitted in the `VALUES()` list of an `INSERT` statement (to specify column values for a row), or in a comparison with a column in a `WHERE` clause to specify a comparison value. However, they are not permitted for identifiers (such as table or column names), or to specify both operands of a binary operator such as the `=` equal sign. The latter restriction is necessary because it would be impossible to determine the parameter type. In general, parameters are legal only in Data Manipulation Language (DML) statements, and not in Data Definition Language (DDL) statements.

The parameter markers must be bound to application variables using `mysql_stmt_bind_param()` before executing the statement.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

If the prepare operation was unsuccessful (that is, `mysql_stmt_prepare()` returns nonzero), the error message can be obtained by calling `mysql_stmt_error()`.

Example

See the Example in Section 21.8.11.10, "mysql_stmt_execute()".

21.8.11.21 mysql_stmt_reset()

```
my_bool mysql_stmt_reset(MYSQL_STMT *stmt)
```

Description

Resets a prepared statement on client and server to state after prepare. It resets the statement on the server, data sent using `mysql_stmt_send_long_data()`, unbuffered result sets and current errors. It does not clear bindings or stored result sets. Stored result sets will be cleared when executing the prepared statement (or closing it).

To re-prepare the statement with another query, use `mysql_stmt_prepare()`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

21.8.11.22 mysql_stmt_result_metadata()

```
MYSQL_RES *mysql_stmt_result_metadata(MYSQL_STMT *stmt)
```

Description

If a statement passed to `mysql_stmt_prepare()` is one that produces a result set, `mysql_stmt_result_metadata()` returns the result set metadata in the form of a pointer to a `MYSQL_RES` structure that can be used to process the meta information such as number of fields and individual field information. This result set pointer can be passed as an argument to any of the field-based API functions that process result set metadata, such as:

- `mysql_num_fields()`

- `mysql_fetch_field()`

- `mysql_fetch_field_direct()`

- `mysql_fetch_fields()`

- `mysql_field_count()`

- `mysql_field_seek()`

- `mysql_field_tell()`

- `mysql_free_result()`

The result set structure should be freed when you are done with it, which you can do by passing it to `mysql_free_result()`. This is similar to the way you free a result set obtained from a call to `mysql_store_result()`.

The result set returned by `mysql_stmt_result_metadata()` contains only metadata. It does not contain any row results. The rows are obtained by using the statement handle with `mysql_stmt_fetch()`.

Return Values

A `MYSQL_RES` result structure. `NULL` if no meta information exists for the prepared query.

Errors

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in .

21.8.11.23 mysql_stmt_row_seek()

```
MYSQL_ROW_OFFSET mysql_stmt_row_seek(MYSQL_STMT *stmt, MYSQL_ROW_OFFSET offset)
```

Description

Sets the row cursor to an arbitrary row in a statement result set. The `offset` value is a row offset that should be a value returned from `mysql_stmt_row_tell()` or from `mysql_stmt_row_seek()`.

This value is not a row number; if you want to seek to a row within a result set by number, use `mysql_stmt_data_seek()` instead.

This function requires that the result set structure contains the entire result of the query, so `mysql_stmt_row_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_stmt_row_seek()`.

Errors

None.

21.8.11.24 mysql_stmt_row_tell()

```
MYSQL_ROW_OFFSET mysql_stmt_row_tell(MYSQL_STMT *stmt)
```

Description

Returns the current position of the row cursor for the last `mysql_stmt_fetch()`. This value can be used as an argument to `mysql_stmt_row_seek()`.

You should use `mysql_stmt_row_tell()` only after `mysql_stmt_store_result()`.

Return Values

The current offset of the row cursor.

Errors

None.

21.8.11.25 mysql_stmt_send_long_data()

```
my_bool mysql_stmt_send_long_data(MYSQL_STMT *stmt, unsigned int
parameter_number, const char *data, unsigned long length)
```

Description

Enables an application to send parameter data to the server in pieces (or "chunks"). Call this function after `mysql_stmt_bind_param()` and before `mysql_stmt_execute()`. It can be called multiple times to send the parts of a character or binary data value for a column, which must be one of the `TEXT` or `BLOB` data types.

`parameter_number` indicates which parameter to associate the data with. Parameters are numbered beginning with 0. `data` is a pointer to a buffer containing data to be sent, and `length` indicates the number of bytes in the buffer.

> **Note**
>
> The next `mysql_stmt_execute()` call ignores the bind buffer for all parameters that have been used with `mysql_stmt_send_long_data()` since last `mysql_stmt_execute()` or `mysql_stmt_reset()`.

If you want to reset/forget the sent data, you can do it with `mysql_stmt_reset()`. See Section 21.8.11.21, "mysql_stmt_reset()".

As of MySQL 5.1.57, the `max_long_data_size` system variable controls the maximum size of parameter values that can be sent with `mysql_stmt_send_long_data()`. If this variable not set at server startup, the default is the value of the `max_allowed_packet` system variable. `max_long_data_size` is deprecated. In MySQL 5.6, it is removed and the maximum parameter size is controlled by `max_allowed_packet`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_INVALID_BUFFER_USE`

  The parameter does not have a string or binary type.

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

The following example demonstrates how to send the data for a `TEXT` column in chunks. It inserts the data value `'MySQL - The most popular Open Source database'` into the `text_column` column. The `mysql` variable is assumed to be a valid connection handle.

```
#define INSERT_QUERY "INSERT INTO \
                      test_long_data(text_column) VALUES(?)"

MYSQL_BIND bind[1];
long       length;

stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(stmt, INSERT_QUERY, strlen(INSERT_QUERY)))
{
  fprintf(stderr, "\n mysql_stmt_prepare(), INSERT failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}
 memset(bind, 0, sizeof(bind));
 bind[0].buffer_type= MYSQL_TYPE_STRING;
 bind[0].length= &length;
 bind[0].is_null= 0;
```

```
/* Bind the buffers */
if (mysql_stmt_bind_param(stmt, bind))
{
  fprintf(stderr, "\n param bind failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Supply data in chunks to server */
 if (mysql_stmt_send_long_data(stmt,0,"MySQL",5))
{
  fprintf(stderr, "\n send_long_data failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Supply the next piece of data */
 if (mysql_stmt_send_long_data(stmt,0,
          " - The most popular Open Source database",40))
{
  fprintf(stderr, "\n send_long_data failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Now, execute the query */
 if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, "\n mysql_stmt_execute failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}
```

21.8.11.26 mysql_stmt_sqlstate()

```
const char *mysql_stmt_sqlstate(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_sqlstate()` returns a null-terminated string containing the SQLSTATE error code for the most recently invoked prepared statement API function that can succeed or fail. The error code consists of five characters. `"00000"` means "no error." The values are specified by ANSI SQL and ODBC. For a list of possible values, see Appendix B, *Errors, Error Codes, and Common Problems*.

Not all MySQL errors are mapped to SQLSTATE codes. The value `"HY000"` (general error) is used for unmapped errors.

Return Values

A null-terminated character string containing the SQLSTATE error code.

21.8.11.27 mysql_stmt_store_result()

```
int mysql_stmt_store_result(MYSQL_STMT *stmt)
```

Description

Result sets are produced by calling `mysql_stmt_execute()` to executed prepared statements for SQL statements such as `SELECT`, `SHOW`, `DESCRIBE`, and `EXPLAIN`. By default, result sets for successfully executed prepared statements are not buffered on the client and `mysql_stmt_fetch()` fetches

them one at a time from the server. To cause the complete result set to be buffered on the client, call `mysql_stmt_store_result()` after binding data buffers with `mysql_stmt_bind_result()` and before calling `mysql_stmt_fetch()` to fetch rows. (For an example, see Section 21.8.11.11, "mysql_stmt_fetch()".)

`mysql_stmt_store_result()` is optional for result set processing, unless you will call `mysql_stmt_data_seek()`, `mysql_stmt_row_seek()`, or `mysql_stmt_row_tell()`. Those functions require a seekable result set.

It is unnecessary to call `mysql_stmt_store_result()` after executing an SQL statement that does not produce a result set, but if you do, it does not harm or cause any notable performance problem. You can detect whether the statement produced a result set by checking if `mysql_stmt_result_metadata()` returns `NULL`. For more information, refer to Section 21.8.11.22, "mysql_stmt_result_metadata()".

> **Note**
>
> MySQL does not by default calculate `MYSQL_FIELD->max_length` for all columns in `mysql_stmt_store_result()` because calculating this would slow down `mysql_stmt_store_result()` considerably and most applications do not need `max_length`. If you want `max_length` to be updated, you can call `mysql_stmt_attr_set(MYSQL_STMT, STMT_ATTR_UPDATE_MAX_LENGTH, &flag)` to enable this. See Section 21.8.11.3, "mysql_stmt_attr_set()".

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

If the application is linked to the embedded server library, runtime error messages will indicate the `libmysqld` rather than `libmysqlclient` library, but the solution to the problem is the same as just described.

21.8.12 C API Threaded Function Descriptions

To create a threaded client, use the functions described in the following sections. See also Section 21.8.4.2, "Writing C API Threaded Client Programs".

21.8.12.1 my_init()

```
void my_init(void)
```

Description

`my_init()` initializes some global variables that MySQL needs. If you are using a thread-safe client library, it also calls `mysql_thread_init()` for this thread.

It is necessary for `my_init()` to be called early in the initialization phase of a program's use of the MySQL library. However, `my_init()` is automatically called by `mysql_init()`, `mysql_library_init()`, `mysql_server_init()`, and `mysql_connect()`. If you ensure that your program invokes one of those functions before any other MySQL calls, there is no need to invoke `my_init()` explicitly.

To access the prototype for `my_init()`, your program should include these header files:

```
#include <my_global.h>
#include <my_sys.h>
```

Return Values

None.

21.8.12.2 mysql_thread_end()

```
void mysql_thread_end(void)
```

Description

This function needs to be called before calling `pthread_exit()` to free memory allocated by `mysql_thread_init()`.

`mysql_thread_end()` *is not invoked automatically by the client library*. It must be called explicitly to avoid a memory leak.

Return Values

None.

21.8.12.3 mysql_thread_init()

```
my_bool mysql_thread_init(void)
```

Description

This function must be called early within each created thread to initialize thread-specific variables. However, you may not necessarily need to invoke it explicitly: `mysql_thread_init()` is automatically called by `my_init()`, which itself is automatically called by `mysql_init()`, `mysql_library_init()`, `mysql_server_init()`, and `mysql_connect()`. If you invoke any of those functions, `mysql_thread_init()` will be called for you.

Return Values

Zero for success. Nonzero if an error occurred.

21.8.12.4 mysql_thread_safe()

```
unsigned int mysql_thread_safe(void)
```

Description

This function indicates whether the client library is compiled as thread-safe.

Return Values

1 if the client library is thread-safe, 0 otherwise.

21.8.13 C API Embedded Server Function Descriptions

MySQL applications can be written to use an embedded server. See Section 21.7, "libmysqld, the Embedded MySQL Server Library". To write such an application, you must link it against the `libmysqld` library by using the `-lmysqld` flag rather than linking it against the `libmysqlclient` client library by using the `-lmysqlclient` flag. However, the calls to initialize and finalize the library are the same whether you write a client application or one that uses the embedded server: Call `mysql_library_init()` to initialize the library and `mysql_library_end()` when you are done with it. See Section 21.8.6, "C API Function Overview".

21.8.13.1 mysql_server_init()

```
int mysql_server_init(int argc, char **argv, char **groups)
```

Description

This function initializes the MySQL library, which must be done before you call any other MySQL function. However, `mysql_server_init()` is deprecated and you should call `mysql_library_init()` instead. See Section 21.8.7.40, "mysql_library_init()".

Return Values

Zero for success. Nonzero if an error occurred.

21.8.13.2 mysql_server_end()

```
void mysql_server_end(void)
```

Description

This function finalizes the MySQL library, which should be done when you are done using the library. However, `mysql_server_end()` is deprecated and `mysql_library_end()` should be used instead. See Section 21.8.7.39, "mysql_library_end()".

Return Values

None.

21.8.14 Common Questions and Problems When Using the C API

21.8.14.1 Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success

It is possible for `mysql_store_result()` to return `NULL` following a successful call to `mysql_query()`. When this happens, it means one of the following conditions occurred:

- There was a `malloc()` failure (for example, if the result set was too large).

- The data could not be read (an error occurred on the connection).

- The query returned no data (for example, it was an `INSERT`, `UPDATE`, or `DELETE`).

You can always check whether the statement should have produced a nonempty result by calling `mysql_field_count()`. If `mysql_field_count()` returns zero, the result is empty and the last query was a statement that does not return values (for example, an `INSERT` or a `DELETE`). If `mysql_field_count()` returns a nonzero value, the statement should have produced a nonempty result. See the description of the `mysql_field_count()` function for an example.

You can test for an error by calling `mysql_error()` or `mysql_errno()`.

21.8.14.2 What Results You Can Get from a Query

In addition to the result set returned by a query, you can also get the following information:

- `mysql_affected_rows()` returns the number of rows affected by the last query when doing an `INSERT`, `UPDATE`, or `DELETE`.

  For a fast re-create, use `TRUNCATE TABLE`.

- `mysql_num_rows()` returns the number of rows in a result set. With `mysql_store_result()`, `mysql_num_rows()` may be called as soon as `mysql_store_result()` returns. With `mysql_use_result()`, `mysql_num_rows()` may be called only after you have fetched all the rows with `mysql_fetch_row()`.

- `mysql_insert_id()` returns the ID generated by the last query that inserted a row into a table with an `AUTO_INCREMENT` index. See Section 21.8.7.37, "mysql_insert_id()".

- Some queries (`LOAD DATA INFILE ...`, `INSERT INTO ... SELECT ...`, `UPDATE`) return additional information. The result is returned by `mysql_info()`. See the description for `mysql_info()` for the format of the string that it returns. `mysql_info()` returns a `NULL` pointer if there is no additional information.

21.8.14.3 How to Get the Unique ID for the Last Inserted Row

If you insert a record into a table that contains an `AUTO_INCREMENT` column, you can obtain the value stored into that column by calling the `mysql_insert_id()` function.

You can check from your C applications whether a value was stored in an `AUTO_INCREMENT` column by executing the following code (which assumes that you've checked that the statement succeeded). It determines whether the query was an `INSERT` with an `AUTO_INCREMENT` index:

```
if ((result = mysql_store_result(&mysql)) == 0 &&
    mysql_field_count(&mysql) == 0 &&
    mysql_insert_id(&mysql) != 0)
{
    used_id = mysql_insert_id(&mysql);
}
```

When a new `AUTO_INCREMENT` value has been generated, you can also obtain it by executing a `SELECT LAST_INSERT_ID()` statement with `mysql_query()` and retrieving the value from the result set returned by the statement.

When inserting multiple values, the last automatically incremented value is returned.

For `LAST_INSERT_ID()`, the most recently generated ID is maintained in the server on a per-connection basis. It is not changed by another client. It is not even changed if you update another `AUTO_INCREMENT` column with a nonmagic value (that is, a value that is not `NULL` and not `0`). Using `LAST_INSERT_ID()` and `AUTO_INCREMENT` columns simultaneously from multiple clients is perfectly valid. Each client will receive the last inserted ID for the last statement *that* client executed.

If you want to use the ID that was generated for one table and insert it into a second table, you can use SQL statements like this:

```
INSERT INTO foo (auto,text)
    VALUES(NULL,'text');          # generate ID by inserting NULL
INSERT INTO foo2 (id,text)
    VALUES(LAST_INSERT_ID(),'text');  # use ID in second table
```

`mysql_insert_id()` returns the value stored into an `AUTO_INCREMENT` column, whether that value is automatically generated by storing `NULL` or `0` or was specified as an explicit value. `LAST_INSERT_ID()` returns only automatically generated `AUTO_INCREMENT` values. If you store an explicit value other than `NULL` or `0`, it does not affect the value returned by `LAST_INSERT_ID()`.

For more information on obtaining the last ID in an `AUTO_INCREMENT` column:

- For information on `LAST_INSERT_ID()`, which can be used within an SQL statement, see Section 12.14, "Information Functions".

- For information on `mysql_insert_id()`, the function you use from within the C API, see Section 21.8.7.37, "mysql_insert_id()".

- For information on obtaining the auto-incremented value when using Connector/J, see Retrieving `AUTO_INCREMENT` Column Values through JDBC.

- For information on obtaining the auto-incremented value when using Connector/ODBC, see Obtaining Auto-Increment Values.

21.8.15 Controlling Automatic Reconnection Behavior

The MySQL client library can perform an automatic reconnection to the server if it finds that the connection is down when you attempt to send a statement to the server to be executed. If auto-reconnect is enabled, the library tries once to reconnect to the server and send the statement again.

Auto-reconnect is disabled by default.

If it is important for your application to know that the connection has been dropped (so that it can exit or take action to adjust for the loss of state information), be sure that auto-reconnect is disabled. To ensure this, call `mysql_options()` with the `MYSQL_OPT_RECONNECT` option:

```
my_bool reconnect = 0;
mysql_options(&mysql, MYSQL_OPT_RECONNECT, &reconnect);
```

If the connection has gone down, the effect of `mysql_ping()` depends on the auto-reconnect state. If auto-reconnect is enabled, `mysql_ping()` performs a reconnect. Otherwise, it returns an error.

Some client programs might provide the capability of controlling automatic reconnection. For example, `mysql` reconnects by default, but the `--skip-reconnect` option can be used to suppress this behavior.

If an automatic reconnection does occur (for example, as a result of calling `mysql_ping()`), there is no explicit indication of it. To check for reconnection, call `mysql_thread_id()` to get the original connection

identifier before calling `mysql_ping()`, then call `mysql_thread_id()` again to see whether the identifier changed.

Automatic reconnection can be convenient because you need not implement your own reconnect code, but if a reconnection does occur, several aspects of the connection state are reset on the server side and your application will not be notified.

The connection-related state is affected as follows:

* Any active transactions are rolled back and autocommit mode is reset.

* All table locks are released.

* All `TEMPORARY` tables are closed (and dropped).

* Session system variables are reinitialized to the values of the corresponding global system variables, including system variables that are set implicitly by statements such as `SET NAMES`.

* User variable settings are lost.

* Prepared statements are released.

* `HANDLER` variables are closed.

* The value of `LAST_INSERT_ID()` is reset to 0.

* Locks acquired with `GET_LOCK()` are released.

If the connection drops, it is possible that the session associated with the connection on the server side will still be running if the server has not yet detected that the client is no longer connected. In this case, any locks held by the original connection still belong to that session, so you may want to kill it by calling `mysql_kill()`.

21.8.16 C API Support for Multiple Statement Execution

By default, `mysql_query()` and `mysql_real_query()` interpret their statement string argument as a single statement to be executed, and you process the result according to whether the statement produces a result set (a set of rows, as for `SELECT`) or an affected-rows count (as for `INSERT`, `UPDATE`, and so forth).

MySQL also supports the execution of a string containing multiple statements separated by semicolon (`;`) characters. This capability is enabled by special options that are specified either when you connect to the server with `mysql_real_connect()` or after connecting by calling` `mysql_set_server_option()`.

Executing a multiple-statement string can produce multiple result sets or row-count indicators. Processing these results involves a different approach than for the single-statement case: After handling the result from the first statement, it is necessary to check whether more results exist and process them in turn if so. To support multiple-result processing, the C API includes the `mysql_more_results()` and `mysql_next_result()` functions. These functions are used at the end of a loop that iterates as long as more results are available. *Failure to process the result this way may result in a dropped connection to the server.*

Multiple-result processing also is required if you execute `CALL` statements for stored procedures. Results from a stored procedure have these characteristics:

* Statements within the procedure may produce result sets (for example, if it executes `SELECT` statements). These result sets are returned in the order that they are produced as the procedure executes.

In general, the caller cannot know how many result sets a procedure will return. Procedure execution may depend on loops or conditional statements that cause the execution path to differ from one call to the next. Therefore, you must be prepared to retrieve multiple results.

- The final result from the procedure is a status result that includes no result set. The status indicates whether the procedure succeeded or an error occurred.

The multiple statement and result capabilities can be used only with `mysql_query()` or `mysql_real_query()`. They cannot be used with the prepared statement interface. Prepared statement handles are defined to work only with strings that contain a single statement. See Section 21.8.8, "C API Prepared Statements".

To enable multiple-statement execution and result processing, the following options may be used:

- The `mysql_real_connect()` function has a `flags` argument for which two option values are relevant:

  - `CLIENT_MULTI_RESULTS` enables the client program to process multiple results. This option *must* be enabled if you execute `CALL` statements for stored procedures that produce result sets. Otherwise, such procedures result in an error `Error 1312 (0A000): PROCEDURE proc_name can't return a result set in the given context`.

  - `CLIENT_MULTI_STATEMENTS` enables `mysql_query()` and `mysql_real_query()` to execute statement strings containing multiple statements separated by semicolons. This option also enables `CLIENT_MULTI_RESULTS` implicitly, so a `flags` argument of `CLIENT_MULTI_STATEMENTS` to `mysql_real_connect()` is equivalent to an argument of `CLIENT_MULTI_STATEMENTS | CLIENT_MULTI_RESULTS`. That is, `CLIENT_MULTI_STATEMENTS` is sufficient to enable multiple-statement execution and all multiple-result processing.

- After the connection to the server has been established, you can use the `mysql_set_server_option()` function to enable or disable multiple-statement execution by passing it an argument of `MYSQL_OPTION_MULTI_STATEMENTS_ON` or `MYSQL_OPTION_MULTI_STATEMENTS_OFF`. Enabling multiple-statement execution with this function also enables processing of "simple" results for a multiple-statement string where each statement produces a single result, but is *not* sufficient to permit processing of stored procedures that produce result sets.

The following procedure outlines a suggested strategy for handling multiple statements:

1. Pass `CLIENT_MULTI_STATEMENTS` to `mysql_real_connect()`, to fully enable multiple-statement execution and multiple-result processing.

2. After calling `mysql_query()` or `mysql_real_query()` and verifying that it succeeds, enter a loop within which you process statement results.

3. For each iteration of the loop, handle the current statement result, retrieving either a result set or an affected-rows count. If an error occurs, exit the loop.

4. At the end of the loop, call `mysql_next_result()` to check whether another result exists and initiate retrieval for it if so. If no more results are available, exit the loop.

One possible implementation of the preceding strategy is shown following. The final part of the loop can be reduced to a simple test of whether `mysql_next_result()` returns nonzero. The code as written distinguishes between no more results and an error, which enables a message to be printed for the latter occurrence.

```
/* connect to server with the CLIENT_MULTI_STATEMENTS option */
if (mysql_real_connect (mysql, host_name, user_name, password,
    db_name, port_num, socket_name, CLIENT_MULTI_STATEMENTS) == NULL)
{
  printf("mysql_real_connect() failed\n");
  mysql_close(mysql);
  exit(1);
}

/* execute multiple statements */
status = mysql_query(mysql,
                     "DROP TABLE IF EXISTS test_table;\
                      CREATE TABLE test_table(id INT);\
                      INSERT INTO test_table VALUES(10);\
                      UPDATE test_table SET id=20 WHERE id=10;\
                      SELECT * FROM test_table;\
                      DROP TABLE test_table");
if (status)
{
  printf("Could not execute statement(s)");
  mysql_close(mysql);
  exit(0);
}

/* process each statement result */
do {
  /* did current statement return data? */
  result = mysql_store_result(mysql);
  if (result)
  {
    /* yes; process rows and free the result set */
    process_result_set(mysql, result);
    mysql_free_result(result);
  }
  else         /* no result set or error */
  {
    if (mysql_field_count(mysql) == 0)
    {
      printf("%lld rows affected\n",
            mysql_affected_rows(mysql));
    }
    else  /* some error occurred */
    {
      printf("Could not retrieve result set\n");
      break;
    }
  }
  /* more results? -1 = no, >0 = error, 0 = yes (keep looping) */
  if ((status = mysql_next_result(mysql)) > 0)
    printf("Could not execute statement\n");
} while (status == 0);

mysql_close(mysql);
```

21.8.17 C API Prepared Statement Problems

Here follows a list of the currently known problems with prepared statements:

- `TIME`, `TIMESTAMP`, and `DATETIME` do not support parts of seconds (for example, from `DATE_FORMAT()`).

- When converting an integer to string, `ZEROFILL` is honored with prepared statements in some cases where the MySQL server does not print the leading zeros. (For example, with `MIN(`*number-with-zerofill*`)`).

- When converting a floating-point number to a string in the client, the rightmost digits of the converted value may differ slightly from those of the original value.

- Before MySQL 5.1.17, prepared statements do not use the query cache. As of 5.1.17, prepared statements use the query cache under the conditions described in Section 8.10.3.1, "How the Query Cache Operates".

- Prepared statements do not support multi-statements (that is, multiple statements within a single string separated by `;` characters).

- In MySQL 5.1, prepared `CALL` statements cannot invoke stored procedures that return result sets because prepared statements do not support multiple result sets. Nor can the calling application access a stored procedure's `OUT` or `INOUT` parameters when the procedure returns. These capabilities are supported beginning with MySQL 5.5.

21.8.18 C API Prepared Statement Handling of Date and Time Values

The binary (prepared statement) protocol enables you to send and receive date and time values (`DATE`, `TIME`, `DATETIME`, and `TIMESTAMP`), using the `MYSQL_TIME` structure. The members of this structure are described in Section 21.8.9, "C API Prepared Statement Data Structures".

To send temporal data values, create a prepared statement using `mysql_stmt_prepare()`. Then, before calling `mysql_stmt_execute()` to execute the statement, use the following procedure to set up each temporal parameter:

1. In the `MYSQL_BIND` structure associated with the data value, set the `buffer_type` member to the type that indicates what kind of temporal value you're sending. For `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` values, set `buffer_type` to `MYSQL_TYPE_DATE`, `MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATETIME`, or `MYSQL_TYPE_TIMESTAMP`, respectively.

2. Set the `buffer` member of the `MYSQL_BIND` structure to the address of the `MYSQL_TIME` structure in which you pass the temporal value.

3. Fill in the members of the `MYSQL_TIME` structure that are appropriate for the type of temporal value to pass.

Use `mysql_stmt_bind_param()` to bind the parameter data to the statement. Then you can call `mysql_stmt_execute()`.

To retrieve temporal values, the procedure is similar, except that you set the `buffer_type` member to the type of value you expect to receive, and the `buffer` member to the address of a `MYSQL_TIME` structure into which the returned value should be placed. Use `mysql_stmt_bind_result()` to bind the buffers to the statement after calling `mysql_stmt_execute()` and before fetching the results.

Here is a simple example that inserts `DATE`, `TIME`, and `TIMESTAMP` data. The `mysql` variable is assumed to be a valid connection handle.

```
MYSQL_TIME  ts;
MYSQL_BIND  bind[3];
MYSQL_STMT  *stmt;

strmov(query, "INSERT INTO test_table(date_field, time_field, \
                          timestamp_field) VALUES(?,?,?)");

stmt = mysql_stmt_init(mysql);
if (!stmt)
```

```
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(mysql, query, strlen(query)))
{
  fprintf(stderr, "\n mysql_stmt_prepare(), INSERT failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

/* set up input buffers for all 3 parameters */
bind[0].buffer_type= MYSQL_TYPE_DATE;
bind[0].buffer= (char *)&ts;
bind[0].is_null= 0;
bind[0].length= 0;
...
bind[1]= bind[2]= bind[0];
...

mysql_stmt_bind_param(stmt, bind);

/* supply the data to be sent in the ts structure */
ts.year= 2002;
ts.month= 02;
ts.day= 03;

ts.hour= 10;
ts.minute= 45;
ts.second= 20;

mysql_stmt_execute(stmt);
..
```

21.8.19 C API Support for Prepared CALL Statements

In MySQL 5.1, prepared CALL statements can be used only for stored procedures that produce at most one result set. Nor can the calling application use placeholders for OUT or INOUT parameters.

MySQL 5.5 expands prepared CALL statement support for stored procedures that produce multiple result sets and to provide placeholder access to OUT and INOUT parameters.

21.9 MySQL PHP API

The MySQL PHP API manual is now published in standalone form, not as part of the MySQL Reference Manual. See MySQL and PHP.

21.10 MySQL Perl API

The Perl DBI module provides a generic interface for database access. You can write a DBI script that works with many different database engines without change. To use DBI with MySQL, install the following:

1. The DBI module.

2. The DBD::mysql module. This is the DataBase Driver (DBD) module for Perl.

3. Optionally, the DBD module for any other type of database server you want to access.

Perl DBI is the recommended Perl interface. It replaces an older interface called mysqlperl, which should be considered obsolete.

These sections contain information about using Perl with MySQL and writing MySQL applications in Perl:

- For installation instructions for Perl DBI support, see Section 2.15, "Perl Installation Notes".

- For an example of reading options from option files, see Section 5.5.4, "Using Client Programs in a Multiple-Server Environment".

- For secure coding tips, see Section 6.1.1, "Security Guidelines".

- For debugging tips, see Section 22.4.1.4, "Debugging mysqld under gdb".

- For some Perl-specific environment variables, see Section 2.14, "Environment Variables".

- For considerations for running on OS X, see Section 2.4, "Installing MySQL on OS X".

- For ways to quote string literals, see Section 9.1.1, "String Literals".

DBI information is available at the command line, online, or in printed form:

- Once you have the `DBI` and `DBD::mysql` modules installed, you can get information about them at the command line with the `perldoc` command:

```
shell> perldoc DBI
shell> perldoc DBI::FAQ
shell> perldoc DBD::mysql
```

  You can also use `pod2man`, `pod2html`, and so on to translate this information into other formats.

- For online information about Perl DBI, visit the DBI Web site, http://dbi.perl.org/. That site hosts a general DBI mailing list. Oracle Corporation hosts a list specifically about `DBD::mysql`; see Section 1.6.1, "MySQL Mailing Lists".

- For printed information, the official DBI book is *Programming the Perl DBI* (Alligator Descartes and Tim Bunce, O'Reilly & Associates, 2000). Information about the book is available at the DBI Web site, http://dbi.perl.org/.

  For information that focuses specifically on using DBI with MySQL, see *MySQL and Perl for the Web* (Paul DuBois, New Riders, 2001). This book's Web site is http://www.kitebird.com/mysql-perl/.

21.11 MySQL Python API

`MySQLdb` is a third-party driver that provides MySQL support for Python, compliant with the Python DB API version 2.0. It can be found at http://sourceforge.net/projects/mysql-python/.

The new MySQL Connector/Python component provides an interface to the same Python API, and is built into the MySQL Server and supported by Oracle. See MySQL Connector/Python Developer Guide for details on the Connector, as well as coding guidelines for Python applications and sample Python code.

21.12 MySQL Ruby APIs

Two APIs are available for Ruby programmers developing MySQL applications:

- The MySQL/Ruby API is based on the `libmysqlclient` API library. For information on installing and using the MySQL/Ruby API, see Section 21.12.1, "The MySQL/Ruby API".

- The Ruby/MySQL API is written to use the native MySQL network protocol (a native driver). For information on installing and using the Ruby/MySQL API, see Section 21.12.2, "The Ruby/MySQL API".

For background and syntax information about the Ruby language, see Ruby Programming Language.

21.12.1 The MySQL/Ruby API

The MySQL/Ruby module provides access to MySQL databases using Ruby through `libmysqlclient`.

For information on installing the module, and the functions exposed, see MySQL/Ruby.

21.12.2 The Ruby/MySQL API

The Ruby/MySQL module provides access to MySQL databases using Ruby through a native driver interface using the MySQL network protocol.

For information on installing the module, and the functions exposed, see Ruby/MySQL.

21.13 MySQL Tcl API

`MySQLtcl` is a simple API for accessing a MySQL database server from the Tcl programming language. It can be found at http://www.xdobry.de/mysqltcl/.

21.14 MySQL Eiffel Wrapper

Eiffel MySQL is an interface to the MySQL database server using the Eiffel programming language, written by Michael Ravits. It can be found at http://efsa.sourceforge.net/archive/ravits/mysql.htm.

Chapter 22 Extending MySQL

Table of Contents

22.1 MySQL Internals

This chapter describes a lot of things that you need to know when working on the MySQL code. To track or contribute to MySQL development, follow the instructions in Section 2.11.3, "Installing MySQL Using a Development Source Tree". If you are interested in MySQL internals, you should also subscribe to our `internals` mailing list. This list has relatively low traffic. For details on how to subscribe, please see Section 1.6.1, "MySQL Mailing Lists". Many MySQL developers at Oracle Corporation are on the `internals` list and we help other people who are working on the MySQL code. Feel free to use this list both to ask questions about the code and to send patches that you would like to contribute to the MySQL project!

22.1.1 MySQL Threads

The MySQL server creates the following threads:

- Connection manager threads handle client connection requests on the network interfaces that the server listens to. On all platforms, one manager thread handles TCP/IP connection requests. On Unix, this manager thread also handles Unix socket file connection requests. On Windows, a manager thread handles shared-memory connection requests, and another handles named-pipe connection requests. The server does not create threads to handle interfaces that it does not listen to. For example, a Windows server that does not have support for named-pipe connections enabled does not create a thread to handle them.

- Connection manager threads associate each client connection with a thread dedicated to it that handles authentication and request processing for that connection. Manager threads create a new thread when necessary but try to avoid doing so by consulting the thread cache first to see whether it contains a thread that can be used for the connection. When a connection ends, its thread is returned to the thread cache if the cache is not full.

  For information about tuning the parameters that control thread resources, see Section 8.12.6.1, "How MySQL Uses Threads for Client Connections".

- On a master replication server, connections from slave servers are handled like client connections: There is one thread per connected slave.

- On a slave replication server, an I/O thread is started to connect to the master server and read updates from it. An SQL thread is started to apply updates read from the master. These two threads run independently and can be started and stopped independently.

- A signal thread handles all signals. This thread also normally handles alarms and calls `process_alarm()` to force timeouts on connections that have been idle too long.

- If `InnoDB` is used, there will be 4 additional threads by default. Those are file I/O threads, controlled by the `innodb_file_io_threads` parameter. See Section 14.6.8, "InnoDB Startup Options and System Variables".

- If `mysqld` is compiled with `-DUSE_ALARM_THREAD`, a dedicated thread that handles alarms is created. This is only used on some systems where there are problems with `sigwait()` or if you want to use the `thr_alarm()` code in your application without a dedicated signal handling thread.

- If the server is started with the `--flush_time=val` option, a dedicated thread is created to flush all tables every `val` seconds.

- Each table for which `INSERT DELAYED` statements are issued gets its own thread. See Section 13.2.5.2, "INSERT DELAYED Syntax".

- If the event scheduler is active, there is one thread for the scheduler, and a thread for each event currently running. See Section 19.4.1, "Event Scheduler Overview".

`mysqladmin processlist` only shows the connection, `INSERT DELAYED`, replication, and event threads.

22.1.2 The MySQL Test Suite

The test system that is included in Unix source and binary distributions makes it possible for users and developers to perform regression tests on the MySQL code. These tests can be run on Unix.

You can also write your own test cases. For information about the MySQL Test Framework, including system requirements, see the manual available at http://dev.mysql.com/doc/mysqltest/2.0/en/.

The current set of test cases doesn't test everything in MySQL, but it should catch most obvious bugs in the SQL processing code, operating system or library issues, and is quite thorough in testing replication. Our goal is to have the tests cover 100% of the code. We welcome contributions to our test suite. You may especially want to contribute tests that examine the functionality critical to your system because this ensures that all future MySQL releases work well with your applications.

The test system consists of a test language interpreter (`mysqltest`), a Perl script to run all tests (`mysql-test-run.pl`), the actual test cases written in a special test language, and their expected results. To run the test suite on your system after a build, type `make test` from the source root directory, or change location to the `mysql-test` directory and type `./mysql-test-run.pl`. If you have installed a binary distribution, change location to the `mysql-test` directory under the installation root directory (for example, `/usr/local/mysql/mysql-test`), and run `./mysql-test-run.pl`. All tests should succeed. If any do not, feel free to try to find out why and report the problem if it indicates a bug in MySQL. See Section 1.7, "How to Report Bugs or Problems".

If one test fails, you should run `mysql-test-run.pl` with the `--force` option to check whether any other tests fail.

If you have a copy of `mysqld` running on the machine where you want to run the test suite, you do not have to stop it, as long as it is not using ports `9306` or `9307`. If either of those ports is taken, you should

set the `MTR_BUILD_THREAD` environment variable to an appropriate value, and the test suite will use a different set of ports for master, slave, NDB, and Instance Manager). For example:

```
shell> export MTR_BUILD_THREAD=31
shell> ./mysql-test-run.pl [options] [test_name]
```

In the `mysql-test` directory, you can run an individual test case with `./mysql-test-run.pl` `test_name`.

If you have a question about the test suite, or have a test case to contribute, send an email message to the MySQL `internals` mailing list. See Section 1.6.1, "MySQL Mailing Lists".

22.2 The MySQL Plugin API

MySQL supports a plugin API that enables creation of server components. Plugins can be loaded at server startup, or loaded and unloaded at runtime without restarting the server. The API is generic and does not specify what plugins can do. The components supported by this interface include, but are not limited to, storage engines, full-text parser plugins, and server extensions.

For example, full-text parser plugins can be used to replace or augment the built-in full-text parser. A plugin can parse text into words using rules that differ from those used by the built-in parser. This can be useful if you need to parse text with characteristics different from those expected by the built-in parser.

The plugin interface is more general than the older user-defined function (UDF) interface.

The plugin interface uses the `plugin` table in the `mysql` database to record information about plugins that have been installed permanently with the `INSTALL PLUGIN` statement. This table is created as part of the MySQL installation process. (If you are upgrading from a version of MySQL older than 5.1, you should run the `mysql_upgrade` command to create this table. See Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables".) Plugins can also be installed for a single server invocation with the `--plugin-load` option. Plugins installed this way are not recorded in the `plugin` table. See Section 5.1.8.1, "Installing and Uninstalling Plugins".

Additional Resources

The book *MySQL 5.1 Plugin Development* by Sergei Golubchik and Andrew Hutchings provides a wealth of detail about the plugin API. Despite the fact that the book's title refers to MySQL Server 5.1, most of the information in it applies to later versions as well.

22.2.1 Types of Plugins

The plugin API enables creation of plugins that implement several capabilities:

- Storage engines

- Full-text parsers

- Daemons

- `INFORMATION_SCHEMA` tables

The following sections provide an overview of these plugin types.

Storage Engine Plugins

The pluggable storage engine architecture used by MySQL Server enables storage engines to be written as plugins and loaded into and unloaded from a running server. For a description of this architecture, see Section 14.4, "Overview of MySQL Storage Engine Architecture".

For information on how to use the plugin API to write storage engines, see MySQL Internals: Writing a Custom Storage Engine.

Full-Text Parser Plugins

MySQL has a built-in parser that it uses by default for full-text operations (parsing text to be indexed, or parsing a query string to determine the terms to be used for a search). For full-text processing, "parsing" means extracting words from text or a query string based on rules that define which character sequences make up a word and where word boundaries lie.

When parsing for indexing purposes, the parser passes each word to the server, which adds it to a full-text index. When parsing a query string, the parser passes each word to the server, which accumulates the words for use in a search.

The parsing properties of the built-in full-text parser are described in Section 12.9, "Full-Text Search Functions". These properties include rules for determining how to extract words from text. The parser is influenced by certain system variables such as `ft_min_word_len` and `ft_max_word_len` that cause words shorter or longer to be excluded, and by the stopword list that identifies common words to be ignored.

The plugin API enables you to provide a full-text parser of your own so that you have control over the basic duties of a parser. A parser plugin can operate in either of two roles:

- The plugin can replace the built-in parser. In this role, the plugin reads the input to be parsed, splits it up into words, and passes the words to the server (either for indexing or for word accumulation).

  One reason to use a parser this way is that you need to use different rules from those of the built-in parser for determining how to split up input into words. For example, the built-in parser considers the text "case-sensitive" to consist of two words "case" and "sensitive," whereas an application might need to treat the text as a single word.

- The plugin can act in conjunction with the built-in parser by serving as a front end for it. In this role, the plugin extracts text from the input and passes the text to the parser, which splits up the text into words using its normal parsing rules. In particular, this parsing will be affected by the `ft_xxx` system variables and the stopword list.

  One reason to use a parser this way is that you need to index content such as PDF documents, XML documents, or `.doc` files. The built-in parser is not intended for those types of input but a plugin can pull out the text from these input sources and pass it to the built-in parser.

It is also possible for a parser plugin to operate in both roles. That is, it could extract text from noncleartext input (the front end role), and also parse the text into words (thus replacing the built-in parser).

A full-text plugin is associated with full-text indexes on a per-index basis. That is, when you install a parser plugin initially, that does not cause it to be used for any full-text operations. It simply becomes available. For example, a full-text parser plugin becomes available to be named in a `WITH PARSER` clause when creating individual `FULLTEXT` indexes. To create such an index at table-creation time, do this:

```
CREATE TABLE t
(
  doc CHAR(255),
  FULLTEXT INDEX (doc) WITH PARSER my_parser
) ENGINE=MyISAM;
```

Or you can add the index after the table has been created:

```
ALTER TABLE t ADD FULLTEXT INDEX (doc) WITH PARSER my_parser;
```

The only SQL change for associating the parser with the index is the `WITH PARSER` clause. Searches are specified as before, with no changes needed for queries.

When you associate a parser plugin with a `FULLTEXT` index, the plugin is required for using the index. If the parser plugin is dropped, any index associated with it becomes unusable. Any attempt to use a table for which a plugin is not available results in an error, although `DROP TABLE` is still possible.

For more information about full-text plugins, see Section 22.2.4.4, "Writing Full-Text Parser Plugins". MySQL 5.1 only supports full-text plugins with `MyISAM`.

Daemon Plugins

A daemon plugin is a simple type of plugin used for code that should be run by the server but that does not communicate with it. MySQL distributions include an example daemon plugin that writes periodic heartbeat messages to a file.

For more information about daemon plugins, see Section 22.2.4.5, "Writing Daemon Plugins".

INFORMATION_SCHEMA Plugins

`INFORMATION_SCHEMA` plugins enable the creation of tables containing server metadata that are exposed to users through the `INFORMATION_SCHEMA` database. For example, `InnoDB` uses `INFORMATION_SCHEMA` plugins to provide tables that contain information about current transactions and locks.

For more information about `INFORMATION_SCHEMA` plugins, see Section 22.2.4.6, "Writing INFORMATION_SCHEMA Plugins".

22.2.2 Plugin API Characteristics

The server plugin API has these characteristics:

- All plugins have several things in common.

  Each plugin has a name that it can be referred to in SQL statements, as well as other metadata such as an author and a description that provide other information. This information can be examined in the `INFORMATION_SCHEMA.PLUGINS` table or using the `SHOW PLUGINS` statement.

- The plugin framework is extendable to accommodate different kinds of plugins.

  Although some aspects of the plugin API are common to all types of plugins, the API also permits type-specific interface elements so that different types of plugins can be created. A plugin with one purpose can have an interface most appropriate to its own requirements and not the requirements of some other plugin type.

  Interfaces for several types of plugins exist, such as storage engines, full-text parser, and `INFORMATION_SCHEMA` tables. Others can be added.

- Plugins can expose information to users.

  A plugin can implement system and status variables that are available through the `SHOW VARIABLES` and `SHOW STATUS` statements.

- The plugin API includes versioning information.

  The version information included in the plugin API enables a plugin library and each plugin that it contains to be self-identifying with respect to the API version that was used to build the library. If the API changes over time, the version numbers will change, but a server can examine a given plugin library's version information to determine whether it supports the plugins in the library.

  There are two types of version numbers. The first is the version for the general plugin framework itself. Each plugin library includes this kind of version number. The second type of version applies to individual plugins. Each specific type of plugin has a version for its interface, so each plugin in a library has a type-specific version number. For example, a library containing a full-text parser plugin has a general plugin API version number, and the plugin has a version number specific to the full-text plugin interface.

- The plugin API implements security restrictions.

  A plugin library must be installed in a specific dedicated directory for which the location is controlled by the server and cannot be changed at runtime. Also, the library must contain specific symbols that identify it as a plugin library. The server will not load something as a plugin if it was not built as a plugin.

In some respects, the server plugin API is similar to the older user-defined function (UDF) API that it supersedes, but the plugin API has several advantages over the older interface. For example, UDFs had no versioning information. Also, the newer plugin interface eliminates the security issues of the older UDF interface. The older interface for writing nonplugin UDFs permitted libraries to be loaded from any directory searched by the system's dynamic linker, and the symbols that identified the UDF library were relatively nonspecific.

22.2.3 Plugin API Components

The server plugin implementation comprises several components.

SQL statements:

- `INSTALL PLUGIN` registers a plugin in the `mysql.plugin` table and loads the plugin code.

- `UNINSTALL PLUGIN` unregisters a plugin from the `mysql.plugin` table and unloads the plugin code.

- The `WITH PARSER` clause for full-text index creation associates a full-text parser plugin with a given `FULLTEXT` index.

- `SHOW PLUGINS` displays information about server plugins.

Command-line options and system variables:

- The `--plugin-load` option enables plugins to be loaded at server startup time.

- The `plugin_dir` system variable indicates the location of the directory where all plugins must be installed. The value of this variable can be specified at server startup with a `--plugin_dir=dir_name` option. `mysql_config --plugindir` displays the default plugin directory path name.

For additional information about plugin loading, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

Plugin-related tables:

- The `INFORMATION_SCHEMA.PLUGINS` table contains plugin information.

- The `mysql.plugin` table lists each plugin that was installed with `INSTALL PLUGIN` and is required for plugin use. For new MySQL installations, this table is created during the installation process. If you are upgrading from a version of MySQL older than 5.1, you should run `mysql_upgrade` to update

your system tables and create the `plugin` table (see Section 4.4.8, "`mysql_upgrade` — Check and Upgrade MySQL Tables").

Source files (the locations indicate where the files are found in MySQL source distributions):

- In the `include/mysql` directory, `plugin.h` exposes the public plugin API. This file should be examined by anyone who wants to write a plugin library. `plugin_xxx.h` files provide additional information that pertains to specific types of plugins.

- In the `sql` directory, `sql_plugin.h` and `sql_plugin.cc` comprise the internal plugin implementation. These files need not be consulted by plugin developers. They may be of interest for those who want to know more about how the server handles plugins.

22.2.4 Writing Plugins

To create a plugin library, you must provide the required descriptor information that indicates what plugins the library file contains, and write the interface functions for each plugin.

Every server plugin must have a general descriptor that provides information to the plugin API, and a type-specific descriptor that provides information about the plugin interface for a given type of plugin. The structure of the general descriptor is the same for all plugin types. The structure of the type-specific descriptor varies among plugin types and is determined by the requirements of what the plugin needs to do. The server plugin interface also enables plugins to expose status and system variables. These variables become visible through the `SHOW STATUS` and `SHOW VARIABLES` statements and the corresponding `INFORMATION_SCHEMA` tables.

You can write plugins in C or C++ (or another language that can use C calling conventions). Plugins are loaded and unloaded dynamically, so your operating system must support dynamic loading and you must have compiled `mysqld` dynamically (not statically).

A server plugin contains code that becomes part of the running server, so when you write the plugin, you are bound by any and all constraints that otherwise apply to writing server code. For example, you may have problems if you attempt to use functions from the `libstdc++` library. These constraints may change in future versions of the server, so it is possible that server upgrades will require revisions to plugins originally written for older servers. For information about these constraints, see Section 2.11.4, "MySQL Source-Configuration Options", and Section 2.11.5, "Dealing with Problems Compiling MySQL".

22.2.4.1 Overview of Plugin Writing

The following procedure provides an overview of the steps needed to create a plugin library. The next sections provide additional details on setting plugin data structures and writing specific types of plugins.

1. In the plugin source file, include the header files that the plugin library needs. The `plugin.h` file is required, and the library might require other files as well. For example:

```
#include <stdlib.h>
#include <ctype.h>
#include <mysql/plugin.h>
```

2. Set up the descriptor information for the plugin library file. This descriptor must contain the general plugin descriptor for each server plugin in the file. For more information, see Library and Plugin Descriptors. In addition, set up the type-specific descriptor for each server plugin in the library. Each plugin's general descriptor points to its type-specific descriptor.

3. Write the plugin interface functions for each plugin. Each plugin's general plugin descriptor points to the initialization and deinitialization functions that the server should invoke when it loads and unloads the plugin. The plugin's type-specific description may also point to interface functions.

4. Set up the status and system variables, if there are any.

5. Compile the plugin library as a shared library and install it in the plugin directory. For more information, see Section 22.2.4.3, "Compiling and Installing Plugin Libraries".

6. Register the plugin with the server. For more information, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

7. Test the plugin to verify that it works properly.

22.2.4.2 Plugin Data Structures

A plugin library file includes descriptor information to indicate what plugins it contains.

The plugin library must include the following descriptor information:

- A library descriptor indicates the general server plugin API version number used by the library and contains a general plugin descriptor for each server plugin in the library. To provide the framework for this descriptor, invoke two macros from the `plugin.h` header file:

```
mysql_declare_plugin(name)
 ... one or more server plugin descriptors here ...
mysql_declare_plugin_end;
```

The macros expand to provide a declaration for the API version automatically. You must provide the plugin descriptors.

- Within the library descriptor, each general server plugin is described by a `st_mysql_plugin` structure. This plugin descriptor structure contains information that is common to every type of server plugin: A value that indicates the plugin type; the plugin name, author, description, and license type; pointers to the initialization and deinitialization functions that the server invokes when it loads and unloads the plugin, and pointers to any status or system variables the plugin implements.

- Each general server plugin descriptor within the library descriptor also contains a pointer to a type-specific plugin descriptor. The structure of the type-specific descriptors varies from one plugin type to another because each type of plugin can have its own API. A type-specific plugin descriptor contains a type-specific API version number and pointers to the functions that are needed to implement that plugin type. For example, a full-text parser plugin has initialization and deinitialization functions, and a main parsing function. The server invokes these functions when it uses the plugin to parse text.

The plugin library also contains the interface functions that are referenced by the general and type-specific descriptors for each plugin in the library.

Library and Plugin Descriptors

Every plugin library must include a library descriptor that contains the general plugin descriptor for each server plugin in the file. This section discusses how to write the library and general descriptors for server plugins.

The library descriptor must define two symbols:

- `_mysql_plugin_interface_version_` specifies the version number of the general plugin framework. This is given by the `MYSQL_PLUGIN_INTERFACE_VERSION` symbol, which is defined in the `plugin.h` file.

- `_mysql_plugin_declarations_` defines an array of plugin declarations, terminated by a declaration with all members set to 0. Each declaration is an instance of the `st_mysql_plugin` structure (also defined in `plugin.h`). There must be one of these for each server plugin in the library.

If the server does not find those two symbols in a library, it does not accept it as a legal plugin library and rejects it with an error. This prevents use of a library for plugin purposes unless it was built specifically as a plugin library.

The conventional way to define the two required symbols is by using the `mysql_declare_plugin()` and `mysql_declare_plugin_end` macros from the `plugin.h` file:

```
mysql_declare_plugin(name)
 ... one or more server plugin descriptors here ...
mysql_declare_plugin_end;
```

Each server plugin must have a general descriptor that provides information to the server plugin API. The general descriptor has the same structure for all plugin types. The `st_mysql_plugin` structure in the `plugin.h` file defines this descriptor:

```
struct st_mysql_plugin
{
  int type;                /* the plugin type (a MYSQL_XXX_PLUGIN value)   */
  void *info;              /* pointer to type-specific plugin descriptor   */
  const char *name;        /* plugin name                                  */
  const char *author;      /* plugin author (for I_S.PLUGINS)              */
  const char *descr;       /* general descriptive text (for I_S.PLUGINS)   */
  int license;             /* the plugin license (PLUGIN_LICENSE_XXX)       */
  int (*init)(void *);     /* the function to invoke when plugin is loaded */
  int (*deinit)(void *);   /* the function to invoke when plugin is unloaded */
  unsigned int version;    /* plugin version (for I_S.PLUGINS)              */
  struct st_mysql_show_var *status_vars;
  struct st_mysql_sys_var **system_vars;
  void * __reserved1;      /* reserved for dependency checking              */
};
```

The `st_mysql_plugin` descriptor structure members are used as follows. `char *` members should be specified as null-terminated strings.

- `type`: The plugin type. This must be one of the plugin-type values from `plugin.h`:

```
/*
  The allowable types of plugins
*/
#define MYSQL_UDF_PLUGIN             0  /* User-defined function        */
#define MYSQL_STORAGE_ENGINE_PLUGIN  1  /* Storage Engine               */
#define MYSQL_FTPARSER_PLUGIN        2  /* Full-text parser plugin      */
#define MYSQL_DAEMON_PLUGIN          3  /* The daemon/raw plugin type */
#define MYSQL_INFORMATION_SCHEMA_PLUGIN  4  /* The I_S plugin type */
...
```

  For example, for a full-text parser plugin, the `type` value is `MYSQL_FTPARSER_PLUGIN`.

- `info`: A pointer to the type-specific descriptor for the plugin. This descriptor's structure depends on the particular type of plugin, unlike that of the general plugin descriptor structure. For version-control purposes, the first member of the type-specific descriptor for every plugin type is expected to be the interface version for the type. This enables the server to check the type-specific version for every plugin no matter its type. Following the version number, the descriptor includes any other members needed, such as callback functions and other information needed by the server to invoke the plugin properly. Later sections on writing particular types of server plugins describe the structure of their type-specific descriptors.

- `name`: A string that gives the plugin name. This is the name that will be listed in the `mysql.plugin` table and by which you refer to the plugin in SQL statements such as `INSTALL PLUGIN` and

UNINSTALL PLUGIN, or with the `--plugin-load` option. The name is also visible in the `INFORMATION_SCHEMA.PLUGINS` table or the output from `SHOW PLUGINS`.

The plugin name should not begin with the name of any server option. If it does, the server will fail to initialize it. For example, the server has a `--socket` option, so you should not use a plugin name such as `socket`, `socket_plugin`, and so forth.

- `author`: A string naming the plugin author. This can be whatever you like.

- `desc`: A string that provides a general description of the plugin. This can be whatever you like.

- `license`: The plugin license type. The value can be one of `PLUGIN_LICENSE_PROPRIETARY`, `PLUGIN_LICENSE_GPL`, or `PLUGIN_LICENSE_BSD`.

- `init`: A once-only initialization function, or `NULL` if there is no such function. The server executes this function when it loads the plugin, which happens for `INSTALL PLUGIN` or, for plugins listed in the `mysql.plugin` table, at server startup. The function takes one argument that points to the internal structure used to identify the plugin. It returns zero for success and nonzero for failure.

- `deinit`: A once-only deinitialization function, or `NULL` if there is no such function. The server executes this function when it unloads the plugin, which happens for `UNINSTALL PLUGIN` or, for plugins listed in the `mysql.plugin` table, at server shutdown. The function takes one argument that points to the internal structure used to identify the plugin It returns zero for success and nonzero for failure.

- `version`: The plugin version number. When the plugin is installed, this value can be retrieved from the `INFORMATION_SCHEMA.PLUGINS` table. The value includes major and minor numbers. If you write the value as a hex constant, the format is `0xMMNN`, where *MM* and *NN* are the major and minor numbers, respectively. For example, `0x0302` represents version 3.2.

- `status_vars`: A pointer to a structure for status variables associated with the plugin, or `NULL` if there are no such variables. When the plugin is installed, these variables are displayed in the output of the `SHOW STATUS` statement.

  The `status_vars` member, if not `NULL`, points to an array of `st_mysql_show_var` structures that describe status variables. See Plugin Status and System Variables.

- `system_vars`: A pointer to a structure for system variables associated with the plugin, or `NULL` if there are no such variables. These options and system variables can be used to help initialize variables within the plugin.

  The `system_vars` member, if not `NULL`, points to an array of `st_mysql_sys_var` structures that describe system variables. See Plugin Status and System Variables.

- `__reserved1`: A placeholder for the future. It should be set to `NULL`.

The server invokes the `init` and `deinit` functions in the general plugin descriptor only when loading and unloading the plugin. They have nothing to do with use of the plugin such as happens when an SQL statement causes the plugin to be invoked.

For example, the descriptor information for a library that contains a single full-text parser plugin named `simple_parser` looks like this:

```
mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                         */
  &simple_parser_descriptor,  /* descriptor                   */
  "simple_parser",            /* name                         */
  "Oracle Corporation",       /* author                       */
```

```
  "Simple Full-Text Parser",  /* description                    */
  PLUGIN_LICENSE_GPL,          /* plugin license                 */
  simple_parser_plugin_init,   /* init function (when loaded)    */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                      /* version                        */
  simple_status,               /* status variables               */
  simple_system_variables,     /* system variables               */
  NULL
}
mysql_declare_plugin_end;
```

For a full-text parser plugin, the type must be `MYSQL_FTPARSER_PLUGIN`. This is the value that identifies the plugin as being legal for use in a `WITH PARSER` clause when creating a `FULLTEXT` index. (No other plugin type is legal for this clause.)

`plugin.h` defines the `mysql_declare_plugin()` and `mysql_declare_plugin_end` macros like this:

```
#ifndef MYSQL_DYNAMIC_PLUGIN
#define __MYSQL_DECLARE_PLUGIN(NAME, VERSION, PSIZE, DECLS)                \
int VERSION= MYSQL_PLUGIN_INTERFACE_VERSION;                               \
int PSIZE= sizeof(struct st_mysql_plugin);                                 \
struct st_mysql_plugin DECLS[]= {
#else
#define __MYSQL_DECLARE_PLUGIN(NAME, VERSION, PSIZE, DECLS)                \
MYSQL_PLUGIN_EXPORT int _mysql_plugin_interface_version_= MYSQL_PLUGIN_INTERFACE_VERSION;  \
MYSQL_PLUGIN_EXPORT int _mysql_sizeof_struct_st_plugin_= sizeof(struct st_mysql_plugin);   \
MYSQL_PLUGIN_EXPORT struct st_mysql_plugin _mysql_plugin_declarations_[]= {
#endif

#define mysql_declare_plugin(NAME) \
__MYSQL_DECLARE_PLUGIN(NAME, \
                builtin_ ## NAME ## _plugin_interface_version, \
                builtin_ ## NAME ## _sizeof_struct_st_plugin, \
                builtin_ ## NAME ## _plugin)

#define mysql_declare_plugin_end ,{0,0,0,0,0,0,0,0,0,0,0,0,0}}
```

> **Note**
>
> Those declarations define the `_mysql_plugin_interface_version_` symbol only if the `MYSQL_DYNAMIC_PLUGIN` symbol is defined. This means that `-DMYSQL_DYNAMIC_PLUGIN` must be provided as part of the compilation command to build the plugin as a shared library.

When the macros are used as just shown, they expand to the following code, which defines both of the required symbols (`_mysql_plugin_interface_version_` and `_mysql_plugin_declarations_`):

```
int _mysql_plugin_interface_version_= MYSQL_PLUGIN_INTERFACE_VERSION;
int _mysql_sizeof_struct_st_plugin_= sizeof(struct st_mysql_plugin);
struct st_mysql_plugin _mysql_plugin_declarations_[]= {
{
  MYSQL_FTPARSER_PLUGIN,       /* type                           */
  &simple_parser_descriptor,   /* descriptor                     */
  "simple_parser",             /* name                           */
  "Oracle Corporation",        /* author                         */
  "Simple Full-Text Parser",   /* description                    */
  PLUGIN_LICENSE_GPL,          /* plugin license                 */
  simple_parser_plugin_init,   /* init function (when loaded)    */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                      /* version                        */
  simple_status,               /* status variables               */
```

```
  simple_system_variables,    /* system variables                 */
  NULL
}
  ,{0,0,0,0,0,0,0,0,0,0,0,0}}
};
```

The preceding example declares a single plugin in the general descriptor, but it is possible to declare multiple plugins. List the declarations one after the other between `mysql_declare_plugin()` and `mysql_declare_plugin_end`, separated by commas.

MySQL server plugins can be written in C or C++ (or another language that can use C calling conventions). If you write a C++ plugin, one C++ feature that you should not use is nonconstant variables to initialize global structures. Members of structures such as the `st_mysql_plugin` structure should be initialized only with constant variables. The `simple_parser` descriptor shown earlier is permissible in a C++ plugin because it satisfies that requirement:

```
mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                             */
  &simple_parser_descriptor,  /* descriptor                       */
  "simple_parser",            /* name                             */
  "Oracle Corporation",       /* author                           */
  "Simple Full-Text Parser",  /* description                      */
  PLUGIN_LICENSE_GPL,         /* plugin license                   */
  simple_parser_plugin_init,  /* init function (when loaded)      */
  simple_parser_plugin_deinit,/* deinit function (when unloaded)  */
  0x0001,                     /* version                          */
  simple_status,              /* status variables                 */
  simple_system_variables,    /* system variables                 */
  NULL
}
mysql_declare_plugin_end;
```

Here is another valid way to write the general descriptor. It uses constant variables to indicate the plugin name, author, and description:

```
const char *simple_parser_name = "simple_parser";
const char *simple_parser_author = "Oracle Corporation";
const char *simple_parser_description = "Simple Full-Text Parser";

mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                             */
  &simple_parser_descriptor,  /* descriptor                       */
  simple_parser_name,         /* name                             */
  simple_parser_author,       /* author                           */
  simple_parser_description,  /* description                      */
  PLUGIN_LICENSE_GPL,         /* plugin license                   */
  simple_parser_plugin_init,  /* init function (when loaded)      */
  simple_parser_plugin_deinit,/* deinit function (when unloaded)  */
  0x0001,                     /* version                          */
  simple_status,              /* status variables                 */
  simple_system_variables,    /* system variables                 */
  NULL
}
mysql_declare_plugin_end;
```

However, the following general descriptor is invalid. It uses structure members to indicate the plugin name, author, and description, but structures are not considered constant initializers in C++:

```
typedef struct
{
```

```
  const char *name;
  const char *author;
  const char *description;
} plugin_info;

plugin_info parser_info = {
  "simple_parser",
  "Oracle Corporation",
  "Simple Full-Text Parser"
};

mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                         */
  &simple_parser_descriptor,  /* descriptor                   */
  parser_info.name,           /* name                         */
  parser_info.author,         /* author                       */
  parser_info.description,    /* description                  */
  PLUGIN_LICENSE_GPL,         /* plugin license               */
  simple_parser_plugin_init,  /* init function (when loaded)  */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                     /* version                      */
  simple_status,              /* status variables             */
  simple_system_variables,    /* system variables             */
  NULL
}
mysql_declare_plugin_end;
```

Plugin Status and System Variables

The server plugin interface enables plugins to expose status and system variables using the `status_vars` and `system_vars` members of the general plugin descriptor.

The `status_vars` member of the general plugin descriptor, if not 0, points to an array of `st_mysql_show_var` structures, each of which describes one status variable, followed by a structure with all members set to 0. The `st_mysql_show_var` structure has this definition:

```
struct st_mysql_show_var {
  const char *name;
  char *value;
  enum enum_mysql_show_type type;
};
```

When the plugin is installed, the plugin name and the `name` value are joined with an underscore to form the name displayed by SHOW STATUS.

The following table shows the permissible status variable `type` values and what the corresponding variable should be.

Table 22.1 Server Plugin Status Variable Types

Variable Type	Meaning
SHOW_BOOL	Pointer to a boolean variable
SHOW_INT	Pointer to an integer variable
SHOW_LONG	Pointer to a long integer variable
SHOW_LONGLONG	Pointer to a longlong integer variable
SHOW_CHAR	A string
SHOW_CHAR_PTR	Pointer to a string
SHOW_ARRAY	Pointer to another st_mysql_show_var array

Variable Type	Meaning
`SHOW_FUNC`	Pointer to a function
`SHOW_DOUBLE`	Pointer to a double

For the `SHOW_FUNC` type, the function is called and fills in its `out` parameter, which then provides information about the variable to be displayed. The function has this signature:

```
#define SHOW_VAR_FUNC_BUFF_SIZE 1024

typedef int (*mysql_show_var_func) (void *thd,
                                    struct st_mysql_show_var *out,
                                    char *buf);
```

The `system_vars` member, if not 0, points to an array of `st_mysql_sys_var` structures, each of which describes one system variable (which can also be set from the command-line or configuration file), followed by a structure with all members set to 0. The `st_mysql_sys_var` structure is defined as follows:

```
struct st_mysql_sys_var {
 int flags;
 const char *name, *comment;
 int (*check)(THD*, struct st_mysql_sys_var *, void*, st_mysql_value*);
 void (*update)(THD*, struct st_mysql_sys_var *, void*, const void*);
};
```

Additional fields are append as required depending upon the flags.

For convenience, a number of macros are defined that make creating new system variables within a plugin much simpler.

Throughout the macros, the following fields are available:

- `name`: An unquoted identifier for the system variable.

- `varname`: The identifier for the static variable. Where not available, it is the same as the `name` field.

- `opt`: Additional use flags for the system variable. The following table shows the permissible flags.

Table 22.2 Server Plugin System Variable Flags

Flag Value	Description
`PLUGIN_VAR_READONLY`	The system variable is read only
`PLUGIN_VAR_NOSYSVAR`	The system variable is not user visible at runtime
`PLUGIN_VAR_NOCMDOPT`	The system variable is not configurable from the command line
`PLUGIN_VAR_NOCMDARG`	No argument is required at the command line (typically used for boolean variables)
`PLUGIN_VAR_RQCMDARG`	An argument is required at the command line (this is the default)
`PLUGIN_VAR_OPCMDARG`	An argument is optional at the command line
`PLUGIN_VAR_MEMALLOC`	Used for string variables; indicates that memory is to be allocated for storage of the string

- `comment`: A descriptive comment to be displayed in the server help message. `NULL` if this variable is to be hidden.

- `check`: The check function, `NULL` for default.

- `update`: The update function, `NULL` for default.

- `default`: The variable default value.

- `minimum`: The variable minimum value.

- `maximum`: The variable maximum value.

- `blocksize`: The variable block size. When the value is set, it is rounded to the nearest multiple of `blocksize`.

A system variable may be accessed either by using the static variable directly or by using the `SYSVAR()` accessor macro. The `SYSVAR()` macro is provided for completeness. Usually it should be used only when the code cannot directly access the underlying variable.

For example:

```
static int my_foo;
static MYSQL_SYSVAR_INT(foo_var, my_foo,
                        PLUGIN_VAR_RQCMDARG, "foo comment",
                        NULL, NULL, 0, 0, INT_MAX, 0);
 ...
  SYSVAR(foo_var)= value;
  value= SYSVAR(foo_var);
  my_foo= value;
  value= my_foo;
```

Session variables may be accessed only through the `THDVAR()` accessor macro. For example:

```
static MYSQL_THDVAR_BOOL(some_flag,
                         PLUGIN_VAR_NOCMDARG, "flag comment",
                         NULL, NULL, FALSE);
 ...
  if (THDVAR(thd, some_flag))
  {
    do_something();
    THDVAR(thd, some_flag)= FALSE;
  }
```

All global and session system variables must be published to `mysqld` before use. This is done by constructing a `NULL`-terminated array of the variables and linking to it in the plugin public interface. For example:

```
static struct st_mysql_sys_var *my_plugin_vars[]= {
  MYSQL_SYSVAR(foo_var),
  MYSQL_SYSVAR(some_flag),
  NULL
};
mysql_declare_plugin(fooplug)
{
  MYSQL_..._PLUGIN,
  &plugin_data,
  "fooplug",
  "foo author",
  "This does foo!",
  PLUGIN_LICENSE_GPL,
  foo_init,
  foo_fini,
  0x0001,
  NULL,
```

```
  my_plugin_vars,
  NULL
}
mysql_declare_plugin_end;
```

The following convenience macros enable you to declare different types of system variables:

- Boolean system variables of type `my_bool`, which is a 1-byte boolean. (0 = FALSE, 1 = TRUE)

```
MYSQL_THDVAR_BOOL(name, opt, comment, check, update, default)
MYSQL_SYSVAR_BOOL(name, varname, opt, comment, check, update, default)
```

- String system variables of type `char*`, which is a pointer to a null-terminated string.

```
MYSQL_THDVAR_STR(name, opt, comment, check, update, default)
MYSQL_SYSVAR_STR(name, varname, opt, comment, check, update, default)
```

- Integer system variables, of which there are several varieties.

  - An `int` system variable, which is typically a 4-byte signed word.

```
MYSQL_THDVAR_INT(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_INT(name, varname, opt, comment, check, update, default,
                 minimum, maximum, blocksize)
```

  - An `unsigned int` system variable, which is typically a 4-byte unsigned word.

```
MYSQL_THDVAR_UINT(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_UINT(name, varname, opt, comment, check, update, default,
                  minimum, maximum, blocksize)
```

  - A `long` system variable, which is typically either a 4- or 8-byte signed word.

```
MYSQL_THDVAR_LONG(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_LONG(name, varname, opt, comment, check, update, default,
                  minimum, maximum, blocksize)
```

  - An `unsigned long` system variable, which is typically either a 4- or 8-byte unsigned word.

```
MYSQL_THDVAR_ULONG(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_ULONG(name, varname, opt, comment, check, update, default,
                   minimum, maximum, blocksize)
```

  - A `long long` system variable, which is typically an 8-byte signed word.

```
MYSQL_THDVAR_LONGLONG(name, opt, comment, check, update,
                      default, minimum, maximum, blocksize)
MYSQL_SYSVAR_LONGLONG(name, varname, opt, comment, check, update,
                      default, minimum, maximum, blocksize)
```

  - An `unsigned long long` system variable, which is typically an 8-byte unsigned word.

```
MYSQL_THDVAR_ULONGLONG(name, opt, comment, check, update,
                       default, minimum, maximum, blocksize)
MYSQL_SYSVAR_ULONGLONG(name, varname, opt, comment, check, update,
                       default, minimum, maximum, blocksize)
```

- An `unsigned long` system variable, which is typically either a 4- or 8-byte unsigned word. The range of possible values is an ordinal of the number of elements in the `typelib`, starting from 0.

```
MYSQL_THDVAR_ENUM(name, opt, comment, check, update, default, typelib)
MYSQL_SYSVAR_ENUM(name, varname, opt, comment, check, update,
                  default, typelib)
```

- An `unsigned long long` system variable, which is typically an 8-byte unsigned word. Each bit represents an element in the `typelib`.

```
MYSQL_THDVAR_SET(name, opt, comment, check, update, default, typelib)
MYSQL_SYSVAR_SET(name, varname, opt, comment, check, update,
                 default, typelib)
```

Internally, all mutable and plugin system variables are stored in a `HASH` structure.

Display of the server command-line help text is handled by compiling a `DYNAMIC_ARRAY` of all variables relevant to command-line options, sorting them, and then iterating through them to display each option.

When a command-line option has been handled, it is then removed from the `argv` by the `handle_option()` function (`my_getopt.c`); in effect, it is consumed.

The server processes command-line options during the plugin installation process, immediately after the plugin has been successfully loaded but before the plugin initialization function has been called

Plugins loaded at runtime do not benefit from any configuration options and must have usable defaults. Once they are installed, they are loaded at `mysqld` initialization time and configuration options can be set at the command line or within `my.cnf`.

Plugins should consider the `thd` parameter to be read only.

22.2.4.3 Compiling and Installing Plugin Libraries

After your plugin is written, you must compile it and install it. The procedure for compiling shared objects varies from system to system. If you build your library using the GNU autotools, `libtool` should be able to generate the correct compilation commands for your system. If the library is named `somepluglib`, you should end up with a shared object file that has a name something like `somepluglib.so`. (The `.so` file name suffix might differ on your system.)

To use the autotools, you'll need to make a few changes to the configuration files at this point to enable the plugin to be compiled and installed. Assume that your MySQL distribution is installed at a base directory of `/usr/local/mysql` and that its header files are located in the `include` directory under the base directory.

Edit `Makefile.am`, which should look something like this:

```
#Makefile.am example for a plugin

pkgplugindir=$(libdir)/mysql/plugin
INCLUDES= -I$(top_builddir)/include -I$(top_srcdir)/include
#noinst_LTLIBRARIES= somepluglib.la
pkgplugin_LTLIBRARIES= somepluglib.la
somepluglib_la_SOURCES= plugin_example.c
somepluglib_la_LDFLAGS= -module -rpath $(pkgplugindir)
somepluglib_la_CFLAGS= -DMYSQL_DYNAMIC_PLUGIN
```

> **Note**
>
> As mentioned in Library and Plugin Descriptors, be sure to specify `-DMYSQL_DYNAMIC_PLUGIN` as part of the compilation command when you build the plugin. The `somepluglib_la_CFLAGS` line takes care of this.

Adjust the `INCLUDES` line to specify the path name to the installed MySQL header files. Edit it to look like this:

```
INCLUDES= -I/usr/local/mysql/include
```

Make sure that the `noinst_LTLIBRARIES` line is commented out or remove it. Make sure that the `pkglib_LTLIBRARIES` line is not commented out; it enables the `make install` command.

Set up the files needed for the `configure` command, invoke it, and run `make`:

```
shell> autoreconf --force --install --symlink
shell> ./configure --prefix=/usr/local/mysql
shell> make
```

The `--prefix` option to `configure` indicates the MySQL base directory under which the plugin should be installed. You can see what value to use for this option with `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'basedir';
+---------------+------------------+
| Variable_name | Value            |
+---------------+------------------+
| base          | /usr/local/mysql |
+---------------+------------------+
```

The location of the plugin directory where you should install the library is given by the `plugin_dir` system variable. For example:

```
mysql> SHOW VARIABLES LIKE 'plugin_dir';
+---------------+----------------------------------+
| Variable_name | Value                            |
+---------------+----------------------------------+
| plugin_dir    | /usr/local/mysql/lib/mysql/plugin |
+---------------+----------------------------------+
```

To install the plugin library, use `make`:

```
shell> make install
```

Verify that `make install` installed the plugin library in the proper directory. After installing it, make sure that the library permissions permit it to be executed by the server.

22.2.4.4 Writing Full-Text Parser Plugins

MySQL supports server-side full-text parser plugins only with `MyISAM`. For introductory information about full-text parser plugins, see Full-Text Parser Plugins.

A full-text parser plugin can be used to replace or modify the built-in full-text parser. This section describes how to write a full-text parser plugin named `simple_parser`. This plugin performs parsing based

on simpler rules than those used by the MySQL built-in full-text parser: Words are nonempty runs of whitespace characters.

The instructions use the source code in the `plugin/fulltext` directory of MySQL source distributions, so change location into that directory. The following procedure describes how the plugin library is created:

1. To write a full-text parser plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

   ```
   #include <mysql/plugin.h>
   ```

   `plugin.h` defines the `MYSQL_FTPARSER_PLUGIN` server plugin type and the data structures needed to declare the plugin.

2. Set up the library descriptor for the plugin library file.

   This descriptor contains the general plugin descriptor for the server plugin. For a full-text parser plugin, the type must be `MYSQL_FTPARSER_PLUGIN`. This is the value that identifies the plugin as being legal for use in a `WITH PARSER` clause when creating a `FULLTEXT` index. (No other plugin type is legal for this clause.)

   For example, the library descriptor for a library that contains a single full-text parser plugin named `simple_parser` looks like this:

   ```
   mysql_declare_plugin(ftexample)
   {
     MYSQL_FTPARSER_PLUGIN,      /* type                          */
     &simple_parser_descriptor,  /* descriptor                    */
     "simple_parser",            /* name                          */
     "Oracle Corporation",       /* author                        */
     "Simple Full-Text Parser",  /* description                   */
     PLUGIN_LICENSE_GPL,         /* plugin license                */
     simple_parser_plugin_init,  /* init function (when loaded)     */
     simple_parser_plugin_deinit,/* deinit function (when unloaded) */
     0x0001,                     /* version                       */
     simple_status,             /* status variables              */
     simple_system_variables,    /* system variables              */
     NULL
   }
   mysql_declare_plugin_end;
   ```

   The `name` member (`simple_parser`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

   For more information, see Library and Plugin Descriptors.

3. Set up the type-specific plugin descriptor.

   Each general plugin descriptor in the library descriptor points to a type-specific descriptor. For a full-text parser plugin, the type-specific descriptor is an instance of the `st_mysql_ftparser` structure in the `plugin.h` file:

   ```
   struct st_mysql_ftparser
   {
     int interface_version;
     int (*parse)(MYSQL_FTPARSER_PARAM *param);
     int (*init)(MYSQL_FTPARSER_PARAM *param);
     int (*deinit)(MYSQL_FTPARSER_PARAM *param);
   ```

```
};
```

As shown by the structure definition, the descriptor has an interface version number and contains pointers to three functions.

The interface version number is specified using a symbol, which is in the form: MYSQL_*xxx*_INTERFACE_VERSION. For full-text parser plugins, the symbol is "MYSQL_FTPARSER_INTERFACE_VERSION". In the source code, you will find the actual interface version number for the full-text parser plugin defined in include/mysql/plugin.h.

The init and deinit members should point to a function or be set to 0 if the function is not needed. The parse member must point to the function that performs the parsing.

In the simple_parser declaration, that descriptor is indicated by &simple_parser_descriptor. The descriptor specifies the version number for the full-text plugin interface (as given by MYSQL_FTPARSER_INTERFACE_VERSION), and the plugin's parsing, initialization, and deinitialization functions:

```
static struct st_mysql_ftparser simple_parser_descriptor=
{
  MYSQL_FTPARSER_INTERFACE_VERSION, /* interface version      */
  simple_parser_parse,              /* parsing function       */
  simple_parser_init,               /* parser init function   */
  simple_parser_deinit              /* parser deinit function */
};
```

A full-text parser plugin is used in two different contexts, indexing and searching. In both contexts, the server calls the initialization and deinitialization functions at the beginning and end of processing each SQL statement that causes the plugin to be invoked. However, during statement processing, the server calls the main parsing function in context-specific fashion:

- For indexing, the server calls the parser for each column value to be indexed.

- For searching, the server calls the parser to parse the search string. The parser might also be called for rows processed by the statement. In natural language mode, there is no need for the server to call the parser. For boolean mode phrase searches or natural language searches with query expansion, the parser is used to parse column values for information that is not in the index. Also, if a boolean mode search is done for a column that has no FULLTEXT index, the built-in parser will be called. (Plugins are associated with specific indexes. If there is no index, no plugin is used.)

The plugin declaration in the general plugin descriptor has init and deinit members that point initialization and deinitialization functions, and so does the type-specific plugin descriptor to which it points. However, these pairs of functions have different purposes and are invoked for different reasons:

- For the plugin declaration in the general plugin descriptor, the initialization and deinitialization functions are invoked when the plugin is loaded and unloaded.

- For the type-specific plugin descriptor, the initialization and deinitialization functions are invoked per SQL statement for which the plugin is used.

Each interface function named in the plugin descriptor should return zero for success or nonzero for failure, and each of them receives an argument that points to a MYSQL_FTPARSER_PARAM structure containing the parsing context. The structure has this definition:

```
typedef struct st_mysql_ftparser_param
{
```

```
    int (*mysql_parse)(struct st_mysql_ftparser_param *,
                       char *doc, int doc_len);
    int (*mysql_add_word)(struct st_mysql_ftparser_param *,
                          char *word, int word_len,
                          MYSQL_FTPARSER_BOOLEAN_INFO *boolean_info);
    void *ftparser_state;
    void *mysql_ftparam;
    struct charset_info_st *cs;
    char *doc;
    int length;
    int flags;
    enum enum_ftparser_mode mode;
} MYSQL_FTPARSER_PARAM;
```

> **Note**
>
> The definition shown is current as of MySQL 5.1.12. It is incompatible with
> versions of MySQL older than 5.1.12.

The structure members are used as follows:

- `mysql_parse`: A pointer to a callback function that invokes the server's built-in parser. Use
  this callback when the plugin acts as a front end to the built-in parser. That is, when the plugin
  parsing function is called, it should process the input to extract the text and pass the text to the
  `mysql_parse` callback.

  The first parameter for this callback function should be the `param` value itself:

  ```
  param->mysql_parse(param, ...);
  ```

  A front end plugin can extract text and pass it all at once to the built-in parser, or it can extract and
  pass text to the built-in parser a piece at a time. However, in this case, the built-in parser treats the
  pieces of text as though there are implicit word breaks between them.

- `mysql_add_word`: A pointer to a callback function that adds a word to a full-text index or to the
  list of search terms. Use this callback when the parser plugin replaces the built-in parser. That
  is, when the plugin parsing function is called, it should parse the input into words and invoke the
  `mysql_add_word` callback for each word.

  The first parameter for this callback function should be the `param` value itself:

  ```
  param->mysql_add_word(param, ...);
  ```

- `ftparser_state`: This is a generic pointer. The plugin can set it to point to information to be used
  internally for its own purposes.

- `mysql_ftparam`: This is set by the server. It is passed as the first argument to the `mysql_parse` or
  `mysql_add_word` callback.

- `cs`: A pointer to information about the character set of the text, or 0 if no information is available.

- `doc`: A pointer to the text to be parsed.

- `length`: The length of the text to be parsed, in bytes.

- `flags`: Parser flags. This is zero if there are no special flags. The only nonzero flag is
  `MYSQL_FTFLAGS_NEED_COPY`, which means that `mysql_add_word()` must save a copy of

the word (that is, it cannot use a pointer to the word because the word is in a buffer that will be overwritten.) This member was added in MySQL 5.1.12.

This flag might be set or reset by MySQL before calling the parser plugin, by the parser plugin itself, or by the `mysql_parse()` function.

- `mode`: The parsing mode. This value will be one of the following constants:

  - `MYSQL_FTPARSER_SIMPLE_MODE`: Parse in fast and simple mode, which is used for indexing and for natural language queries. The parser should pass to the server only those words that should be indexed. If the parser uses length limits or a stopword list to determine which words to ignore, it should not pass such words to the server.

  - `MYSQL_FTPARSER_WITH_STOPWORDS`: Parse in stopword mode. This is used in boolean searches for phrase matching. The parser should pass all words to the server, even stopwords or words that are outside any normal length limits.

  - `MYSQL_FTPARSER_FULL_BOOLEAN_INFO`: Parse in boolean mode. This is used for parsing boolean query strings. The parser should recognize not only words but also boolean-mode operators and pass them to the server as tokens using the `mysql_add_word` callback. To tell the server what kind of token is being passed, the plugin needs to fill in a `MYSQL_FTPARSER_BOOLEAN_INFO` structure and pass a pointer to it.

If the parser is called in boolean mode, the `param->mode` value will be `MYSQL_FTPARSER_FULL_BOOLEAN_INFO`. The `MYSQL_FTPARSER_BOOLEAN_INFO` structure that the parser uses for passing token information to the server looks like this:

```
typedef struct st_mysql_ftparser_boolean_info
{
  enum enum_ft_token_type type;
  int yesno;
  int weight_adjust;
  char wasign;
  char trunc;
  /* These are parser state and must be removed. */
  char prev;
  char *quot;
} MYSQL_FTPARSER_BOOLEAN_INFO;
```

The parser should fill in the structure members as follows:

- `type`: The token type. The following table shows the permissible types.

Table 22.3 Full-Text Parser Token Types

Token Value	Meaning
`FT_TOKEN_EOF`	End of data
`FT_TOKEN_WORD`	A regular word
`FT_TOKEN_LEFT_PAREN`	The beginning of a group or subexpression
`FT_TOKEN_RIGHT_PAREN`	The end of a group or subexpression
`FT_TOKEN_STOPWORD`	A stopword

- `yesno`: Whether the word must be present for a match to occur. 0 means that the word is optional but increases the match relevance if it is present. Values larger than 0 mean that the word must be present. Values smaller than 0 mean that the word must not be present.

- `weight_adjust`: A weighting factor that determines how much a match for the word counts. It can be used to increase or decrease the word's importance in relevance calculations. A value of zero indicates no weight adjustment. Values greater than or less than zero mean higher or lower weight, respectively. The examples at Section 12.9.2, "Boolean Full-Text Searches", that use the `<` and `>` operators illustrate how weighting works.

- `wasign`: The sign of the weighting factor. A negative value acts like the `~` boolean-search operator, which causes the word's contribution to the relevance to be negative.

- `trunc`: Whether matching should be done as if the boolean-mode `*` truncation operator had been given.

Plugins should not use the `prev` and `quot` members of the `MYSQL_FTPARSER_BOOLEAN_INFO` structure.

> **Note**
>
> The plugin parser framework does not support:
>
> - The `@distance` boolean operator.
>
> - A leading plus sign (`+`) or minus sign (`-`) boolean operator followed by a space and then a word (`'+ apple'` or `'- apple'`). The leading plus or minus sign must be directly adjacent to the word, for example: `'+apple'` or `'-apple'`.
>
> For information about boolean full-text search operators, see Section 12.9.2, "Boolean Full-Text Searches".

4. Set up the plugin interface functions.

   The general plugin descriptor in the library descriptor names the initialization and deinitialization functions that the server should invoke when it loads and unloads the plugin. For `simple_parser`, these functions do nothing but return zero to indicate that they succeeded:

   ```
   static int simple_parser_plugin_init(void *arg __attribute__((unused)))
   {
     return(0);
   }

   static int simple_parser_plugin_deinit(void *arg __attribute__((unused)))
   {
     return(0);
   }
   ```

   Because those functions do not actually do anything, you could omit them and specify 0 for each of them in the plugin declaration.

   The type-specific plugin descriptor for `simple_parser` names the initialization, deinitialization, and parsing functions that the server invokes when the plugin is used. For `simple_parser`, the initialization and deinitialization functions do nothing:

   ```
   static int simple_parser_init(MYSQL_FTPARSER_PARAM *param
                             __attribute__((unused)))
   {
     return(0);
   ```

```
}

static int simple_parser_deinit(MYSQL_FTPARSER_PARAM *param
                                __attribute__((unused)))
{
  return(0);
}
```

Here too, because those functions do nothing, you could omit them and specify 0 for each of them in the plugin descriptor.

The main parsing function, `simple_parser_parse()`, acts as a replacement for the built-in full-text parser, so it needs to split text into words and pass each word to the server. The parsing function's first argument is a pointer to a structure that contains the parsing context. This structure has a `doc` member that points to the text to be parsed, and a `length` member that indicates how long the text is. The simple parsing done by the plugin considers nonempty runs of whitespace characters to be words, so it identifies words like this:

```
static int simple_parser_parse(MYSQL_FTPARSER_PARAM *param)
{
  char *end, *start, *docend= param->doc + param->length;

  for (end= start= param->doc;; end++)
  {
    if (end == docend)
    {
      if (end > start)
        add_word(param, start, end - start);
      break;
    }
    else if (isspace(*end))
    {
      if (end > start)
        add_word(param, start, end - start);
      start= end + 1;
    }
  }
  return(0);
}
```

As the parser finds each word, it invokes a function `add_word()` to pass the word to the server. `add_word()` is a helper function only; it is not part of the plugin interface. The parser passes the parsing context pointer to `add_word()`, as well as a pointer to the word and a length value:

```
static void add_word(MYSQL_FTPARSER_PARAM *param, char *word, size_t len)
{
  MYSQL_FTPARSER_BOOLEAN_INFO bool_info=
    { FT_TOKEN_WORD, 0, 0, 0, 0, ' ', 0 };

  param->mysql_add_word(param, word, len, &bool_info);
}
```

For boolean-mode parsing, `add_word()` fills in the members of the `bool_info` structure as described earlier in the discussion of the `st_mysql_ftparser_boolean_info` structure.

5. Set up the status variables. For the `simple_parser` plugin, the following status variable array sets up one status variable with a value that is static text, and another with a value that is stored in a long integer variable:

```
long number_of_calls= 0;
```

```
struct st_mysql_show_var simple_status[]=
{
  {"static", (char *)"just a static text", SHOW_CHAR},
  {"called", (char *)&number_of_calls,    SHOW_LONG},
  {0,0,0}
};
```

When the plugin is installed, the plugin name and the `name` value are joined with an underscore to form the name displayed by `SHOW STATUS`. For the array just shown, the resulting status variable names are `simple_parser_static` and `simple_parser_called`. This convention means that you can easily display the variables for a plugin using its name:

```
mysql> SHOW STATUS LIKE 'simple_parser%';
+----------------------+-------------------+
| Variable_name        | Value             |
+----------------------+-------------------+
| simple_parser_static | just a static text |
| simple_parser_called | 0                 |
+----------------------+-------------------+
```

6. To compile and install a plugin library object file, use the instructions in Section 22.2.4.3, "Compiling and Installing Plugin Libraries". To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `simple_parser` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `mypluglib.so` (the `.so` suffix might differ depending on your platform).

7. To use the plugin, register it with the server. For example, to register the plugin at runtime, use this statement (changing the suffix as necessary):

```
mysql> INSTALL PLUGIN simple_parser SONAME 'mypluglib.so';
```

For additional information about plugin loading, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

8. To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.1.8.2, "Obtaining Server Plugin Information".

9. Test the plugin to verify that it works properly.

Create a table that contains a string column and associate the parser plugin with a `FULLTEXT` index on the column:

```
mysql> CREATE TABLE t (c VARCHAR(255),
    ->    FULLTEXT (c) WITH PARSER simple_parser
    -> ) ENGINE=MyISAM;
Query OK, 0 rows affected (0.01 sec)
```

Insert some text into the table and try some searches. These should verify that the parser plugin treats all nonwhitespace characters as word characters:

```
mysql> INSERT INTO t VALUES
    ->    ('latin1_general_cs is a case-sensitive collation'),
    ->    ('I\'d like a case of oranges'),
    ->    ('this is sensitive information'),
    ->    ('another row'),
    ->    ('yet another row');
```

```
Query OK, 5 rows affected (0.02 sec)
Records: 5  Duplicates: 0  Warnings: 0

mysql> SELECT c FROM t;
+------------------------------------------------+
| c                                              |
+------------------------------------------------+
| latin1_general_cs is a case-sensitive collation |
| I'd like a case of oranges                     |
| this is sensitive information                  |
| another row                                    |
| yet another row                                |
+------------------------------------------------+
5 rows in set (0.00 sec)

mysql> SELECT MATCH(c) AGAINST('case') FROM t;
+--------------------------+
| MATCH(c) AGAINST('case') |
+--------------------------+
|                        0 |
|            1.2968142032623 |
|                        0 |
|                        0 |
|                        0 |
+--------------------------+
5 rows in set (0.00 sec)

mysql> SELECT MATCH(c) AGAINST('sensitive') FROM t;
+-------------------------------+
| MATCH(c) AGAINST('sensitive') |
+-------------------------------+
|                             0 |
|                             0 |
|                 1.3253291845322 |
|                             0 |
|                             0 |
+-------------------------------+
5 rows in set (0.01 sec)

mysql> SELECT MATCH(c) AGAINST('case-sensitive') FROM t;
+------------------------------------+
| MATCH(c) AGAINST('case-sensitive') |
+------------------------------------+
|                    1.3109166622162 |
|                                  0 |
|                                  0 |
|                                  0 |
|                                  0 |
+------------------------------------+
5 rows in set (0.01 sec)

mysql> SELECT MATCH(c) AGAINST('I\'d') FROM t;
+--------------------------+
| MATCH(c) AGAINST('I\'d') |
+--------------------------+
|                        0 |
|            1.2968142032623 |
|                        0 |
|                        0 |
|                        0 |
+--------------------------+
5 rows in set (0.01 sec)
```

Neither "case" nor "insensitive" match "case-insensitive" the way that they would for the built-in parser.

22.2.4.5 Writing Daemon Plugins

A daemon plugin is a simple type of plugin used for code that should be run by the server but that does not communicate with it. This section describes how to write a daemon server plugin, using the example plugin found in the `plugin/daemon_example` directory of MySQL source distributions. That directory contains the `daemon_example.cc` source file for a daemon plugin named `daemon_example` that writes a heartbeat string at regular intervals to a file named `mysql-heartbeat.log` in the data directory.

To write a daemon plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <mysql/plugin.h>
```

`plugin.h` defines the `MYSQL_DAEMON_PLUGIN` server plugin type and the data structures needed to declare the plugin.

The `daemon_example.cc` file sets up the library descriptor as follows. The library descriptor includes a single general server plugin descriptor.

```
mysql_declare_plugin(daemon_example)
{
  MYSQL_DAEMON_PLUGIN,
  &daemon_example_plugin,
  "daemon_example",
  "Brian Aker",
  "Daemon example, creates a heartbeat beat file in mysql-heartbeat.log",
  PLUGIN_LICENSE_GPL,
  daemon_example_plugin_init, /* Plugin Init */
  daemon_example_plugin_deinit, /* Plugin Deinit */
  0x0100 /* 1.0 */,
  NULL,                       /* status variables              */
  NULL,                       /* system variables              */
  NULL                        /* config options                */
}
mysql_declare_plugin_end;
```

The `name` member (`daemon_example`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The second member of the plugin descriptor, `daemon_example_plugin`, points to the type-specific daemon plugin descriptor. This structure consists only of the type-specific API version number:

```
struct st_mysql_daemon daemon_example_plugin=
{ MYSQL_DAEMON_INTERFACE_VERSION  };
```

The type-specific structure has no interface functions. There is no communication between the server and the plugin, except that the server calls the initialization and deinitialization functions from the general plugin descriptor to start and stop the plugin:

- `daemon_example_plugin_init()` opens the heartbeat file and spawns a thread that wakes up periodically and writes the next message to the file.

- `daemon_example_plugin_deinit()` closes the file and performs other cleanup.

To compile and install a plugin library object file, use the instructions in Section 22.2.4.3, "Compiling and Installing Plugin Libraries". To make the library file available for use, install it in the plugin directory (the

directory named by the `plugin_dir` system variable). For the `daemon_example` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `libdaemon_example.so` (the `.so` suffix might differ depending on your platform).

To use the plugin, register it with the server. For example, to register the plugin at runtime, use this statement (change the suffix as necessary):

```
mysql> INSTALL PLUGIN daemon_example SONAME 'libdaemon_example.so';
```

For additional information about plugin loading, see Section 5.1.8.1, "Installing and Uninstalling Plugins".

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.1.8.2, "Obtaining Server Plugin Information".

While the plugin is loaded, it writes a heartbeat string at regular intervals to a file named `mysql-heartbeat.log` in the data directory. This file grows without limit, so after you have satistifed yourself that the plugin operates correctly, unload it:

```
mysql> UNINSTALL PLUGIN daemon_example;
```

22.2.4.6 Writing INFORMATION_SCHEMA Plugins

This section describes how to write a server-side `INFORMATION_SCHEMA` table plugin. For example code that implements such plugins, see the `sql/sql_show.cc` file of a MySQL source distribution. You can also look at the example plugins found in the `InnoDB` source. See the `handler/i_s.cc` and `handler/ha_innodb.cc` files within the `InnoDB` source tree (in the `storage/innodb_plugin` directory).

To write an `INFORMATION_SCHEMA` table plugin, include the following header files in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <sql_class.h>
#include <table.h>
```

These header files are located in the `sql` directory of MySQL source distributions. They contain C++ structures, so the source file for an `INFORMATION_SCHEMA` plugin must be compiled as C++ (not C) code.

The source file for the example plugin developed here is named `simple_i_s_table.cc`. It creates a simple `INFORMATION_SCHEMA` table named `SIMPLE_I_S_TABLE` that has two columns named `NAME` and `VALUE`. The general descriptor for a plugin library that implements the table looks like this:

```
mysql_declare_plugin(simple_i_s_library)
{
  MYSQL_INFORMATION_SCHEMA_PLUGIN,
  &simple_table_info,               /* type-specific descriptor */
  "SIMPLE_I_S_TABLE",               /* table name */
  "Author Name",                    /* author */
  "Simple INFORMATION_SCHEMA table", /* description */
  PLUGIN_LICENSE_GPL,               /* license type */
  simple_table_init,                /* init function */
  NULL,
  0x0100,                           /* version = 1.0 */
  NULL,                             /* no status variables */
  NULL,                             /* no system variables */
  NULL                              /* no reserved information */
}
```

```
mysql_declare_plugin_end;
```

The `name` member (`SIMPLE_I_S_TABLE`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The `simple_table_info` member of the general descriptor points to the type-specific descriptor, which consists only of the type-specific API version number:

```
static struct st_mysql_information_schema simple_table_info =
{ MYSQL_INFORMATION_SCHEMA_INTERFACE_VERSION };
```

The general descriptor points to the initialization and deinitialization functions:

- The initialization function provides information about the table structure and a function that populates the table.

- The deinitialization function performs any required cleanup. If no cleanup is needed, this descriptor member can be `NULL` (as in the example shown).

The initialization function should return 0 for success, 1 if an error occurs. The function receives a generic pointer, which it should interpret as a pointer to the table structure:

```
static int table_init(void *ptr)
{
  ST_SCHEMA_TABLE *schema_table= (ST_SCHEMA_TABLE*)ptr;

  schema_table->fields_info= simple_table_fields;
  schema_table->fill_table= simple_fill_table;
  return 0;
}
```

The function should set these two members of the table structure:

- `fields_info`: An array of `ST_FIELD_INFO` structures that contain information about each column.

- `fill_table`: A function that populates the table.

The array pointed to by `fields_info` should contain one element per column of the `INFORMATION_SCHEMA` plus a terminating element. The following `simple_table_fields` array for the example plugin indicates that `SIMPLE_I_S_TABLE` has two columns. `NAME` is string-valued with a length of 10 and `VALUE` is integer-valued with a display width of 20. The last structure marks the end of the array.

```
static ST_FIELD_INFO simple_table_fields[]=
{
  {"NAME", 10, MYSQL_TYPE_STRING, 0, 0 0, 0},
  {"VALUE", 6, MYSQL_TYPE_LONG, 0, MY_I_S_UNSIGNED, 0, 0},
  {0, 0, MYSQL_TYPE_NULL, 0, 0, 0, 0}
};
```

For more information about the column information structure, see the definition of `ST_FIELD_INFO` in the `table.h` header file. The permissible `MYSQL_TYPE_xxx` type values are those used in the C API; see Section 21.8.5, "C API Data Structures".

The `fill_table` member should be set to a function that populates the table and returns 0 for success, 1 if an error occurs. For the example plugin, the `simple_fill_table()` function looks like this:

```
static int simple_fill_table(THD *thd, TABLE_LIST *tables, COND *cond)
{
  TABLE *table= tables->table;

  table->field[0]->store("Name 1", 6, system_charset_info);
  table->field[1]->store(1);
  if (schema_table_store_record(thd, table))
    return 1;
  table->field[0]->store("Name 2", 6, system_charset_info);
  table->field[1]->store(2);
  if (schema_table_store_record(thd, table))
    return 1;
  return 0;
}
```

For each row of the INFORMATION_SCHEMA table, this function initializes each column, then calls schema_table_store_record() to install the row. The store() method arguments depend on the type of value to be stored. For column 0 (NAME, a string), store() takes a pointer to a string, its length, and information about the character set of the string:

```
store(const char *to, uint length, CHARSET_INFO *cs);
```

For column 1 (VALUE, an integer), store() takes the value and a flag indicating whether it is unsigned:

```
store(longlong nr, bool unsigned_value);
```

For other examples of how to populate INFORMATION_SCHEMA tables, search for instances of schema_table_store_record() in sql_show.cc.

To compile and install a plugin library object file, use the instructions in Section 22.2.4.3, "Compiling and Installing Plugin Libraries". To make the library file available for use, install it in the plugin directory (the directory named by the plugin_dir system variable).

To test the plugin, install it:

```
mysql> INSTALL PLUGIN SIMPLE_I_S_TABLE SONAME 'simple_i_s_table.so';
```

Verify that the table is present:

```
mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
    -> WHERE TABLE_NAME = 'SIMPLE_I_S_TABLE';
+------------------+
| TABLE_NAME       |
+------------------+
| SIMPLE_I_S_TABLE |
+------------------+
```

Try to select from it:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.SIMPLE_I_S_TABLE;
+--------+-------+
| NAME   | VALUE |
+--------+-------+
| Name 1 |     1 |
| Name 2 |     2 |
+--------+-------+
```

Uninstall it:

```
mysql> UNINSTALL PLUGIN SIMPLE_I_S_TABLE;
```

22.3 Adding New Functions to MySQL

There are three ways to add new functions to MySQL:

- You can add functions through the user-defined function (UDF) interface. User-defined functions are compiled as object files and then added to and removed from the server dynamically using the `CREATE FUNCTION` and `DROP FUNCTION` statements. See Section 13.7.3.1, "CREATE FUNCTION Syntax for User-Defined Functions".

- You can add functions as native (built-in) MySQL functions. Native functions are compiled into the `mysqld` server and become available on a permanent basis.

- Another way to add functions is by creating stored functions. These are written using SQL statements rather than by compiling object code. The syntax for writing stored functions is not covered here. See Section 19.2, "Using Stored Routines (Procedures and Functions)".

Each method of creating compiled functions has advantages and disadvantages:

- If you write user-defined functions, you must install object files in addition to the server itself. If you compile your function into the server, you don't need to do that.

- Native functions require you to modify a source distribution. UDFs do not. You can add UDFs to a binary MySQL distribution. No access to MySQL source is necessary.

- If you upgrade your MySQL distribution, you can continue to use your previously installed UDFs, unless you upgrade to a newer version for which the UDF interface changes. For native functions, you must repeat your modifications each time you upgrade.

Whichever method you use to add new functions, they can be invoked in SQL statements just like native functions such as `ABS()` or `SOUNDEX()`.

See Section 9.2.4, "Function Name Parsing and Resolution", for the rules describing how the server interprets references to different kinds of functions.

The following sections describe features of the UDF interface, provide instructions for writing UDFs, discuss security precautions that MySQL takes to prevent UDF misuse, and describe how to add native MySQL functions.

For example source code that illustrates how to write UDFs, take a look at the `sql/udf_example.c` file that is provided in MySQL source distributions.

22.3.1 Features of the User-Defined Function Interface

The MySQL interface for user-defined functions provides the following features and capabilities:

- Functions can return string, integer, or real values and can accept arguments of those same types.

- You can define simple functions that operate on a single row at a time, or aggregate functions that operate on groups of rows.

- Information is provided to functions that enables them to check the number, types, and names of the arguments passed to them.

- You can tell MySQL to coerce arguments to a given type before passing them to a function.

- You can indicate that a function returns `NULL` or that an error occurred.

22.3.2 Adding a New User-Defined Function

For the UDF mechanism to work, functions must be written in C or C++ and your operating system must support dynamic loading. MySQL source distributions include a file `sql/udf_example.c` that defines five UDF functions. Consult this file to see how UDF calling conventions work. The `include/mysql_com.h` header file defines UDF-related symbols and data structures, although you need not include this header file directly; it is included by `mysql.h`.

A UDF contains code that becomes part of the running server, so when you write a UDF, you are bound by any and all constraints that apply to writing server code. For example, you may have problems if you attempt to use functions from the `libstdc++` library. These constraints may change in future versions of the server, so it is possible that server upgrades will require revisions to UDFs that were originally written for older servers. For information about these constraints, see Section 2.11.4, "MySQL Source-Configuration Options", and Section 2.11.5, "Dealing with Problems Compiling MySQL".

To be able to use UDFs, you must link `mysqld` dynamically. Don't configure MySQL using `--with-mysqld-ldflags=-all-static`. If you want to use a UDF that needs to access symbols from `mysqld` (for example, the `metaphone` function in `sql/udf_example.c` uses `default_charset_info`), you must link the program with `-rdynamic` (see `man dlopen`). If you plan to use UDFs, the rule of thumb is to configure MySQL with `--with-mysqld-ldflags=-rdynamic` unless you have a very good reason not to.

For each function that you want to use in SQL statements, you should define corresponding C (or C++) functions. In the following discussion, the name "xxx" is used for an example function name. To distinguish between SQL and C/C++ usage, `XXX()` (uppercase) indicates an SQL function call, and `xxx()` (lowercase) indicates a C/C++ function call.

> **Note**
>
> When using C++ you can encapsulate your C functions within:
>
> ```
> extern "C" { ... }
> ```
>
> This ensures that your C++ function names remain readable in the completed UDF.

The following list describes the C/C++ functions that you write to implement the interface for a function named `XXX()`. The main function, `xxx()`, is required. In addition, a UDF requires at least one of the other functions described here, for reasons discussed in Section 22.3.2.6, "UDF Security Precautions".

- `xxx()`

  The main function. This is where the function result is computed. The correspondence between the SQL function data type and the return type of your C/C++ function is shown here.

SQL Type	C/C++ Type
STRING	char *
INTEGER	long long
REAL	double

  It is also possible to declare a `DECIMAL` function, but currently the value is returned as a string, so you should write the UDF as though it were a `STRING` function. `ROW` functions are not implemented.

- `xxx_init()`

The initialization function for `xxx()`. If present, it can be used for the following purposes:

- To check the number of arguments to `XXX()`.

- To verify that the arguments are of a required type or, alternatively, to tell MySQL to coerce arguments to the required types when the main function is called.

- To allocate any memory required by the main function.

- To specify the maximum length of the result.

- To specify (for `REAL` functions) the maximum number of decimal places in the result.

- To specify whether the result can be `NULL`.

- `xxx_deinit()`

  The deinitialization function for `xxx()`. If present, it should deallocate any memory allocated by the initialization function.

When an SQL statement invokes `XXX()`, MySQL calls the initialization function `xxx_init()` to let it perform any required setup, such as argument checking or memory allocation. If `xxx_init()` returns an error, MySQL aborts the SQL statement with an error message and does not call the main or deinitialization functions. Otherwise, MySQL calls the main function `xxx()` once for each row. After all rows have been processed, MySQL calls the deinitialization function `xxx_deinit()` so that it can perform any required cleanup.

For aggregate functions that work like `SUM()`, you must also provide the following functions:

- `xxx_clear()`

  Reset the current aggregate value but do not insert the argument as the initial aggregate value for a new group.

- `xxx_add()`

  Add the argument to the current aggregate value.

MySQL handles aggregate UDFs as follows:

1. Call `xxx_init()` to let the aggregate function allocate any memory it needs for storing results.

2. Sort the table according to the `GROUP BY` expression.

3. Call `xxx_clear()` for the first row in each new group.

4. Call `xxx_add()` for each row that belongs in the same group.

5. Call `xxx()` to get the result for the aggregate when the group changes or after the last row has been processed.

6. Repeat steps 3 to 5 until all rows has been processed

7. Call `xxx_deinit()` to let the UDF free any memory it has allocated.

All functions must be thread-safe. This includes not just the main function, but the initialization and deinitialization functions as well, and also the additional functions required by aggregate functions. A

consequence of this requirement is that you are not permitted to allocate any global or static variables that change! If you need memory, you should allocate it in `xxx_init()` and free it in `xxx_deinit()`.

22.3.2.1 UDF Calling Sequences for Simple Functions

This section describes the different functions that you need to define when you create a simple UDF. Section 22.3.2, "Adding a New User-Defined Function", describes the order in which MySQL calls these functions.

The main `xxx()` function should be declared as shown in this section. Note that the return type and parameters differ, depending on whether you declare the SQL function `XXX()` to return `STRING`, `INTEGER`, or `REAL` in the `CREATE FUNCTION` statement:

For `STRING` functions:

```
char *xxx(UDF_INIT *initid, UDF_ARGS *args,
          char *result, unsigned long *length,
          char *is_null, char *error);
```

For `INTEGER` functions:

```
long long xxx(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

For `REAL` functions:

```
double xxx(UDF_INIT *initid, UDF_ARGS *args,
           char *is_null, char *error);
```

`DECIMAL` functions return string values and should be declared the same way as `STRING` functions. `ROW` functions are not implemented.

The initialization and deinitialization functions are declared like this:

```
my_bool xxx_init(UDF_INIT *initid, UDF_ARGS *args, char *message);

void xxx_deinit(UDF_INIT *initid);
```

The `initid` parameter is passed to all three functions. It points to a `UDF_INIT` structure that is used to communicate information between functions. The `UDF_INIT` structure members follow. The initialization function should fill in any members that it wishes to change. (To use the default for a member, leave it unchanged.)

- `my_bool maybe_null`

  `xxx_init()` should set `maybe_null` to `1` if `xxx()` can return `NULL`. The default value is `1` if any of the arguments are declared `maybe_null`.

- `unsigned int decimals`

  The number of decimal digits to the right of the decimal point. The default value is the maximum number of decimal digits in the arguments passed to the main function. For example, if the function is passed `1.34`, `1.345`, and `1.3`, the default would be 3, because `1.345` has 3 decimal digits.

  For arguments that have no fixed number of decimals, the `decimals` value is set to 31, which is 1 more than the maximum number of decimals permitted for the `DECIMAL`, `FLOAT`, and `DOUBLE` data types.

A `decimals` value of 31 is used for arguments in cases such as a `FLOAT` or `DOUBLE` column declared without an explicit number of decimals (for example, `FLOAT` rather than `FLOAT(10,3)`) and for floating-point constants such as `1345E-3`. It is also used for string and other nonnumber arguments that might be converted within the function to numeric form.

The value to which the `decimals` member is initialized is only a default. It can be changed within the function to reflect the actual calculation performed. The default is determined such that the largest number of decimals of the arguments is used. If the number of decimals is 31 for even one of the arguments, that is the value used for `decimals`.

- `unsigned int max_length`

  The maximum length of the result. The default `max_length` value differs depending on the result type of the function. For string functions, the default is the length of the longest argument. For integer functions, the default is 21 digits. For real functions, the default is 13 plus the number of decimal digits indicated by `initid->decimals`. (For numeric functions, the length includes any sign or decimal point characters.)

  If you want to return a blob value, you can set `max_length` to 65KB or 16MB. This memory is not allocated, but the value is used to decide which data type to use if there is a need to temporarily store the data.

- `char *ptr`

  A pointer that the function can use for its own purposes. For example, functions can use `initid->ptr` to communicate allocated memory among themselves. `xxx_init()` should allocate the memory and assign it to this pointer:

  ```
  initid->ptr = allocated_memory;
  ```

  In `xxx()` and `xxx_deinit()`, refer to `initid->ptr` to use or deallocate the memory.

- `my_bool const_item`

  `xxx_init()` should set `const_item` to `1` if `xxx()` always returns the same value and to `0` otherwise.

22.3.2.2 UDF Calling Sequences for Aggregate Functions

This section describes the different functions that you need to define when you create an aggregate UDF. Section 22.3.2, "Adding a New User-Defined Function", describes the order in which MySQL calls these functions.

- `xxx_reset()`

  This function is called when MySQL finds the first row in a new group. It should reset any internal summary variables and then use the given `UDF_ARGS` argument as the first value in your internal summary value for the group. Declare `xxx_reset()` as follows:

  ```
  void xxx_reset(UDF_INIT *initid, UDF_ARGS *args,
                 char *is_null, char *error);
  ```

  `xxx_reset()` is not needed or used in MySQL 5.1, in which the UDF interface uses `xxx_clear()` instead. However, you can define both `xxx_reset()` and `xxx_clear()` if you want to have your UDF work with older versions of the server. (If you do include both functions, the `xxx_reset()` function in many cases can be implemented internally by calling `xxx_clear()` to reset all variables, and then calling `xxx_add()` to add the `UDF_ARGS` argument as the first value in the group.)

- `xxx_clear()`

  This function is called when MySQL needs to reset the summary results. It is called at the beginning for each new group but can also be called to reset the values for a query where there were no matching rows. Declare `xxx_clear()` as follows:

  ```
  void xxx_clear(UDF_INIT *initid, char *is_null, char *error);
  ```

  `is_null` is set to point to `CHAR(0)` before calling `xxx_clear()`.

  If something went wrong, you can store a value in the variable to which the `error` argument points. `error` points to a single-byte variable, not to a string buffer.

  `xxx_clear()` is required by MySQL 5.1.

- `xxx_add()`

  This function is called for all rows that belong to the same group. You should use it to add the value in the `UDF_ARGS` argument to your internal summary variable.

  ```
  void xxx_add(UDF_INIT *initid, UDF_ARGS *args,
               char *is_null, char *error);
  ```

The `xxx()` function for an aggregate UDF should be declared the same way as for a nonaggregate UDF. See Section 22.3.2.1, "UDF Calling Sequences for Simple Functions".

For an aggregate UDF, MySQL calls the `xxx()` function after all rows in the group have been processed. You should normally never access its `UDF_ARGS` argument here but instead return a value based on your internal summary variables.

Return value handling in `xxx()` should be done the same way as for a nonaggregate UDF. See Section 22.3.2.4, "UDF Return Values and Error Handling".

The `xxx_reset()` and `xxx_add()` functions handle their `UDF_ARGS` argument the same way as functions for nonaggregate UDFs. See Section 22.3.2.3, "UDF Argument Processing".

The pointer arguments to `is_null` and `error` are the same for all calls to `xxx_reset()`, `xxx_clear()`, `xxx_add()` and `xxx()`. You can use this to remember that you got an error or whether the `xxx()` function should return `NULL`. You should not store a string into `*error`! `error` points to a single-byte variable, not to a string buffer.

`*is_null` is reset for each group (before calling `xxx_clear()`). `*error` is never reset.

If `*is_null` or `*error` are set when `xxx()` returns, MySQL returns `NULL` as the result for the group function.

22.3.2.3 UDF Argument Processing

The `args` parameter points to a `UDF_ARGS` structure that has the members listed here:

- `unsigned int arg_count`

  The number of arguments. Check this value in the initialization function if you require your function to be called with a particular number of arguments. For example:

  ```
  if (args->arg_count != 2)
  {
  ```

```
    strcpy(message,"XXX() requires two arguments");
    return 1;
}
```

For other `UDF_ARGS` member values that are arrays, array references are zero-based. That is, refer to array members using index values from 0 to `args->arg_count` − 1.

- `enum Item_result *arg_type`

  A pointer to an array containing the types for each argument. The possible type values are `STRING_RESULT`, `INT_RESULT`, `REAL_RESULT`, and `DECIMAL_RESULT`.

  To make sure that arguments are of a given type and return an error if they are not, check the `arg_type` array in the initialization function. For example:

  ```
  if (args->arg_type[0] != STRING_RESULT ||
      args->arg_type[1] != INT_RESULT)
  {
      strcpy(message,"XXX() requires a string and an integer");
      return 1;
  }
  ```

  Arguments of type `DECIMAL_RESULT` are passed as strings, so you should handle them the same way as `STRING_RESULT` values.

  As an alternative to requiring your function's arguments to be of particular types, you can use the initialization function to set the `arg_type` elements to the types you want. This causes MySQL to coerce arguments to those types for each call to `xxx()`. For example, to specify that the first two arguments should be coerced to string and integer, respectively, do this in `xxx_init()`:

  ```
  args->arg_type[0] = STRING_RESULT;
  args->arg_type[1] = INT_RESULT;
  ```

  Exact-value decimal arguments such as `1.3` or `DECIMAL` column values are passed with a type of `DECIMAL_RESULT`. However, the values are passed as strings. If you want to receive a number, use the initialization function to specify that the argument should be coerced to a `REAL_RESULT` value:

  ```
  args->arg_type[2] = REAL_RESULT;
  ```

- `char **args`

  `args->args` communicates information to the initialization function about the general nature of the arguments passed to your function. For a constant argument `i`, `args->args[i]` points to the argument value. (See later for instructions on how to access the value properly.) For a nonconstant argument, `args->args[i]` is `0`. A constant argument is an expression that uses only constants, such as `3` or `4*7-2` or `SIN(3.14)`. A nonconstant argument is an expression that refers to values that may change from row to row, such as column names or functions that are called with nonconstant arguments.

  For each invocation of the main function, `args->args` contains the actual arguments that are passed for the row currently being processed.

  If argument `i` represents `NULL`, `args->args[i]` is a null pointer (0). If the argument is not `NULL`, functions can refer to it as follows:

- An argument of type `STRING_RESULT` is given as a string pointer plus a length, to enable handling of binary data or data of arbitrary length. The string contents are available as `args->args[i]` and the string length is `args->lengths[i]`. Do not assume that the string is null-terminated.

- For an argument of type `INT_RESULT`, you must cast `args->args[i]` to a `long long` value:

```
long long int_val;
int_val = *((long long*) args->args[i]);
```

- For an argument of type `REAL_RESULT`, you must cast `args->args[i]` to a `double` value:

```
double    real_val;
real_val = *((double*) args->args[i]);
```

- For an argument of type `DECIMAL_RESULT`, the value is passed as a string and should be handled like a `STRING_RESULT` value.

- `ROW_RESULT` arguments are not implemented.

- `unsigned long *lengths`

  For the initialization function, the `lengths` array indicates the maximum string length for each argument. You should not change these. For each invocation of the main function, `lengths` contains the actual lengths of any string arguments that are passed for the row currently being processed. For arguments of types `INT_RESULT` or `REAL_RESULT`, `lengths` still contains the maximum length of the argument (as for the initialization function).

- `char *maybe_null`

  For the initialization function, the `maybe_null` array indicates for each argument whether the argument value might be null (0 if no, 1 if yes).

- `char **attributes`

  `args->attributes` communicates information about the names of the UDF arguments. For argument `i`, the attribute name is available as a string in `args->attributes[i]` and the attribute length is `args->attribute_lengths[i]`. Do not assume that the string is null-terminated.

  By default, the name of a UDF argument is the text of the expression used to specify the argument. For UDFs, an argument may also have an optional `[AS]` *alias_name* clause, in which case the argument name is *alias_name*. The `attributes` value for each argument thus depends on whether an alias was given.

  Suppose that a UDF `my_udf()` is invoked as follows:

```
SELECT my_udf(expr1, expr2 AS alias1, expr3 alias2);
```

  In this case, the `attributes` and `attribute_lengths` arrays will have these values:

```
args->attributes[0] = "expr1"
args->attribute_lengths[0] = 5

args->attributes[1] = "alias1"
args->attribute_lengths[1] = 6
```

```
args->attributes[2] = "alias2"
args->attribute_lengths[2] = 6
```

- `unsigned long *attribute_lengths`

  The `attribute_lengths` array indicates the length of each argument name.

22.3.2.4 UDF Return Values and Error Handling

The initialization function should return `0` if no error occurred and `1` otherwise. If an error occurs, `xxx_init()` should store a null-terminated error message in the `message` parameter. The message is returned to the client. The message buffer is `MYSQL_ERRMSG_SIZE` characters long, but you should try to keep the message to less than 80 characters so that it fits the width of a standard terminal screen.

The return value of the main function `xxx()` is the function value, for `long long` and `double` functions. A string function should return a pointer to the result and set `*length` to the length (in bytes) of the return value. For example:

```
memcpy(result, "result string", 13);
*length = 13;
```

MySQL passes a buffer to the `xxx()` function using the `result` parameter. This buffer is sufficiently long to hold 255 characters, which can be multibyte characters. The `xxx()` function can store the result in this buffer if it fits, in which case the return value should be a pointer to the buffer. If the function stores the result in a different buffer, it should return a pointer to that buffer.

If your string function does not use the supplied buffer (for example, if it needs to return a string longer than 255 characters), you must allocate the space for your own buffer with `malloc()` in your `xxx_init()` function or your `xxx()` function and free it in your `xxx_deinit()` function. You can store the allocated memory in the `ptr` slot in the `UDF_INIT` structure for reuse by future `xxx()` calls. See Section 22.3.2.1, "UDF Calling Sequences for Simple Functions".

To indicate a return value of `NULL` in the main function, set `*is_null` to `1`:

```
*is_null = 1;
```

To indicate an error return in the main function, set `*error` to `1`:

```
*error = 1;
```

If `xxx()` sets `*error` to `1` for any row, the function value is `NULL` for the current row and for any subsequent rows processed by the statement in which `XXX()` was invoked. (`xxx()` is not even called for subsequent rows.)

22.3.2.5 UDF Compiling and Installing

Files implementing UDFs must be compiled and installed on the host where the server runs. This process is described below for the example UDF file `sql/udf_example.c` that is included in MySQL source distributions.

If a UDF will be referred to in statements that will be replicated to slave servers, you must ensure that every slave also has the function available. Otherwise, replication will fail on the slaves when they attempt to invoke the function.

The immediately following instructions are for Unix. Instructions for Windows are given later in this section.

The `udf_example.c` file contains the following functions:

- `metaphon()` returns a metaphon string of the string argument. This is something like a soundex string, but it is more tuned for English.

- `myfunc_double()` returns the sum of the ASCII values of the characters in its arguments, divided by the sum of the length of its arguments.

- `myfunc_int()` returns the sum of the length of its arguments.

- `sequence([const int])` returns a sequence starting from the given number or 1 if no number has been given.

- `lookup()` returns the IP address for a host name.

- `reverse_lookup()` returns the host name for an IP address. The function may be called either with a single string argument of the form `'xxx.xxx.xxx.xxx'` or with four numbers.

- `avgcost()` returns an average cost. This is an aggregate function.

A dynamically loadable file should be compiled as a sharable object file, using a command something like this:

```
shell> gcc -shared -o udf_example.so udf_example.c
```

If you are using `gcc` with `configure` and `libtool` (which is how MySQL is configured), you should be able to create `udf_example.so` with a simpler command:

```
shell> make udf_example.la
```

After you compile a shared object containing UDFs, you must install it and tell MySQL about it. Compiling a shared object from `udf_example.c` using `gcc` directly produces a file named `udf_example.so`. Compiling the shared object using `make` produces a file named something like `udf_example.so.0.0.0` in the `.libs` directory (the exact name may vary from platform to platform). Copy the shared object to the server's plugin directory and name it `udf_example.so`. This directory is given by the value of the `plugin_dir` system variable.

> **Note**
>
> This is a change in MySQL 5.1. For earlier versions of MySQL, the shared object can be located in any directory that is searched by your system's dynamic linker.

On some systems, the `ldconfig` program that configures the dynamic linker does not recognize a shared object unless its name begins with `lib`. In this case you should rename a file such as `udf_example.so` to `libudf_example.so`.

On Windows, you can compile user-defined functions by using the following procedure:

1. Obtain the development source for MySQL 5.1. See Section 2.1.2, "How to Get MySQL".

2. Obtain the `CMake` build utility, if necessary, from http://www.cmake.org. (Version 2.6 or later is required).

3. In the source tree, look in the `sql` directory. There are files named `udf_example.def` `udf_example.c` there. Copy both files from this directory to your working directory.

4. Create a `CMake makefile` (`CMakeLists.txt`) with these contents:

```
PROJECT(udf_example)

# Path for MySQL include directory
INCLUDE_DIRECTORIES("c:/mysql/include")

ADD_DEFINITIONS("-DHAVE_DLOPEN")
ADD_LIBRARY(udf_example MODULE udf_example.c udf_example.def)
TARGET_LINK_LIBRARIES(udf_example wsock32)
```

5. Create the VC project and solution files:

```
cmake -G "<Generator>"
```

Invoking `cmake --help` shows you a list of valid Generators.

6. Create `udf_example.dll`:

```
devenv udf_example.sln /build Release
```

After the shared object file has been installed, notify `mysqld` about the new functions with the following statements. If object files have a suffix different from `.so` on your system, substitute the correct suffix throughout (for example, `.dll` on Windows).

```
mysql> CREATE FUNCTION metaphon RETURNS STRING SONAME 'udf_example.so';
mysql> CREATE FUNCTION myfunc_double RETURNS REAL SONAME 'udf_example.so';
mysql> CREATE FUNCTION myfunc_int RETURNS INTEGER SONAME 'udf_example.so';
mysql> CREATE FUNCTION sequence RETURNS INTEGER SONAME 'udf_example.so';
mysql> CREATE FUNCTION lookup RETURNS STRING SONAME 'udf_example.so';
mysql> CREATE FUNCTION reverse_lookup
    ->         RETURNS STRING SONAME 'udf_example.so';
mysql> CREATE AGGREGATE FUNCTION avgcost
    ->         RETURNS REAL SONAME 'udf_example.so';
```

Once installed, a function remains installed until it is uninstalled.

To delete functions, use `DROP FUNCTION`:

```
mysql> DROP FUNCTION metaphon;
mysql> DROP FUNCTION myfunc_double;
mysql> DROP FUNCTION myfunc_int;
mysql> DROP FUNCTION sequence;
mysql> DROP FUNCTION lookup;
mysql> DROP FUNCTION reverse_lookup;
mysql> DROP FUNCTION avgcost;
```

The `CREATE FUNCTION` and `DROP FUNCTION` statements update the `func` system table in the `mysql` database. The function's name, type and shared library name are saved in the table. You must have the `INSERT` or `DELETE` privilege for the `mysql` database to create or drop functions, respectively.

You should not use `CREATE FUNCTION` to add a function that has previously been created. If you need to reinstall a function, you should remove it with `DROP FUNCTION` and then reinstall it with `CREATE FUNCTION`. You would need to do this, for example, if you recompile a new version of your function, so that `mysqld` gets the new version. Otherwise, the server continues to use the old version.

An active function is one that has been loaded with `CREATE FUNCTION` and not removed with `DROP FUNCTION`. All active functions are reloaded each time the server starts, unless you start `mysqld` with the `--skip-grant-tables` option. In this case, UDF initialization is skipped and UDFs are unavailable.

22.3.2.6 UDF Security Precautions

MySQL takes several measures to prevent misuse of user-defined functions.

UDF object files cannot be placed in arbitrary directories. They must be located in the server's plugin directory. This directory is given by the value of the `plugin_dir` system variable.

> **Note**
>
> This is a change in MySQL 5.1. For earlier versions of MySQL, the shared object can be located in any directory that is searched by your system's dynamic linker.

To use `CREATE FUNCTION` or `DROP FUNCTION`, you must have the `INSERT` or `DELETE` privilege, respectively, for the `mysql` database. This is necessary because those statements add and delete rows from the `mysql.func` table.

UDFs should have at least one symbol defined in addition to the `xxx` symbol that corresponds to the main `xxx()` function. These auxiliary symbols correspond to the `xxx_init()`, `xxx_deinit()`, `xxx_reset()`, `xxx_clear()`, and `xxx_add()` functions. `mysqld` also supports an `--allow-suspicious-udfs` option that controls whether UDFs that have only an `xxx` symbol can be loaded. By default, the option is off, to prevent attempts at loading functions from shared object files other than those containing legitimate UDFs. If you have older UDFs that contain only the `xxx` symbol and that cannot be recompiled to include an auxiliary symbol, it may be necessary to specify the `--allow-suspicious-udfs` option. Otherwise, you should avoid enabling this capability.

22.3.3 Adding a New Native Function

To add a new native MySQL function, use the procedure described here, which requires that you use a source distribution. You cannot add native functions to a binary distribution because it is necessary to modify MySQL source code and compile MySQL from the modified source. If you migrate to another version of MySQL (for example, when a new version is released), you must repeat the procedure with the new version.

If the new native function will be referred to in statements that will be replicated to slave servers, you must ensure that every slave server also has the function available. Otherwise, replication will fail on the slaves when they attempt to invoke the function.

To add a new native function, follow these steps to modify source files in the `sql` directory. For MySQL 5.1, the first two steps apply only as of 5.1.13. For older versions, see the instructions in the corresponding section of the MySQL 5.0 manual.

1. Create a subclass for the function in `item_create.cc`:

    *   If the function takes a fixed number of arguments, create a subclass of `Create_func_arg0`, `Create_func_arg1`, `Create_func_arg2`, or `Create_func_arg3`, respectively, depending on whether the function takes zero, one, two, or three arguments. For examples, see the `Create_func_uuid`, `Create_func_abs`, `Create_func_pow`, and `Create_func_lpad` classes.

    *   If the function takes a variable number of arguments, create a subclass of `Create_native_func`. For an example, see `Create_func_concat`.

2. To provide a name by which the function can be referred to in SQL statements, register the name in `item_create.cc` by adding a line to this array:

```
static Native_func_registry func_array[]
```

You can register several names for the same function. For example, see the lines for `"LCASE"` and `"LOWER"`, which are aliases for `Create_func_lcase`.

3. In `item_func.h`, declare a class inheriting from `Item_num_func` or `Item_str_func`, depending on whether your function returns a number or a string.

4. In `item_func.cc`, add one of the following declarations, depending on whether you are defining a numeric or string function:

```
double   Item_func_newname::val()
longlong Item_func_newname::val_int()
String  *Item_func_newname::Str(String *str)
```

If you inherit your object from any of the standard items (like `Item_num_func`), you probably only have to define one of these functions and let the parent object take care of the other functions. For example, the `Item_str_func` class defines a `val()` function that executes `atof()` on the value returned by `::str()`.

5. If the function is nondeterministic, include the following statement in the item constructor to indicate that function results should not be cached:

```
current_thd->lex->safe_to_cache_query=0;
```

A function is nondeterministic if, given fixed values for its arguments, it can return different results for different invocations.

6. You should probably also define the following object function:

```
void Item_func_newname::fix_length_and_dec()
```

This function should at least calculate `max_length` based on the given arguments. `max_length` is the maximum number of characters the function may return. This function should also set `maybe_null = 0` if the main function can't return a `NULL` value. The function can check whether any of the function arguments can return `NULL` by checking the arguments' `maybe_null` variable. Look at `Item_func_mod::fix_length_and_dec` for a typical example of how to do this.

All functions must be thread-safe. In other words, do not use any global or static variables in the functions without protecting them with mutexes.

If you want to return `NULL` from `::val()`, `::val_int()`, or `::str()`, you should set `null_value` to 1 and return 0.

For `::str()` object functions, there are additional considerations to be aware of:

- The `String *str` argument provides a string buffer that may be used to hold the result. (For more information about the `String` type, take a look at the `sql_string.h` file.)

- The `::str()` function should return the string that holds the result, or `(char*) 0` if the result is `NULL`.

- All current string functions try to avoid allocating any memory unless absolutely necessary!

22.4 Debugging and Porting MySQL

This section helps you port MySQL to other operating systems. Do check the list of currently supported operating systems first. See Section 2.1, "General Installation Guidance". If you have created a new port

of MySQL, please let us know so that we can list it here and on our Web site (http://www.mysql.com/), recommending it to other users.

> **Note**
>
> If you create a new port of MySQL, you are free to copy and distribute it under the GPL license, but it does not make you a copyright holder of MySQL.

A working POSIX thread library is needed for the server.

Both the server and the client need a working C++ compiler. We use `gcc` on many platforms. Other compilers that are known to work are Sun Studio, HP-UX `aCC`, IBM AIX `xlC_r`), Intel `ecc/icc`. With previous versions on the respective platforms, we also used Irix `cc` and Compaq `cxx`.

> **Important**
>
> If you are trying to build MySQL 5.1 with `icc` on the IA64 platform, and need support for MySQL Cluster, you should first ensure that you are using `icc` version 9.1.043 or later. (For details, see Bug #21875.)

To compile only the client, use `./configure --without-server`.

If you want or need to change any `Makefile` or the `configure` script, you also need GNU Automake and Autoconf. See Section 2.11.3, "Installing MySQL Using a Development Source Tree".

All steps needed to remake everything from the most basic files.

```
/bin/rm */.deps/*.P
/bin/rm -f config.cache
aclocal
autoheader
aclocal
automake
autoconf
./configure --with-debug=full --prefix='your installation directory'

# The makefiles generated above need GNU make 3.75 or newer.
# (called gmake below)
gmake clean all install init-db
```

If you run into problems with a new port, you may have to do some debugging of MySQL! See Section 22.4.1, "Debugging a MySQL Server".

> **Note**
>
> Before you start debugging `mysqld`, first get the test programs `mysys/thr_alarm` and `mysys/thr_lock` to work. This ensures that your thread installation has even a remote chance to work!

22.4.1 Debugging a MySQL Server

If you are using some functionality that is very new in MySQL, you can try to run `mysqld` with the `--skip-new` (which disables all new, potentially unsafe functionality). See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

Binary distributions of MySQL server from Oracle include a specific debug binary, `mysqld-debug`. This is a build including the debugging information and is built in the same way as the debug build format

described in Section 22.4.1.1, "Compiling MySQL for Debugging". You should use this build when debugging the MySQL server.

If `mysqld` doesn't want to start, you should verify that you don't have any `my.cnf` files that interfere with your setup! You can check your `my.cnf` arguments with `mysqld --print-defaults` and avoid using them by starting with `mysqld --no-defaults ...`.

If `mysqld` starts to eat up CPU or memory or if it "hangs," you can use `mysqladmin processlist status` to find out if someone is executing a query that takes a long time. It may be a good idea to run `mysqladmin -i10 processlist status` in some window if you are experiencing performance problems or problems when new clients can't connect.

The command `mysqladmin debug` dumps some information about locks in use, used memory and query usage to the MySQL log file. This may help solve some problems. This command also provides some useful information even if you haven't compiled MySQL for debugging!

If the problem is that some tables are getting slower and slower you should try to optimize the table with `OPTIMIZE TABLE` or `myisamchk`. See Chapter 5, *MySQL Server Administration*. You should also check the slow queries with `EXPLAIN`.

You should also read the OS-specific section in this manual for problems that may be unique to your environment. See Section 2.1, "General Installation Guidance".

22.4.1.1 Compiling MySQL for Debugging

If you have some very specific problem, you can always try to debug MySQL. To do this you must configure MySQL with the `--with-debug` or the `--with-debug=full` option. You can check whether MySQL was compiled with debugging by doing: `mysqld --help`. If the `--debug` flag is listed with the options then you have debugging enabled. `mysqladmin ver` also lists the `mysqld` version as `mysql ... --debug` in this case.

If you are using `gcc`, the recommended `configure` line is:

```
CC=gcc CFLAGS="-O2" CXX=gcc CXXFLAGS="-O2 -felide-constructors \
   -fno-exceptions -fno-rtti" ./configure --prefix=/usr/local/mysql \
   --with-debug --with-extra-charsets=complex
```

This avoids problems with the `libstdc++` library and with C++ exceptions (many compilers have problems with C++ exceptions in threaded code) and compile a MySQL version with support for all character sets.

If you suspect a memory overrun error, you can configure MySQL with `--with-debug=full`, which installs a memory allocation (`SAFEMALLOC`) checker. However, running with `SAFEMALLOC` is quite slow, so if you get performance problems you should start `mysqld` with the `--skip-safemalloc` option. This disables the memory overrun checks for each call to `malloc()` and `free()`.

If `mysqld` stops crashing when you compile it with `--with-debug`, you probably have found a compiler bug or a timing bug within MySQL. In this case, you can try to add `-g` to the `CFLAGS` and `CXXFLAGS` variables above and not use `--with-debug`. If `mysqld` dies, you can at least attach to it with `gdb` or use `gdb` on the core file to find out what happened.

When you configure MySQL for debugging you automatically enable a lot of extra safety check functions that monitor the health of `mysqld`. If they find something "unexpected," an entry is written to `stderr`, which `mysqld_safe` directs to the error log! This also means that if you are having some unexpected problems with MySQL and are using a source distribution, the first thing you should do is to configure

MySQL for debugging! (The second thing is to send mail to a MySQL mailing list and ask for help. See Section 1.6.1, "MySQL Mailing Lists". If you believe that you have found a bug, please use the instructions at Section 1.7, "How to Report Bugs or Problems".

In the Windows MySQL distribution, `mysqld.exe` is by default compiled with support for trace files.

22.4.1.2 Creating Trace Files

If the `mysqld` server doesn't start or if you can cause it to crash quickly, you can try to create a trace file to find the problem.

To do this, you must have a `mysqld` that has been compiled with debugging support. You can check this by executing `mysqld -V`. If the version number ends with `-debug`, it is compiled with support for trace files. (On Windows, the debugging server is named `mysqld-debug` rather than `mysqld`.)

Start the `mysqld` server with a trace log in `/tmp/mysqld.trace` on Unix or `\mysqld.trace` on Windows:

```
shell> mysqld --debug
```

On Windows, you should also use the `--standalone` flag to not start `mysqld` as a service. In a console window, use this command:

```
C:\> mysqld-debug --debug --standalone
```

After this, you can use the `mysql.exe` command-line tool in a second console window to reproduce the problem. You can stop the `mysqld` server with `mysqladmin shutdown`.

The trace file can become **very large**! To generate a smaller trace file, you can use debugging options something like this:

```
mysqld --debug=d,info,error,query,general,where:O,/tmp/mysqld.trace
```

This only prints information with the most interesting tags to the trace file.

If you make a bug report about this, please only send the lines from the trace file to the appropriate mailing list where something seems to go wrong! If you can't locate the wrong place, you can open a bug report and upload the trace file to the report, so that a MySQL developer can take a look at it. For instructions, see Section 1.7, "How to Report Bugs or Problems".

The trace file is made with the **DBUG** package by Fred Fish. See Section 22.4.3, "The DBUG Package".

22.4.1.3 Using pdb to create a Windows crashdump

Starting with MySQL 5.1.12 the Program Database files (extension `pdb`) are included in the Noinstall distribution of MySQL. These files provide information for debugging your MySQL installation in the event of a problem.

The PDB file contains more detailed information about `mysqld` and other tools that enables more detailed trace and dump files to be created. You can use these with Dr Watson, `WinDbg` and Visual Studio to debug `mysqld`.

For more information on PDB files, see Microsoft Knowledge Base Article 121366. For more information on the debugging options available, see Debugging Tools for Windows.

Dr Watson is installed with all Windows distributions, but if you have installed Windows development tools, Dr Watson may have been replaced with WinDbg, the debugger included with Visual Studio, or the debugging tools provided with Borland or Delphi.

To generate a crash file using Dr Watson, follow these steps:

1. Start Dr Watson by running `drwtsn32.exe` interactively using the `-i` option:

   ```
   C:\> drwtsn32 -i
   ```

2. Set the **Log File Path** to the directory where you want to store trace files.

3. Make sure **Dump All Thread Contexts** and **Append To Existing Log File**.

4. Uncheck **Dump Symbol Table**, **Visual Notification**, **Sound Notification** and **Create Crash Dump File**.

5. Set the **Number of Instructions** to a suitable value to capture enough calls in the stacktrace. A value of at 25 should be enough.

Note that the file generated can become very large.

22.4.1.4 Debugging mysqld under gdb

On most systems you can also start `mysqld` from `gdb` to get more information if `mysqld` crashes.

With some older `gdb` versions on Linux you must use `run --one-thread` if you want to be able to debug `mysqld` threads. In this case, you can only have one thread active at a time. It is best to upgrade to `gdb` 5.1 because thread debugging works much better with this version!

NPTL threads (the new thread library on Linux) may cause problems while running `mysqld` under `gdb`. Some symptoms are:

- `mysqld` hangs during startup (before it writes `ready for connections`).

- `mysqld` crashes during a `pthread_mutex_lock()` or `pthread_mutex_unlock()` call.

In this case, you should set the following environment variable in the shell before starting `gdb`:

```
LD_ASSUME_KERNEL=2.4.1
export LD_ASSUME_KERNEL
```

When running `mysqld` under `gdb`, you should disable the stack trace with `--skip-stack-trace` to be able to catch segfaults within `gdb`.

Use the `--gdb` option to `mysqld` to install an interrupt handler for `SIGINT` (needed to stop `mysqld` with `^C` to set breakpoints) and disable stack tracing and core file handling.

It is very hard to debug MySQL under `gdb` if you do a lot of new connections the whole time as `gdb` doesn't free the memory for old threads. You can avoid this problem by starting `mysqld` with `thread_cache_size` set to a value equal to `max_connections` + 1. In most cases just using `--thread_cache_size=5'` helps a lot!

If you want to get a core dump on Linux if `mysqld` dies with a SIGSEGV signal, you can start `mysqld` with the `--core-file` option. This core file can be used to make a backtrace that may help you find out why `mysqld` died:

```
shell> gdb mysqld core
gdb>    backtrace full
gdb>    quit
```

See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

If you are using gdb 4.17.x or above on Linux, you should install a .gdb file, with the following information, in your current directory:

```
set print sevenbit off
handle SIGUSR1 nostop noprint
handle SIGUSR2 nostop noprint
handle SIGWAITING nostop noprint
handle SIGLWP nostop noprint
handle SIGPIPE nostop
handle SIGALRM nostop
handle SIGHUP nostop
handle SIGTERM nostop noprint
```

If you have problems debugging threads with gdb, you should download gdb 5.x and try this instead. The new gdb version has very improved thread handling!

Here is an example how to debug mysqld:

```
shell> gdb /usr/local/libexec/mysqld
gdb> run
...
backtrace full # Do this when mysqld crashes
```

Include the preceding output in a bug report, which you can file using the instructions in Section 1.7, "How to Report Bugs or Problems".

If mysqld hangs, you can try to use some system tools like strace or /usr/proc/bin/pstack to examine where mysqld has hung.

```
strace /tmp/log libexec/mysqld
```

If you are using the Perl DBI interface, you can turn on debugging information by using the trace method or by setting the DBI_TRACE environment variable.

22.4.1.5 Using a Stack Trace

On some operating systems, the error log contains a stack trace if mysqld dies unexpectedly. You can use this to find out where (and maybe why) mysqld died. See Section 5.4.2, "The Error Log". To get a stack trace, you must not compile mysqld with the -fomit-frame-pointer option to gcc. See Section 22.4.1.1, "Compiling MySQL for Debugging".

A stack trace in the error log looks something like this:

```
mysqld got signal 11;
Attempting backtrace. You can use the following information
to find out where mysqld died. If you see no messages after
this, something went terribly wrong...

stack_bottom = 0x41fd0110 thread_stack 0x40000
mysqld(my_print_stacktrace+0x32)[0x9da402]
mysqld(handle_segfault+0x28a)[0x6648e9]
/lib/libpthread.so.0[0x7f1a5af000f0]
```

```
/lib/libc.so.6(strcmp+0x2)[0x7f1a5a10f0f2]
mysqld(_Z21check_change_passwordP3THDPKcS2_Pcj+0x7c)[0x7412cb]
mysqld(_ZN16set_var_password5checkEP3THD+0xd0)[0x688354]
mysqld(_Z17sql_set_variablesP3THDP4ListI12set_var_baseE+0x68)[0x688494]
mysqld(_Z21mysql_execute_commandP3THD+0x41a0)[0x67a170]
mysqld(_Z11mysql_parseP3THDPKcjPS2_+0x282)[0x67f0ad]
mysqld(_Z16dispatch_command19enum_server_commandP3THDPcj+0xbb7[0x67fdf8]
mysqld(_Z10do_commandP3THD+0x24d)[0x6811b6]
mysqld(handle_one_connection+0x11c)[0x66e05e]
```

If resolution of function names for the trace fails, the trace contains less information:

```
mysqld got signal 11;
Attempting backtrace. You can use the following information
to find out where mysqld died. If you see no messages after
this, something went terribly wrong...

stack_bottom = 0x41fd0110 thread_stack 0x40000
[0x9da402]
[0x6648e9]
[0x7f1a5af000f0]
[0x7f1a5a10f0f2]
[0x7412cb]
[0x688354]
[0x688494]
[0x67a170]
[0x67f0ad]
[0x67fdf8]
[0x6811b6]
[0x66e05e]
```

In the latter case, you can use the `resolve_stack_dump` utility to determine where `mysqld` died by using the following procedure:

1. Copy the numbers from the stack trace to a file, for example `mysqld.stack`. The numbers should not include the surrounding square brackets:

   ```
   0x9da402
   0x6648e9
   0x7f1a5af000f0
   0x7f1a5a10f0f2
   0x7412cb
   0x688354
   0x688494
   0x67a170
   0x67f0ad
   0x67fdf8
   0x6811b6
   0x66e05e
   ```

2. Make a symbol file for the `mysqld` server:

   ```
   shell> nm -n libexec/mysqld > /tmp/mysqld.sym
   ```

   If `mysqld` is not linked statically, use the following command instead:

   ```
   shell> nm -D -n libexec/mysqld > /tmp/mysqld.sym
   ```

   If you want to decode C++ symbols, use the `--demangle`, if available, to `nm`. If your version of `nm` does not have this option, you will need to use the `c++filt` command after the stack dump has been produced to demangle the C++ names.

3. Execute the following command:

```
shell> resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack
```

If you were not able to include demangled C++ names in your symbol file, process the `resolve_stack_dump` output using `c++filt`:

```
shell> resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack | c++filt
```

This prints out where `mysqld` died. If that does not help you find out why `mysqld` died, you should create a bug report and include the output from the preceding command with the bug report.

However, in most cases it does not help us to have just a stack trace to find the reason for the problem. To be able to locate the bug or provide a workaround, in most cases we need to know the statement that killed `mysqld` and preferably a test case so that we can repeat the problem! See Section 1.7, "How to Report Bugs or Problems".

22.4.1.6 Using Server Logs to Find Causes of Errors in mysqld

Note that before starting `mysqld` with the general query log enabled, you should check all your tables with `myisamchk`. See Chapter 5, *MySQL Server Administration*.

If `mysqld` dies or hangs, you should start `mysqld` with the general query log enabled. See Section 5.4.3, "The General Query Log". When `mysqld` dies again, you can examine the end of the log file for the query that killed `mysqld`.

If you use the default general query log file, the log is stored in the database directory as `host_name.log` In most cases it is the last query in the log file that killed `mysqld`, but if possible you should verify this by restarting `mysqld` and executing the found query from the `mysql` command-line tools. If this works, you should also test all complicated queries that didn't complete.

You can also try the command `EXPLAIN` on all `SELECT` statements that takes a long time to ensure that `mysqld` is using indexes properly. See Section 13.8.2, "EXPLAIN Syntax".

You can find the queries that take a long time to execute by starting `mysqld` with the slow query log enabled. See Section 5.4.5, "The Slow Query Log".

If you find the text `mysqld restarted` in the error log file (normally named `hostname.err`) you probably have found a query that causes `mysqld` to fail. If this happens, you should check all your tables with `myisamchk` (see Chapter 5, *MySQL Server Administration*), and test the queries in the MySQL log files to see whether one fails. If you find such a query, try first upgrading to the newest MySQL version. If this doesn't help and you can't find anything in the `mysql` mail archive, you should report the bug to a MySQL mailing list. The mailing lists are described at http://lists.mysql.com/, which also has links to online list archives.

If you have started `mysqld` with `--myisam-recover`, MySQL automatically checks and tries to repair `MyISAM` tables if they are marked as 'not closed properly' or 'crashed'. If this happens, MySQL writes an entry in the `hostname.err` file `'Warning: Checking table ...'` which is followed by `Warning: Repairing table` if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further. See Section 5.1.3, "Server Command Options".

It is not a good sign if `mysqld` did die unexpectedly, but in this case, you should not investigate the `Checking table...` messages, but instead try to find out why `mysqld` died.

22.4.1.7 Making a Test Case If You Experience Table Corruption

The following procedure applies to `MyISAM` tables. For information about steps to take when encountering `InnoDB` table corruption, see Section 1.7, "How to Report Bugs or Problems".

If you encounter corrupted `MyISAM` tables or if `mysqld` always fails after some update statements, you can test whether the issue is reproducible by doing the following:

1. Stop the MySQL daemon with `mysqladmin shutdown`.

2. Make a backup of the tables to guard against the very unlikely case that the repair does something bad.

3. Check all tables with `myisamchk -s database/*.MYI`. Repair any corrupted tables with `myisamchk -r database/table.MYI`.

4. Make a second backup of the tables.

5. Remove (or move away) any old log files from the MySQL data directory if you need more space.

6. Start `mysqld` with the binary log enabled. If you want to find a statement that crashes `mysqld`, you should start the server with the general query log enabled as well. See Section 5.4.3, "The General Query Log", and Section 5.4.4, "The Binary Log".

7. When you have gotten a crashed table, stop the `mysqld` server.

8. Restore the backup.

9. Restart the `mysqld` server *without* the binary log enabled.

10. Re-execute the statements with `mysqlbinlog binary-log-file | mysql`. The binary log is saved in the MySQL database directory with the name `hostname-bin.NNNNNN`.

11. If the tables are corrupted again or you can get `mysqld` to die with the above command, you have found a reproducible bug. FTP the tables and the binary log to our bugs database using the instructions given in Section 1.7, "How to Report Bugs or Problems". If you are a support customer, you can use the MySQL Customer Support Center (http://www.mysql.com/support/) to alert the MySQL team about the problem and have it fixed as soon as possible.

You can also use the script `mysql_find_rows` to just execute some of the update statements if you want to narrow down the problem.

22.4.2 Debugging a MySQL Client

To be able to debug a MySQL client with the integrated debug package, you should configure MySQL with `--with-debug` or `--with-debug=full`. See Section 2.11.4, "MySQL Source-Configuration Options".

Before running a client, you should set the `MYSQL_DEBUG` environment variable:

```
shell> MYSQL_DEBUG=d:t:O,/tmp/client.trace
shell> export MYSQL_DEBUG
```

This causes clients to generate a trace file in `/tmp/client.trace`.

If you have problems with your own client code, you should attempt to connect to the server and run your query using a client that is known to work. Do this by running `mysql` in debugging mode (assuming that you have compiled MySQL with debugging on):

```
shell> mysql --debug=d:t:O,/tmp/client.trace
```

This provides useful information in case you mail a bug report. See Section 1.7, "How to Report Bugs or Problems".

If your client crashes at some 'legal' looking code, you should check that your `mysql.h` include file matches your MySQL library file. A very common mistake is to use an old `mysql.h` file from an old MySQL installation with new MySQL library.

22.4.3 The DBUG Package

The MySQL server and most MySQL clients are compiled with the DBUG package originally created by Fred Fish. When you have configured MySQL for debugging, this package makes it possible to get a trace file of what the program is doing. See Section 22.4.1.2, "Creating Trace Files".

This section summarizes the argument values that you can specify in debug options on the command line for MySQL programs that have been built with debugging support. For more information about programming with the DBUG package, see the DBUG manual in the `dbug` directory of MySQL source distributions. It's best to use a recent distribution to get the most updated DBUG manual.

The DBUG package can be used by invoking a program with the `--debug[=debug_options]` or `-#[debug_options]` option. If you specify the `--debug` or `-#` option without a `debug_options` value, most MySQL programs use a default value. The server default is `d:t:i:o,/tmp/mysqld.trace` on Unix and `d:t:i:O,\mysqld.trace` on Windows. The effect of this default is:

- `d`: Enable output for all debug macros

- `t`: Trace function calls and exits

- `i`: Add PID to output lines

- `o,/tmp/mysqld.trace`, `O,\mysqld.trace`: Set the debug output file.

Most client programs use a default `debug_options` value of `d:t:o,/tmp/program_name.trace`, regardless of platform.

Here are some example debug control strings as they might be specified on a shell command line:

```
--debug=d:t
--debug=d:f,main,subr1:F:L:t,20
--debug=d,input,output,files:n
--debug=d:t:i:O,\\mysqld.trace
```

For `mysqld`, it is also possible to change DBUG settings at runtime by setting the `debug` system variable. This variable has global and session values:

```
mysql> SET GLOBAL debug = 'debug_options';
mysql> SET SESSION debug = 'debug_options';
```

Changes at runtime require the `SUPER` privilege, even for the session value.

The `debug_options` value is a sequence of colon-separated fields:

```
field_1:field_2:...:field_N
```

Each field within the value consists of a mandatory flag character, optionally preceded by a `+` or `-` character, and optionally followed by a comma-delimited list of modifiers:

```
[+|-]flag[,modifier,modifier,...,modifier]
```

The following table describes the permitted flag characters. Unrecognized flag characters are silently ignored.

Flag	Description
d	Enable output from DBUG_*XXX* macros for the current state. May be followed by a list of keywords, which enables output only for the DBUG macros with that keyword. An empty list of keywords enables output for all macros. In MySQL, common debug macro keywords to enable are `enter`, `exit`, `error`, `warning`, `info`, and `loop`.
D	Delay after each debugger output line. The argument is the delay, in tenths of seconds, subject to machine capabilities. For example, `D,20` specifies a delay of two seconds.
f	Limit debugging, tracing, and profiling to the list of named functions. An empty list enables all functions. The appropriate `d` or `t` flags must still be given; this flag only limits their actions if they are enabled.
F	Identify the source file name for each line of debug or trace output.
i	Identify the process with the PID or thread ID for each line of debug or trace output.
L	Identify the source file line number for each line of debug or trace output.
n	Print the current function nesting depth for each line of debug or trace output.
N	Number each line of debug output.
o	Redirect the debugger output stream to the specified file. The default output is `stderr`.
O	Like `o`, but the file is really flushed between each write. When needed, the file is closed and reopened between each write.
p	Limit debugger actions to specified processes. A process must be identified with the `DBUG_PROCESS` macro and match one in the list for debugger actions to occur.
P	Print the current process name for each line of debug or trace output.
r	When pushing a new state, do not inherit the previous state's function nesting level. Useful when the output is to start at the left margin.
S	Do function `_sanity(_file_,_line_)` at each debugged function until `_sanity()` returns something that differs from 0. (Mostly used with `safemalloc` to find memory leaks.)
t	Enable function call/exit trace lines. May be followed by a list (containing only one modifier) giving a numeric maximum trace level, beyond which no output occurs for either debugging or tracing macros. The default is a compile time option.

The leading `+` or `-` character and trailing list of modifiers are used for flag characters such as `d` or `f` that can enable a debug operation for all applicable modifiers or just some of them:

- With no leading `+` or `-`, the flag value is set to exactly the modifier list as given.

- With a leading `+` or `-`, the modifiers in the list are added to or subtracted from the current modifier list.

The following examples show how this works for the `d` flag. An empty `d` list enabled output for all debug macros. A nonempty list enables output only for the macro keywords in the list.

These statements set the d value to the modifier list as given:

```
mysql> SET debug = 'd';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
mysql> SET debug = 'd,error,warning';
mysql> SELECT @@debug;
+-----------------+
| @@debug         |
+-----------------+
| d,error,warning |
+-----------------+
```

A leading + or - adds to or subtracts from the current d value:

```
mysql> SET debug = '+d,loop';
mysql> SELECT @@debug;
+----------------------+
| @@debug              |
+----------------------+
| d,error,warning,loop |
+----------------------+
mysql> SET debug = '-d,error,loop';
mysql> SELECT @@debug;
+-----------+
| @@debug   |
+-----------+
| d,warning |
+-----------+
```

Adding to "all macros enabled" results in no change:

```
mysql> SET debug = 'd';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
mysql> SET debug = '+d,loop';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
```

Disabling all enabled macros disables the d flag entirely:

```
mysql> SET debug = 'd,error,loop';
mysql> SELECT @@debug;
+--------------+
| @@debug      |
+--------------+
| d,error,loop |
+--------------+
mysql> SET debug = '-d,error,loop';
mysql> SELECT @@debug;
```

```
+---------+
| @@debug |
+---------+
|         |
+---------+
```

Note

The + and − modifiers are not always handled correctly and can leave a flag value in an incorrect state. Verify your `debug`-setting sequence in advance or set it without using + or −.

Chapter 23 MySQL Enterprise Edition

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MySQL Enterprise Edition is a commercial product. Like MySQL Community Edition, MySQL Enterprise Edition includes MySQL Server, a fully integrated transaction-safe, ACID-compliant database with full commit, rollback, crash-recovery, and row-level locking capabilities. In addition, MySQL Enterprise Edition includes the following components designed to provide monitoring and online backup, as well as improved security and scalability:

The following sections briefly discuss each of these components and indicate where to find more detailed information. To learn more about commercial products, see http://www.mysql.com/products/.

* MySQL Enterprise Monitor

* MySQL Enterprise Backup

* MySQL Enterprise Security

* MySQL Enterprise Encryption

* MySQL Enterprise Audit

* MySQL Enterprise Firewall

* MySQL Enterprise Thread Pool

23.1 MySQL Enterprise Monitor Overview

MySQL Enterprise Monitor is an enterprise monitoring system for MySQL that keeps an eye on your MySQL servers, notifies you of potential issues and problems, and advises you how to fix the issues. MySQL Enterprise Monitor can monitor all kinds of configurations, from a single MySQL server that is important to your business, all the way up to a huge farm of MySQL servers powering a busy web site.

The following discussion briefly summarizes the basic components that make up the MySQL Enterprise Monitor product. For more information, see the MySQL Enterprise Monitor manual, available at http://dev.mysql.com/doc/mysql-monitor/en/.

MySQL Enterprise Monitor components can be installed in various configurations depending on your database and network topology, to give you the best combination of reliable and responsive monitoring data, with minimal overhead on the database server machines. A typical MySQL Enterprise Monitor installation consists of:

* One or more MySQL servers to monitor. MySQL Enterprise Monitor can monitor both Community and Enterprise MySQL server releases.

- A MySQL Enterprise Monitor Agent for each monitored host.

- A single MySQL Enterprise Service Manager, which collates information from the agents and provides the user interface to the collected data.

MySQL Enterprise Monitor is designed to monitor one or more MySQL servers. The monitoring information is collected by using an agent, *MySQL Enterprise Monitor Agent*. The agent communicates with the hosts and MySQL servers that it monitors, collecting variables, status and health information, and sending this information to the MySQL Enterprise Service Manager.

The information collected by the agent about each MySQL server and host you are monitoring is sent to the *MySQL Enterprise Service Manager*. This server collates all of the information from the agents. As it collates the information sent by the agents, the MySQL Enterprise Service Manager continually tests the collected data, comparing the status of the server to reasonable values. When thresholds are reached, the server can trigger an event (including an alarm and notification) to highlight a potential issue, such as low memory, high CPU usage, or more complex conditions such insufficient buffer sizes and status information. We call each test, with its associated threshold value, a *rule*.

These rules, and the alarms and notifications, are each known as a *MySQL Enterprise Advisors*. Advisors form a critical part of the MySQL Enterprise Service Manager, as they provide warning information and troubleshooting advice about potential problems.

The MySQL Enterprise Service Manager includes a web server, and you interact with it through any web browser. This interface, the MySQL Enterprise Monitor User Interface, displays all of the information collected by the agents, and lets you view all of your servers and their current status as a group or individually. You control and configure all aspects of the service using the MySQL Enterprise Monitor User Interface.

The information supplied by the MySQL Enterprise Monitor Agent processes also includes statistical and query information, which you can view in the form of graphs. For example, you can view aspects such as server load, query numbers, or index usage information as a graph over time. The graph lets you pinpoint problems or potential issues on your server, and can help diagnose the impact from database or external problems (such as external system or network failure) by examining the data from a specific time interval.

The MySQL Enterprise Monitor Agent can also be configured to collect detailed information about the queries executed on your server, including the row counts and performance times for executing each query. You can correlate the detailed query data with the graphical information to identify which queries were executing when you experienced a particularly high load, index or other issue. The query data is supported by a system called Query Analyzer, and the data can be presented in different ways depending on your needs.

23.2 MySQL Enterprise Backup Overview

MySQL Enterprise Backup performs hot backup operations for MySQL databases. The product is architected for efficient and reliable backups of tables created by the InnoDB storage engine. For completeness, it can also back up tables from MyISAM and other storage engines.

The following discussion briefly summarizes MySQL Enterprise Backup. For more information, see the MySQL Enterprise Backup manual, available at http://dev.mysql.com/doc/mysql-enterprise-backup/en/.

Hot backups are performed while the database is running and applications are reading and writing to it. This type of backup does not block normal database operations, and it captures even changes that occur while the backup is happening. For these reasons, hot backups are desirable when your database "grows up" -- when the data is large enough that the backup takes significant time, and when your data is important enough to your business that you must capture every last change, without taking your application, web site, or web service offline.

MySQL Enterprise Backup does a hot backup of all tables that use the InnoDB storage engine. For tables using MyISAM or other non-InnoDB storage engines, it does a "warm" backup, where the database continues to run, but those tables cannot be modified while being backed up. For efficient backup operations, you can designate InnoDB as the default storage engine for new tables, or convert existing tables to use the InnoDB storage engine.

23.3 MySQL Enterprise Security Overview

MySQL Enterprise Edition provides plugins that implement authentication using external services:

- MySQL Enterprise Edition includes an authentication plugin that enables MySQL Server to use PAM (Pluggable Authentication Modules) to authenticate MySQL users. PAM enables a system to use a standard interface to access various kinds of authentication methods, such as Unix passwords or an LDAP directory. For more information, see The PAM Authentication Plugin.

- MySQL Enterprise Edition includes an authentication plugin that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password. For more information, see The Windows Native Authentication Plugin.

- MySQL Enterprise Edition includes a keyring plugin that uses Oracle Key Vault for keyring backend storage. For more information, see The MySQL Keyring.

For other related Enterprise security features, see Section 23.4, "MySQL Enterprise Encryption Overview".

23.4 MySQL Enterprise Encryption Overview

MySQL Enterprise Edition includes a set of encryption functions based on the OpenSSL library that expose OpenSSL capabilities at the SQL level. These functions enable Enterprise applications to perform the following operations:

- Implement added data protection using public-key asymmetric cryptography

- Create public and private keys and digital signatures

- Perform asymmetric encryption and decryption

- Use cryptographic hashing for digital signing and data verification and validation

For more information, see MySQL Enterprise Encryption Functions.

For other related Enterprise security features, see Section 23.3, "MySQL Enterprise Security Overview".

23.5 MySQL Enterprise Audit Overview

MySQL Enterprise Edition includes MySQL Enterprise Audit, implemented using a server plugin. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access.

For more information, see MySQL Enterprise Audit.

23.6 MySQL Enterprise Firewall Overview

MySQL Enterprise Edition includes MySQL Enterprise Firewall, an application-level firewall that enables database administrators to permit or deny SQL statement execution based on matching against whitelists of accepted statement patterns. This helps harden MySQL Server against attacks such as SQL injection or attempts to exploit applications by using them outside of their legitimate query workload characteristics.

Each MySQL account registered with the firewall has its own statement whitelist, enabling protection to be tailored per account. For a given account, the firewall can operate in recording or protecting mode, for training in the accepted statement patterns or protection against unacceptable statements.

For more information, see MySQL Enterprise Firewall.

23.7 MySQL Enterprise Thread Pool Overview

MySQL Enterprise Edition includes MySQL Enterprise Thread Pool, implemented using a server plugin. The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. In MySQL Enterprise Edition, a thread pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections.

For more information, see MySQL Enterprise Thread Pool.

Chapter 24 MySQL Workbench

MySQL Workbench provides a graphical tool for working with MySQL servers and databases. MySQL Workbench fully supports MySQL versions 5.1 and above.

The following discussion briefly describes MySQL Workbench capabilities. For more information, see the MySQL Workbench manual, available at http://dev.mysql.com/doc/workbench/en/.

MySQL Workbench provides five main areas of functionality:

- **SQL Development**: Enables you to create and manage connections to database servers. As well as enabling you to configure connection parameters, MySQL Workbench provides the capability to execute SQL queries on the database connections using the built-in SQL Editor. This functionality replaces that previously provided by the Query Browser standalone application.

- **Data Modeling**: Enables you to create models of your database schema graphically, reverse and forward engineer between a schema and a live database, and edit all aspects of your database using the comprehensive Table Editor. The Table Editor provides easy-to-use facilities for editing Tables, Columns, Indexes, Triggers, Partitioning, Options, Inserts and Privileges, Routines and Views.

- **Server Administration**: Enables you to create and administer server instances.

- **Data Migration**: Allows you to migrate from Microsoft SQL Server, Sybase ASE, SQLite, SQL Anywhere, PostreSQL, and other RDBMS tables, objects and data to MySQL. Migration also supports migrating from earlier versions of MySQL to the latest releases.

- **MySQL Enterprise Support**: Support for Enterprise products such as MySQL Enterprise Backup and MySQL Audit.

MySQL Workbench is available in two editions, the Community Edition and the Commercial Edition. The Community Edition is available free of charge. The Commercial Edition provides additional Enterprise features, such as database documentation generation, at low cost.

Appendix A MySQL 5.1 Frequently Asked Questions

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A.1 MySQL 5.1 FAQ: General

A.1.1. Which version of MySQL is production-ready (GA)?

MySQL 5.7 and MySQL 5.6 are supported for production use.

MySQL 5.7 achieved General Availability (GA) status with MySQL 5.7.9, which was released for production use on 21 October 2015.

MySQL 5.6 achieved General Availability (GA) status with MySQL 5.6.10, which was released for production use on 5 February 2013.

MySQL 5.5 achieved General Availability (GA) status with MySQL 5.5.8, which was released for production use on 3 December 2010. The MySQL 5.5 series is no longer current, but still supported in production.

MySQL 5.1 achieved General Availability (GA) status with MySQL 5.1.30, which was released for production use on 14 November 2008. Active development for MySQL 5.1 has ended.

MySQL 5.0 achieved General Availability (GA) status with MySQL 5.0.15, which was released for production use on 19 October 2005. Active development for MySQL 5.0 has ended.

A.1.2. What is the state of development (non-GA) versions?

MySQL follows a milestone release model that introduces pre-production-quality features and stabilizes them to release quality (see http://dev.mysql.com/doc/mysql-development-cycle/en/index.html). This process then repeats, so releases cycle between pre-production and release quality status. Please check the change logs to identify the status of a given release.

MySQL 5.4 was a development series. Work on this series has ceased.

A successor to MySQL 5.7 is being actively developed using the milestone release methodology described above.

A.1.3. Can MySQL 5.1 do subqueries?

Yes. See Section 13.2.9, "Subquery Syntax".

A.1.4. Can MySQL 5.1 perform multiple-table inserts, updates, and deletes?

Yes. For the syntax required to perform multiple-table updates, see Section 13.2.10, "UPDATE Syntax"; for that required to perform multiple-table deletes, see Section 13.2.2, "DELETE Syntax".

A multiple-table insert can be accomplished using a trigger whose `FOR EACH ROW` clause contains multiple `INSERT` statements within a `BEGIN ... END` block. See Section 19.3, "Using Triggers".

A.1.5. Does MySQL 5.1 have a Query Cache? Does it work on Server, Instance or Database?

Yes. The query cache operates on the server level, caching complete result sets matched with the original query string. If an exactly identical query is made (which often happens, particularly in web applications), no parsing or execution is necessary; the result is sent directly from the cache. Various tuning options are available. See Section 8.10.3, "The MySQL Query Cache".

A.1.6. Does MySQL 5.1 have Sequences?

No. However, MySQL has an `AUTO_INCREMENT` system, which in MySQL 5.1 can also handle inserts in a multi-master replication setup. With the `auto_increment_increment` and `auto_increment_offset` system variables, you can set each server to generate auto-increment values that don't conflict with other servers. The `auto_increment_increment` value should be greater than the number of servers, and each server should have a unique offset.

A.1.7. Does MySQL 5.1 have a `NOW()` function with fractions of seconds?

No, but support was added in 5.6.4.

Also, MySQL does parse time strings with a fractional component. See Section 11.3.2, "The TIME Type".

A.1.8. Does MySQL 5.1 work with multi-core processors?

Yes. MySQL is fully multi-threaded, and will make use of multiple CPUs, provided that the operating system supports them.

A.1.9. Why do I see multiple processes for `mysqld`?

When using LinuxThreads, you should see a minimum of three `mysqld` processes running. These are in fact threads. There is one thread for the LinuxThreads manager, one thread to handle connections, and one thread to handle alarms and signals.

A.1.10. Can MySQL 5.1 perform ACID transactions?

Yes. All current MySQL versions support transactions. The `InnoDB` storage engine offers full ACID transactions with row-level locking, multi-versioning, nonlocking repeatable reads, and all four SQL standard isolation levels.

The `NDB` storage engine supports the `READ COMMITTED` transaction isolation level only.

A.2 MySQL 5.1 FAQ: Storage Engines

A.2.1. Where can I obtain complete documentation for MySQL storage engines and the pluggable storage engine architecture?

See Chapter 14, *Storage Engines*. That chapter contains information about all MySQL storage engines except for the `NDB` storage engine used for MySQL Cluster; `NDB` is covered in Chapter 17, *MySQL Cluster NDB 6.1 - 7.1*.

A.2.2. Are there any new storage engines in MySQL 5.1?

Yes:

- The `InnoDB Plugin` is available as an alternative to the built-in version of the `InnoDB` storage engine. It includes a number of features such as the Barracuda file format, table compression, and new configuration options for performance. As you upgrade to MySQL 5.5 and higher, these features become core features of the MySQL server, and `InnoDB` becomes the default storage engine for new tables.

- There have been significant improvements in existing storage engines, in particular for the `NDB` storage engine that forms the basis for MySQL Cluster.

- The `IBMDB2I` storage engine is included in the IBM i5/OS (TAR packages) and IBM i5/OS (SAVF packages).

A.2.3. Have any storage engines been removed in MySQL 5.1?

Yes. MySQL 5.1 no longer supports the `BDB` storage engine. Any existing `BDB` tables should be converted to another storage engine before upgrading to MySQL 5.1.

A.2.4. What are the unique benefits of the `ARCHIVE` storage engine?

The `ARCHIVE` storage engine is ideally suited for storing large amounts of data without indexes; it has a very small footprint, and performs selects using table scans. See Section 14.12, "The ARCHIVE Storage Engine", for details.

A.2.5. Do the new features in MySQL 5.1 apply to all storage engines?

The general new features such as views, stored procedures, triggers, `INFORMATION_SCHEMA`, precision math (`DECIMAL` column type), and the `BIT` column type, apply to all storage engines. There are also additions and changes for specific storage engines.

A.3 MySQL 5.1 FAQ: Server SQL Mode

A.3.1. What are server SQL modes?

Server SQL modes define what SQL syntax MySQL should support and what kind of data validation checks it should perform. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers. The MySQL Server apply these modes individually to different clients. For more information, see Section 5.1.7, "Server SQL Modes".

A.3.2. How many server SQL modes are there?

Each mode can be independently switched on and off. See Section 5.1.7, "Server SQL Modes", for a complete list of available modes.

A.3.3. How do you determine the server SQL mode?

You can set the default SQL mode (for `mysqld` startup) with the `--sql-mode` option. Using the statement `SET [GLOBAL|SESSION] sql_mode='modes'`, you can change the settings from within a connection, either locally to the connection, or to take effect globally. You can retrieve the current mode by issuing a `SELECT @@sql_mode` statement.

A.3.4. Is the mode dependent on the database or connection?

A mode is not linked to a particular database. Modes can be set locally to the session (connection), or globally for the server. you can change these settings using `SET [GLOBAL|SESSION] sql_mode='modes'`.

A.3.5. Can the rules for strict mode be extended?

When we refer to *strict mode*, we mean a mode where at least one of the modes `TRADITIONAL`, `STRICT_TRANS_TABLES`, or `STRICT_ALL_TABLES` is enabled. Options can be combined, so you can add restrictions to a mode. See Section 5.1.7, "Server SQL Modes", for more information.

A.3.6. Does strict mode impact performance?

The intensive validation of input data that some settings requires more time than if the validation is not done. While the performance impact is not that great, if you do not require such validation (perhaps your application already handles all of this), then MySQL gives you the option of leaving strict mode disabled. However—if you do require it—strict mode can provide such validation.

A.3.7. What is the default server SQL mode when MySQL 5.1 is installed?

By default, no special modes are enabled. For information about all available modes and MySQL's default behavior, see Section 5.1.7, "Server SQL Modes".

A.4 MySQL 5.1 FAQ: Stored Procedures and Functions

A.4.1. Does MySQL 5.1 support stored procedures and functions?

Yes. MySQL 5.1 supports two types of stored routines—stored procedures and stored functions.

A.4.2. Where can I find documentation for MySQL stored procedures and stored functions?

See Section 19.2, "Using Stored Routines (Procedures and Functions)".

A.4.3. Is there a discussion forum for MySQL stored procedures?

Yes. See http://forums.mysql.com/list.php?98.

A.4.4. Where can I find the ANSI SQL 2003 specification for stored procedures?

Unfortunately, the official specifications are not freely available (ANSI makes them available for purchase). However, there are books—such as *SQL-99 Complete, Really* by Peter Gulutzan and Trudy Pelzer—which give a comprehensive overview of the standard, including coverage of stored procedures.

A.4.5. How do you manage stored routines?

It is always good practice to use a clear naming scheme for your stored routines. You can manage stored procedures with `CREATE [FUNCTION|PROCEDURE]`, `ALTER [FUNCTION|PROCEDURE]`, `DROP [FUNCTION|PROCEDURE]`, and `SHOW CREATE [FUNCTION|PROCEDURE]`. You can obtain information about existing stored procedures using the `ROUTINES` table in the `INFORMATION_SCHEMA` database (see Section 20.16, "The INFORMATION_SCHEMA ROUTINES Table").

A.4.6. Is there a way to view all stored procedures and stored functions in a given database?

Yes. For a database named *dbname*, use this query on the `INFORMATION_SCHEMA.ROUTINES` table:

```
SELECT ROUTINE_TYPE, ROUTINE_NAME
    FROM INFORMATION_SCHEMA.ROUTINES
    WHERE ROUTINE_SCHEMA='dbname';
```

For more information, see Section 20.16, "The INFORMATION_SCHEMA ROUTINES Table".

The body of a stored routine can be viewed using `SHOW CREATE FUNCTION` (for a stored function) or `SHOW CREATE PROCEDURE` (for a stored procedure). See Section 13.7.5.11, "SHOW CREATE PROCEDURE Syntax", for more information.

A.4.7. Where are stored procedures stored?

In the `proc` table of the `mysql` system database. However, you should not access the tables in the system database directly. Instead, use `SHOW CREATE FUNCTION` to obtain information about stored functions, and `SHOW CREATE PROCEDURE` to obtain information about stored procedures. See Section 13.7.5.11, "SHOW CREATE PROCEDURE Syntax", for more information about these statements.

You can also query the `ROUTINES` table in the `INFORMATION_SCHEMA` database—see Section 20.16, "The INFORMATION_SCHEMA ROUTINES Table", for information about this table.

A.4.8. Is it possible to group stored procedures or stored functions into packages?

No. This is not supported in MySQL 5.1.

A.4.9. Can a stored procedure call another stored procedure?

Yes.

A.4.10. Can a stored procedure call a trigger?

A stored procedure can execute an SQL statement, such as an `UPDATE`, that causes a trigger to activate.

A.4.11. Can a stored procedure access tables?

Yes. A stored procedure can access one or more tables as required.

A.4.12. Do stored procedures have a statement for raising application errors?

Not in MySQL 5.1. The SQL standard `SIGNAL` and `RESIGNAL` statements are implemented in MySQL 5.5.

A.4.13. Do stored procedures provide exception handling?

MySQL implements `HANDLER` definitions according to the SQL standard. See Section 13.6.7.2, "DECLARE ... HANDLER Syntax", for details.

A.4.14. Can MySQL 5.1 stored routines return result sets?

Stored procedures can, but stored functions cannot. If you perform an ordinary `SELECT` inside a stored procedure, the result set is returned directly to the client. You need to use the MySQL 4.1 (or above) client/server protocol for this to work. This means that—for instance—in PHP, you need to use the `mysqli` extension rather than the old `mysql` extension.

A.4.15. Is `WITH RECOMPILE` supported for stored procedures?

Not in MySQL 5.1.

A.4.16 Is there a MySQL equivalent to using `mod_plsql` as a gateway on Apache to talk directly to a stored procedure in the database?

There is no equivalent in MySQL 5.1.

A.4.17 Can I pass an array as input to a stored procedure?

Not in MySQL 5.1.

A.4.18 Can I pass a cursor as an `IN` parameter to a stored procedure?

In MySQL 5.1, cursors are available inside stored procedures only.

A.4.19 Can I return a cursor as an `OUT` parameter from a stored procedure?

In MySQL 5.1, cursors are available inside stored procedures only. However, if you do not open a cursor on a `SELECT`, the result will be sent directly to the client. You can also `SELECT INTO` variables. See Section 13.2.8, "SELECT Syntax".

A.4.20 Can I print out a variable's value within a stored routine for debugging purposes?

Yes, you can do this in a *stored procedure*, but not in a stored function. If you perform an ordinary `SELECT` inside a stored procedure, the result set is returned directly to the client. You will need to use the MySQL 4.1 (or above) client/server protocol for this to work. This means that—for instance—in PHP, you need to use the `mysqli` extension rather than the old `mysql` extension.

A.4.21 Can I commit or roll back transactions inside a stored procedure?

Yes. However, you cannot perform transactional operations within a stored function.

A.4.22 Do MySQL 5.1 stored procedures and functions work with replication?

Yes, standard actions carried out in stored procedures and functions are replicated from a master MySQL server to a slave server. There are a few limitations that are described in detail in Section 19.7, "Binary Logging of Stored Programs".

A.4.23 Are stored procedures and functions created on a master server replicated to a slave?

Yes, creation of stored procedures and functions carried out through normal DDL statements on a master server are replicated to a slave, so the objects will exist on both servers. `ALTER` and `DROP` statements for stored procedures and functions are also replicated.

A.4.24 How are actions that take place inside stored procedures and functions replicated?

MySQL records each DML event that occurs in a stored procedure and replicates those individual actions to a slave server. The actual calls made to execute stored procedures are not replicated.

Stored functions that change data are logged as function invocations, not as the DML events that occur inside each function.

A.4.25 Are there special security requirements for using stored procedures and functions together with replication?

Yes. Because a slave server has authority to execute any statement read from a master's binary log, special security constraints exist for using stored functions with replication. If replication or binary logging in general (for the purpose of point-in-time recovery) is active, then MySQL DBAs have two security options open to them:

1. Any user wishing to create stored functions must be granted the `SUPER` privilege.

2. Alternatively, a DBA can set the `log_bin_trust_function_creators` system variable to 1, which enables anyone with the standard `CREATE ROUTINE` privilege to create stored functions.

A.4.26. What limitations exist for replicating stored procedure and function actions?

Nondeterministic (random) or time-based actions embedded in stored procedures may not replicate properly. By their very nature, randomly produced results are not predictable and cannot be exactly reproduced, and therefore, random actions replicated to a slave will not mirror those performed on a master. Declaring stored functions to be `DETERMINISTIC` or setting the `log_bin_trust_function_creators` system variable to 0 will not allow random-valued operations to be invoked.

In addition, time-based actions cannot be reproduced on a slave because the timing of such actions in a stored procedure is not reproducible through the binary log used for replication. It records only DML events and does not factor in timing constraints.

Finally, nontransactional tables for which errors occur during large DML actions (such as bulk inserts) may experience replication issues in that a master may be partially updated from DML activity, but no updates are done to the slave because of the errors that occurred. A workaround is for a function's DML actions to be carried out with the `IGNORE` keyword so that updates on the master that cause errors are ignored and updates that do not cause errors are replicated to the slave.

A.4.27. Do the preceding limitations affect MySQL's ability to do point-in-time recovery?

The same limitations that affect replication do affect point-in-time recovery.

A.4.28. What is being done to correct the aforementioned limitations?

As of MySQL 5.1.5, you can choose either statement-based replication or row-based replication. The original replication implementation is based on statement-based binary logging. Row-based binary logging resolves the limitations mentioned earlier.

Beginning with MySQL 5.1.8, *mixed* replication is also available (by starting the server with `--binlog-format=mixed`). This hybrid, "smart" form of replication "knows" whether statement-level replication can safely be used, or row-level replication is required.

For additional information, see Section 16.1.2, "Replication Formats".

A.5 MySQL 5.1 FAQ: Triggers

A.5.1. Where can I find the documentation for MySQL 5.1 triggers?

See Section 19.3, "Using Triggers".

A.5.2. Is there a discussion forum for MySQL Triggers?

Yes. It is available at http://forums.mysql.com/list.php?99.

A.5.3. Does MySQL 5.1 have statement-level or row-level triggers?

In MySQL 5.1, all triggers are `FOR EACH ROW`—that is, the trigger is activated for each row that is inserted, updated, or deleted. MySQL 5.1 does not support triggers using `FOR EACH STATEMENT`.

A.5.4. Are there any default triggers?

Not explicitly. MySQL does have specific special behavior for some `TIMESTAMP` columns, as well as for columns which are defined using `AUTO_INCREMENT`.

A.5.5. How are triggers managed in MySQL?

In MySQL 5.1, triggers can be created using the `CREATE TRIGGER` statement, and dropped using `DROP TRIGGER`. See Section 13.1.19, "CREATE TRIGGER Syntax", and Section 13.1.30, "DROP TRIGGER Syntax", for more about these statements.

Information about triggers can be obtained by querying the `INFORMATION_SCHEMA.TRIGGERS` table. See Section 20.23, "The INFORMATION_SCHEMA TRIGGERS Table".

A.5.6. Is there a way to view all triggers in a given database?

Yes. You can obtain a listing of all triggers defined on database `dbname` using a query on the `INFORMATION_SCHEMA.TRIGGERS` table such as the one shown here:

```
SELECT TRIGGER_NAME, EVENT_MANIPULATION, EVENT_OBJECT_TABLE, ACTION_STATEMENT
    FROM INFORMATION_SCHEMA.TRIGGERS
    WHERE TRIGGER_SCHEMA='dbname';
```

For more information about this table, see Section 20.23, "The INFORMATION_SCHEMA TRIGGERS Table".

You can also use the `SHOW TRIGGERS` statement, which is specific to MySQL. See Section 13.7.5.40, "SHOW TRIGGERS Syntax".

A.5.7. Where are triggers stored?

Triggers are stored in `.TRG` files, with one such file one per table.

A.5.8. Can a trigger call a stored procedure?

Yes.

A.5.9. Can triggers access tables?

A trigger can access both old and new data in its own table. A trigger can also affect other tables, but it is not permitted to modify a table that is already being used (for reading or writing) by the statement that invoked the function or trigger.

A.5.10. Can a table have multiple triggers with the same trigger event and action time?

In MySQL 5.1, there cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. This limitation is lifted in MySQL 5.7.

A.5.11 Can triggers call an external application through a UDF?

Yes. For example, a trigger could invoke the `sys_exec()` UDF.

A.5.12 Is it possible for a trigger to update tables on a remote server?

Yes. A table on a remote server could be updated using the `FEDERATED` storage engine. (See Section 14.11, "The FEDERATED Storage Engine").

A.5.13 Do triggers work with replication?

Yes. However, the way in which they work depends whether you are using MySQL's "classic" statement-based replication available in all versions of MySQL, or the row-based replication format introduced in MySQL 5.1.

When using statement-based replication, triggers on the slave are executed by statements that are executed on the master (and replicated to the slave).

When using row-based replication, triggers are not executed on the slave due to statements that were run on the master and then replicated to the slave. Instead, when using row-based replication, the changes caused by executing the trigger on the master are applied on the slave.

For more information, see Section 16.4.1.36, "Replication and Triggers".

A.5.14 How are actions carried out through triggers on a master replicated to a slave?

Again, this depends on whether you are using statement-based or row-based replication.

Statement-based replication.   First, the triggers that exist on a master must be re-created on the slave server. Once this is done, the replication flow works as any other standard DML statement that participates in replication. For example, consider a table `EMP` that has an `AFTER` insert trigger, which exists on a master MySQL server. The same `EMP` table and `AFTER` insert trigger exist on the slave server as well. The replication flow would be:

1. An `INSERT` statement is made to `EMP`.

2. The `AFTER` trigger on `EMP` activates.

3. The `INSERT` statement is written to the binary log.

4. The replication slave picks up the `INSERT` statement to `EMP` and executes it.

5. The `AFTER` trigger on `EMP` that exists on the slave activates.

Row-based replication.   When you use row-based replication, the changes caused by executing the trigger on the master are applied on the slave. However, the triggers themselves are not actually executed on the slave under row-based replication. This is because, if both the master and the slave applied the changes from the master and—in addition—the trigger causing these changes were applied on the slave, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

In most cases, the outcome is the same for both row-based and statement-based replication. However, if you use different triggers on the master and slave, you cannot use row-based replication. (This is because the row-based format replicates the changes made by triggers

executing on the master to the slaves, rather than the statements that caused the triggers to execute, and the corresponding triggers on the slave are not executed.) Instead, any statements causing such triggers to be executed must be replicated using statement-based replication.

For more information, see Section 16.4.1.36, "Replication and Triggers".

A.6 MySQL 5.1 FAQ: Views

A.6.1. Where can I find documentation covering MySQL Views?

See Section 19.5, "Using Views".

A.6.2. Is there a discussion forum for MySQL Views?

Yes. See http://forums.mysql.com/list.php?100

A.6.3. What happens to a view if an underlying table is dropped or renamed?

After a view has been created, it is possible to drop or alter a table or view to which the definition refers. To check a view definition for problems of this kind, use the `CHECK TABLE` statement. (See Section 13.7.2.3, "CHECK TABLE Syntax".)

A.6.4. Does MySQL 5.1 have table snapshots?

No.

A.6.5. Does MySQL 5.1 have materialized views?

No.

A.6.6. Can you insert into views that are based on joins?

It is possible, provided that your `INSERT` statement has a column list that makes it clear there is only one table involved.

You *cannot* insert into multiple tables with a single insert on a view.

A.7 MySQL 5.1 FAQ: INFORMATION_SCHEMA

A.7.1. Where can I find documentation for the MySQL `INFORMATION_SCHEMA` database?

See Chapter 20, *INFORMATION_SCHEMA Tables*

A.7.2. Is there a discussion forum for `INFORMATION_SCHEMA`?

See http://forums.mysql.com/list.php?101.

A.7.3. Where can I find the ANSI SQL 2003 specification for `INFORMATION_SCHEMA`?

Unfortunately, the official specifications are not freely available. (ANSI makes them available for purchase.) However, there are books available—such as *SQL-99 Complete, Really* by Peter Gulutzan and Trudy Pelzer—which give a comprehensive overview of the standard, including `INFORMATION_SCHEMA`.

A.7.4. What is the difference between the Oracle Data Dictionary and MySQL's `INFORMATION_SCHEMA`?

Both Oracle and MySQL provide metadata in tables. However, Oracle and MySQL use different table names and column names. MySQL's implementation is more similar to those found in DB2 and SQL Server, which also support `INFORMATION_SCHEMA` as defined in the SQL standard.

A.7.5. Can I add to or otherwise modify the tables found in the `INFORMATION_SCHEMA` database?

No. Since applications may rely on a certain standard structure, this should not be modified. For this reason, *we cannot support bugs or other issues which result from modifying `INFORMATION_SCHEMA` tables or data*.

A.8 MySQL 5.1 FAQ: Migration

A.8.1. Where can I find information on how to migrate from MySQL 5.0 to MySQL 5.1?

For detailed upgrade information, see Section 2.13.1, "Upgrading MySQL". Do not skip a major version when upgrading, but rather complete the process in steps, upgrading from one major version to the next in each step. This may seem more complicated, but it will you save time and trouble—if you encounter problems during the upgrade, their origin will be easier to identify, either by you or—if you have a MySQL Enterprise subscription—by MySQL support.

A.8.2. How has storage engine (table type) support changed in MySQL 5.1 from previous versions?

Storage engine support has changed as follows:

- Support for `ISAM` tables was removed in MySQL 5.0 and you should now use the `MyISAM` storage engine in place of `ISAM`. To convert a table *tblname* from `ISAM` to `MyISAM`, simply issue a statement such as this one:

  ```
  ALTER TABLE tblname ENGINE=MYISAM;
  ```

- Internal `RAID` for `MyISAM` tables was also removed in MySQL 5.0. This was formerly used to allow large tables in file systems that did not support file sizes greater than 2GB. All modern file systems allow for larger tables; in addition, there are now other solutions such as `MERGE` tables and views.

- The `VARCHAR` column type now retains trailing spaces in all storage engines.

- `MEMORY` tables (formerly known as `HEAP` tables) can also contain `VARCHAR` columns.

A.9 MySQL 5.1 FAQ: Security

A.9.1. Where can I find documentation that addresses security issues for MySQL?

The best place to start is Chapter 6, *Security*.

Other portions of the MySQL Documentation which you may find useful with regard to specific security concerns include the following:

- Section 6.1.1, "Security Guidelines".

- Section 6.1.3, "Making MySQL Secure Against Attackers".

- Section B.5.3.2, "How to Reset the Root Password".

- Section 6.1.5, "How to Run MySQL as a Normal User".

- Section 22.3.2.6, "UDF Security Precautions".

- Section 6.1.4, "Security-Related mysqld Options and Variables".

- Section 6.1.6, "Security Issues with LOAD DATA LOCAL".

- Section 2.12, "Postinstallation Setup and Testing".

- Section 6.4, "Using Secure Connections".

A.9.2. Does MySQL 5.1 have native support for SSL?

Most 5.1 binaries have support for SSL connections between the client and server. See Section 6.4, "Using Secure Connections".

You can also tunnel a connection using SSH, if (for example) the client application does not support SSL connections. For an example, see Section 6.4.7, "Connecting to MySQL Remotely from Windows with SSH".

A.9.3. Is SSL support built into MySQL binaries, or must I recompile the binary myself to enable it?

Most 5.1 binaries have SSL enabled for client/server connections that are secured, authenticated, or both. See Section 6.4, "Using Secure Connections".

A.9.4. Does MySQL 5.1 have built-in authentication against LDAP directories?

No.

As of MySQL 5.5.16, the Enterprise edition includes a PAM Authentication Plugin that supports authentication against an LDAP directory.

A.9.5. Does MySQL 5.1 include support for Roles Based Access Control (RBAC)?

Not at this time.

A.10 MySQL 5.1 FAQ: MySQL Cluster

In the following section, we answer questions that are frequently asked about MySQL Cluster and the `NDBCLUSTER` storage engine.

A.10.1 Which versions of the MySQL software support Cluster? Do I have to compile from source?

MySQL Cluster is not supported in standard MySQL Server 5.1 releases. Instead, MySQL Cluster is provided as a separate product. Currently, the following MySQL Cluster release series are available for production use:

- **MySQL Cluster NDB 7.2.**   This series is a previous General Availability (GA) version of MySQL Cluster, still available for production, although we recommend that new deployments use the latest MySQL Cluster NDB 7.4 release. The most recent MySQL Cluster NDB 7.2 release can be obtained from http://dev.mysql.com/downloads/cluster/.

- **MySQL Cluster NDB 7.3.**   This series is a General Availability (GA) version of MySQL Cluster, still available for production, although we recommend that new deployments use the latest MySQL Cluster NDB 7.4 release. The most recent MySQL Cluster NDB 7.3 release can be obtained from http://dev.mysql.com/downloads/cluster/.

- **MySQL Cluster NDB 7.4.**   This series is the latest Generally Available (GA) version of MySQL Cluster, based on version 7.4 of the `NDB` storage engine and MySQL Server 5.6. New deployments should use the latest release in this series. The most recent MySQL Cluster NDB 7.4 release can be obtained from http://dev.mysql.com/downloads/cluster/.

  For an overview of improvements made in MySQL Cluster NDB 7.4, see What is New in MySQL Cluster NDB 7.4.

- **MySQL Cluster NDB 7.5.**   This series is the latest development version of MySQL Cluster, based on version 7.5 of the `NDB` storage engine and MySQL Server 5.7. MySQL Cluster NDB 7.5 is available for testing and previewing of new features, but is not yet considered ready for production use; new deployments intended for production should continue to use the latest GA release in this series, which is currently MySQL Cluster NDB 7.4. The most recent MySQL Cluster NDB 7.4 and 7.5 releases can be obtained from http://dev.mysql.com/downloads/cluster/.

  For an overview of improvements made in MySQL Cluster NDB 7.5, see What is New in MySQL Cluster NDB 7.5.

You should use MySQL Cluster NDB 7.3 or MySQL Cluster NDB 7.4 for any new deployments; if you are using an older version of MySQL Cluster, you should upgrade to one of these soon as possible. For an overview of improvements made in MySQL Cluster NDB 7.4, see What is New in MySQL Cluster NDB 7.4; for information about improvements made in MySQL Cluster NDB 7.3, see What is New in MySQL Cluster NDB 7.3.

You can determine whether your MySQL Server has `NDB` support using one of the statements `SHOW VARIABLES LIKE 'have_%'`, `SHOW ENGINES`, or `SHOW PLUGINS`.

A.10.2. What happened to MySQL Cluster NDB 6.4?

Because of the number and impact of new features introduced into MySQL Cluster following the General Availability of MySQL Cluster NDB 6.3, it was decided that the following release series represented a "major" new release series rather than a "minor" one, and should be known as MySQL Cluster 7.0.

The earliest development versions of MySQL Cluster NDB 7.0 were originally designated "MySQL Cluster 6.4", and the first four releases in this series were identified as MySQL Cluster NDB 6.4.0 through NDB 6.4.3. MySQL Cluster NDB 7.0.4 was the fifth MySQL Cluster NDB 7.0 release; it was the successor to MySQL Cluster NDB 6.4.3.

For more information about MySQL Cluster NDB 7.0, see Section 17.1.4.3, "What is New in MySQL Cluster NDB 7.0", and http://dev.mysql.com/doc/relnotes/mysql-cluster/7.1/en/mysql-cluster-news-7-0.html.

A.10.3. What do "NDB" and "NDBCLUSTER" mean?

"NDB" stands for "**N**etwork **D**ata**b**ase". `NDB` and `NDBCLUSTER` are both names for the storage engine that enables clustering support with MySQL. `NDB` is preferred, but either name is correct.

A.10.4. What is the difference between using MySQL Cluster versus using MySQL Replication?

In traditional MySQL replication, a master MySQL server updates one or more slaves. Transactions are committed sequentially, and a slow transaction can cause the slave to lag behind the master. This means that if the master fails, it is possible that the slave might not have recorded the last few transactions. If a transaction-safe engine such as `InnoDB` is being used, a transaction will either be complete on the slave or not applied at all, but replication does not guarantee that all data on the master and the slave will be consistent at all times. In MySQL Cluster, all data nodes are kept in synchrony, and a transaction committed by any one data node is committed for all data nodes. In the event of a data node failure, all remaining data nodes remain in a consistent state.

In short, whereas standard MySQL replication is *asynchronous*, MySQL Cluster is *synchronous*.

Asynchronous replication for MySQL Cluster is available in MySQL 5.1 and later. *MySQL Cluster Replication* (also sometimes known as "geo-replication") includes the capability to replicate both between two MySQL Clusters, and from a MySQL Cluster to a non-Cluster MySQL server. See Section 17.6, "MySQL Cluster Replication".

A.10.5. Do I need any special networking to run MySQL Cluster? How do computers in a cluster communicate?

MySQL Cluster is intended to be used in a high-bandwidth environment, with computers connecting using TCP/IP. Its performance depends directly upon the connection speed between the cluster's computers. The minimum connectivity requirements for MySQL Cluster include a typical 100-megabit Ethernet network or the equivalent. We recommend you use gigabit Ethernet whenever available.

A.10.6. How many computers do I need to run a MySQL Cluster, and why?

A minimum of three computers is required to run a viable cluster. However, the minimum *recommended* number of computers in a MySQL Cluster is four: one each to run the management and SQL nodes, and two computers to serve as data nodes. The purpose of the two data nodes is to provide redundancy; the management node must run on a separate machine to guarantee continued arbitration services in the event that one of the data nodes fails.

To provide increased throughput and high availability, you should use multiple SQL nodes (MySQL Servers connected to the cluster). It is also possible (although not strictly necessary) to run multiple management servers.

A.10.7. What do the different computers do in a MySQL Cluster?

A MySQL Cluster has both a physical and logical organization, with computers being the physical elements. The logical or functional elements of a cluster are referred to as *nodes*, and a computer housing a cluster node is sometimes referred to as a *cluster host*. There are three types of nodes, each corresponding to a specific role within the cluster. These are:

- **Management node.**   This node provides management services for the cluster as a whole, including startup, shutdown, backups, and configuration data for the other nodes. The management node server is implemented as the application `ndb_mgmd`; the management client used to control MySQL Cluster is `ndb_mgm`. See Section 17.4.4, "`ndb_mgmd` — The MySQL Cluster Management Server Daemon", and Section 17.4.5, "`ndb_mgm` — The MySQL Cluster Management Client", for information about these programs.

- **Data node.** This type of node stores and replicates data. Data node functionality is handled by instances of the `NDB` data node process `ndbd`. For more information, see Section 17.4.1, "`ndbd` — The MySQL Cluster Data Node Daemon".

- **SQL node.** This is simply an instance of MySQL Server (`mysqld`) that is built with support for the `NDBCLUSTER` storage engine and started with the `--ndb-cluster` option to enable the engine and the `--ndb-connectstring` option to enable it to connect to a MySQL Cluster management server. For more about these options, see MySQL Server Options for MySQL Cluster.

  > **Note**
  >
  > An *API node* is any application that makes direct use of Cluster data nodes for data storage and retrieval. An SQL node can thus be considered a type of API node that uses a MySQL Server to provide an SQL interface to the Cluster. You can write such applications (that do not depend on a MySQL Server) using the NDB API, which supplies a direct, object-oriented transaction and scanning interface to MySQL Cluster data; see MySQL Cluster API Overview: The NDB API, for more information.

A.10.8. When I run the `SHOW` command in the MySQL Cluster management client, I see a line of output that looks like this:

```
id=2    @10.100.10.32  (Version: 5.6.32-ndb-7.3.15 Nodegroup: 0, *)
```

What does the `*` mean? How is this node different from the others?

The simplest answer is, "It's not something you can control, and it's nothing that you need to worry about in any case, unless you're a software engineer writing or analyzing the MySQL Cluster source code".

If you don't find that answer satisfactory, here's a longer and more technical version:

A number of mechanisms in MySQL Cluster require distributed coordination among the data nodes. These distributed algorithms and protocols include global checkpointing, DDL (schema) changes, and node restart handling. To make this coordination simpler, the data nodes "elect" one of their number to act as leader. (This node was once referred to as a "master", but this terminology was dropped to avoid confusion with master server in MySQL Replication.) There is no user-facing mechanism for influencing this selection, which is completely automatic; the fact that it *is* automatic is a key part of MySQL Cluster's internal architecture.

When a node acts as the "leader" for any of these mechanisms, it is usually the point of coordination for the activity, and the other nodes act as "followers", carrying out their parts of the activity as directed by the leader. If the node acting as leader fails, then the remaining nodes elect a new leader. Tasks in progress that were being coordinated by the old leader may either fail or be continued by the new leader, depending on the actual mechanism involved.

It is possible for some of these different mechanisms and protocols to have different leader nodes, but in general the same leader is chosen for all of them. The node indicated as the leader in the output of `SHOW` in the management client is known internally as the `DICT` manager (see The DBDICT Block, in the *MySQL Cluster API Developer Guide*, for more information), responsible for coordinating DDL and metadata activity.

MySQL Cluster is designed in such a way that the choice of leader has no discernible effect outside the cluster itself. For example, the current leader does not have significantly higher CPU or resource usage than the other data nodes, and failure of the leader should not have a significantly different impact on the cluster than the failure of any other data node.

A.10.9. With which operating systems can I use MySQL Cluster?

MySQL Cluster is supported on most Unix-like operating systems. Beginning with MySQL Cluster NDB 7.1.3, MySQL Cluster is also supported in production on Microsoft Windows operating systems.

For more detailed information concerning the level of support which is offered for MySQL Cluster on various operating system versions, operating system distributions, and hardware platforms, please refer to http://www.mysql.com/support/supportedplatforms/cluster.html.

A.10.10. What are the hardware requirements for running MySQL Cluster?

MySQL Cluster should run on any platform for which `NDB`-enabled binaries are available. For data nodes and API nodes, faster CPUs and more memory are likely to improve performance, and 64-bit CPUs are likely to be more effective than 32-bit processors. There must be sufficient memory on machines used for data nodes to hold each node's share of the database (see *How much RAM do I Need?* for more information). For a computer which is used only for running the MySQL Cluster management server, the requirements are minimal; a common desktop PC (or the equivalent) is generally sufficient for this task. Nodes can communicate through the standard TCP/IP network and hardware. They can also use the high-speed SCI protocol; however, special networking hardware and software are required to use SCI (see Section 17.3.4, "Using High-Speed Interconnects with MySQL Cluster").

A.10.11. How much RAM do I need to use MySQL Cluster? Is it possible to use disk memory at all?

Formerly MySQL Cluster was in-memory only. MySQL 5.1 and later also provide the ability to store MySQL Cluster on disk. (Note that we have no plans to backport this capability to previous releases.) See Section 17.5.12, "MySQL Cluster Disk Data Tables", for more information.

For in-memory `NDB` tables, you can use the following formula for obtaining a rough estimate of how much RAM is needed for each data node in the cluster:

```
(SizeofDatabase × NumberOfReplicas × 1.1 ) / NumberOfDataNodes
```

To calculate the memory requirements more exactly requires determining, for each table in the cluster database, the storage space required per row (see Section 11.7, "Data Type Storage Requirements", for details), and multiplying this by the number of rows. You must also remember to account for any column indexes as follows:

- Each primary key or hash index created for an `NDBCLUSTER` table requires 21−25 bytes per record. These indexes use `IndexMemory`.

- Each ordered index requires 10 bytes storage per record, using `DataMemory`.

- Creating a primary key or unique index also creates an ordered index, unless this index is created with `USING HASH`. In other words:

  - A primary key or unique index on a Cluster table normally takes up 31 to 35 bytes per record.

  - However, if the primary key or unique index is created with `USING HASH`, then it requires only 21 to 25 bytes per record.

Creating MySQL Cluster tables with `USING HASH` for all primary keys and unique indexes will generally cause table updates to run more quickly—in some cases by a much as 20 to 30 percent faster than updates on tables where `USING HASH` was not used in creating primary and unique keys. This is due to the fact that less memory is required (because no ordered indexes are created), and that less CPU must be utilized (because fewer indexes must be read and possibly updated). However, it also means that queries that could otherwise use range scans must be satisfied by other means, which can result in slower selects.

When calculating Cluster memory requirements, you may find useful the `ndb_size.pl` utility which is available in recent MySQL 5.1 releases. This Perl script connects to a current (non-Cluster) MySQL database and creates a report on how much space that database would require if it used the `NDBCLUSTER` storage engine. For more information, see Section 17.4.24, "`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator".

It is especially important to keep in mind that *every MySQL Cluster table must have a primary key*. The `NDB` storage engine creates a primary key automatically if none is defined; this primary key is created without `USING HASH`.

You can determine how much memory is being used for storage of MySQL Cluster data and indexes at any given time using the `REPORT MEMORYUSAGE` command in the `ndb_mgm` client; see Section 17.5.2, "Commands in the MySQL Cluster Management Client", for more information. In addition, warnings are written to the cluster log when 80% of available `DataMemory` or `IndexMemory` is in use, and again when usage reaches 85%, 90%, and so on.

A.10.12. What file systems can I use with MySQL Cluster? What about network file systems or network shares?

Generally, any file system that is native to the host operating system should work well with MySQL Cluster. If you find that a given file system works particularly well (or not so especially well) with MySQL Cluster, we invite you to discuss your findings in the MySQL Cluster Forums.

For Windows, we recommend that you use `NTFS` file systems for MySQL Cluster, just as we do for standard MySQL. We do not test MySQL Cluster with `FAT` or `VFAT` file systems. Because of this, we do not recommend their use with MySQL or MySQL Cluster.

MySQL Cluster is implemented as a shared-nothing solution; the idea behind this is that the failure of a single piece of hardware should not cause the failure of multiple cluster nodes, or possibly even the failure of the cluster as a whole. For this reason, the use of network shares or network file systems is not supported for MySQL Cluster. This also applies to shared storage devices such as SANs.

A.10.13. Can I run MySQL Cluster nodes inside virtual machines (such as those created by VMWare, Parallels, or Xen)?

This is possible but not recommended for a production environment with MySQL Cluster versions prior to MySQL Cluster NDB 7.2.

For deployment in virtualized environments, you should use MySQL Cluster NDB 7.2 or later.

A.10.14. I am trying to populate a MySQL Cluster database. The loading process terminates prematurely and I get an error message like this one:

```
ERROR 1114: The table 'my_cluster_table' is full
```

Why is this happening?

The cause is very likely to be that your setup does not provide sufficient RAM for all table data and all indexes, *including the primary key required by the* `NDB` *storage engine and automatically created in the event that the table definition does not include the definition of a primary key*.

It is also worth noting that all data nodes should have the same amount of RAM, since no data node in a cluster can use more memory than the least amount available to any individual data node. For example, if there are four computers hosting Cluster data nodes, and three of these have 3GB of RAM available to store Cluster data while the remaining data node has only 1GB RAM, then each data node can devote at most 1GB to MySQL Cluster data and indexes.

In some cases it is possible to get `Table is full` errors in MySQL client applications even when `ndb_mgm -e "ALL REPORT MEMORYUSAGE"` shows significant free `DataMemory`. You can force `NDB` to create extra partitions for MySQL Cluster tables and thus have more memory available for hash indexes by using the `MAX_ROWS` option for `CREATE TABLE`. In general, setting `MAX_ROWS` to twice the number of rows that you expect to store in the table should be sufficient.

For similar reasons, you can also sometimes encounter problems with data node restarts on nodes that are heavily loaded with data. In MySQL Cluster NDB 7.1 and later, the addition of the `MinFreePct` parameter helps with this issue by reserving a portion (5% by default) of `DataMemory` and `IndexMemory` for use in restarts. This reserved memory is not available for storing `NDB` tables or data.

A.10.15. MySQL Cluster uses TCP/IP. Does this mean that I can run it over the Internet, with one or more nodes in remote locations?

It is *very* unlikely that a cluster would perform reliably under such conditions, as MySQL Cluster was designed and implemented with the assumption that it would be run under conditions guaranteeing dedicated high-speed connectivity such as that found in a LAN setting using 100 Mbps or gigabit Ethernet—preferably the latter. We neither test nor warrant its performance using anything slower than this.

Also, it is extremely important to keep in mind that communications between the nodes in a MySQL Cluster are not secure; they are neither encrypted nor safeguarded by any other protective mechanism. The most secure configuration for a cluster is in a private network behind a firewall, with no direct access to any Cluster data or management nodes from outside. (For SQL nodes, you should take the same precautions as you would with any other instance of the MySQL server.) For more information, see Section 17.5.11, "MySQL Cluster Security Issues".

A.10.16. Do I have to learn a new programming or query language to use MySQL Cluster?

No. Although some specialized commands are used to manage and configure the cluster itself, only standard (My)SQL statements are required for the following operations:

- Creating, altering, and dropping tables

- Inserting, updating, and deleting table data

- Creating, changing, and dropping primary and unique indexes

Some specialized configuration parameters and files are required to set up a MySQL Cluster—see Section 17.3.3, "MySQL Cluster Configuration Files", for information about these.

A few simple commands are used in the MySQL Cluster management client (`ndb_mgm`) for tasks such as starting and stopping cluster nodes. See Section 17.5.2, "Commands in the MySQL Cluster Management Client".

A.10.17. What programming languages and APIs are supported by MySQL Cluster?

MySQL Cluster 5.1 and later support the same programming APIs and languages as the standard MySQL Server, including ODBC, .Net, the MySQL C API, and numerous drivers for popular scripting languages such as PHP, Perl, and Python. MySQL Cluster applications written using these APIs behave similarly to other MySQL applications; they transmit SQL statements to a MySQL Server (in the case of MySQL Cluster, an SQL node), and receive responses containing rows of data. For more information about these APIs, see Chapter 21, *Connectors and APIs*.

MySQL Cluster 5.1 and later also support application programming using the NDB API, which provides a low-level C++ interface to MySQL Cluster data without needing to go through a MySQL Server. See The NDB API. In addition, many `NDBCLUSTER` management functions are exposed by the C-language MGM API; see The MGM API, for more information.

MySQL Cluster NDB 7.1 and later also support Java application programming using ClusterJ, which supports a domain object model of data using sessions and transactions. See Java and MySQL Cluster, for more information.

A.10.18. Does MySQL Cluster include any management tools?

MySQL Cluster includes a command line client for performing basic management functions. See Section 17.4.5, "`ndb_mgm` — The MySQL Cluster Management Client", and Section 17.5.2, "Commands in the MySQL Cluster Management Client".

MySQL Cluster NDB 7.0 and later is also supported by MySQL Cluster Manager, a separate product providing an advanced command line interface that can automate many MySQL Cluster management tasks such as rolling restarts and configuration changes. For more information about MySQL Cluster Manager, see MySQL™ Cluster Manager 1.3.6 User Manual.

A.10.19. How do I find out what an error or warning message means when using MySQL Cluster?

There are two ways in which this can be done:

- From within the `mysql` client, use `SHOW ERRORS` or `SHOW WARNINGS` immediately upon being notified of the error or warning condition.

- From a system shell prompt, use `perror --ndb error_code`.

A.10.20. Is MySQL Cluster transaction-safe? What isolation levels are supported?

Yes. For tables created with the `NDB` storage engine, transactions are supported. Currently, MySQL Cluster supports only the `READ COMMITTED` transaction isolation level.

A.10.21. What storage engines are supported by MySQL Cluster?

Clustering with MySQL is supported only by the `NDB` storage engine. That is, in order for a table to be shared between nodes in a MySQL Cluster, the table must be created using `ENGINE=NDB` (or the equivalent option `ENGINE=NDBCLUSTER`).

It is possible to create tables using other storage engines (such as `InnoDB` or `MyISAM`) on a MySQL server being used with a MySQL Cluster, but since these tables do not use `NDB`, they do not participate in clustering; each such table is strictly local to the individual MySQL server instance on which it is created.

A.10.22. In the event of a catastrophic failure—say, for instance, the whole city loses power *and* my UPS fails —would I lose all my data?

All committed transactions are logged. Therefore, although it is possible that some data could be lost in the event of a catastrophe, this should be quite limited. Data loss can be further reduced by

minimizing the number of operations per transaction. (It is not a good idea to perform large numbers of operations per transaction in any case.)

A.10.23 Is it possible to use `FULLTEXT` indexes with MySQL Cluster?

`FULLTEXT` indexing is currently supported only by the `MyISAM` storage engine. See Section 12.9, "Full-Text Search Functions", for more information.

A.10.24 Can I run multiple nodes on a single computer?

It is possible but not always advisable. One of the chief reasons to run a cluster is to provide redundancy. To obtain the full benefits of this redundancy, each node should reside on a separate machine. If you place multiple nodes on a single machine and that machine fails, you lose all of those nodes. For this reason, if you do run multiple data nodes on a single machine, it is *extremely* important that they be set up in such a way that the failure of this machine does not cause the loss of all the data nodes in a given node group.

Given that MySQL Cluster can be run on commodity hardware loaded with a low-cost (or even no-cost) operating system, the expense of an extra machine or two is well worth it to safeguard mission-critical data. It also worth noting that the requirements for a cluster host running a management node are minimal. This task can be accomplished with a 300 MHz Pentium or equivalent CPU and sufficient RAM for the operating system, plus a small amount of overhead for the `ndb_mgmd` and `ndb_mgm` processes.

It is acceptable to run multiple cluster data nodes on a single host that has multiple CPUs, cores, or both. MySQL Cluster NDB 7.0 and later also provide a multi-threaded version of the data node binary intended for use on such systems. For more information, see Section 17.4.3, "`ndbmtd` — The MySQL Cluster Data Node Daemon (Multi-Threaded)".

It is also possible in some cases to run data nodes and SQL nodes concurrently on the same machine; how well such an arrangement performs is dependent on a number of factors such as number of cores and CPUs as well as the amount of disk and memory available to the data node and SQL node processes, and you must take these factors into account when planning such a configuration.

A.10.25 Can I add data nodes to a MySQL Cluster without restarting it?

In MySQL Cluster NDB 7.0 and later, it is possible to add new data nodes to a running MySQL Cluster without taking it offline. For more information, see Section 17.5.13, "Adding MySQL Cluster Data Nodes Online".

For other types of MySQL Cluster nodes, a rolling restart is all that is required (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster").

(In MySQL Cluster NDB 6.3 and earlier releases, it was not possible to add new data nodes without shutting down and restarting the MySQL Cluster.)

A.10.26 Are there any limitations that I should be aware of when using MySQL Cluster?

Limitations on `NDB` tables in MySQL NDB 6.3, MySQL Cluster NDB 7.0, and MySQL Cluster NDB 7.1 include the following:

- Temporary tables are not supported; a `CREATE TEMPORARY TABLE` statement using `ENGINE=NDB` or `ENGINE=NDBCLUSTER` fails with an error.

- The only types of user-defined partitioning supported for `NDBCLUSTER` tables are `KEY` and `LINEAR KEY`. Trying to create an `NDB` table using any other partitioning type fails with an error.

- `FULLTEXT` indexes are not supported.

- Index prefixes are not supported. Only complete columns may be indexed.

- Spatial indexes are not supported (although spatial columns can be used). See Section 11.5, "Extensions for Spatial Data".

- Prior to MySQL Cluster NDB 6.3.19, the `NDBCLUSTER` storage engine did not support partial transactions or partial rollbacks of transactions. Beginning with MySQL Cluster NDB 6.3.19, this limitation has been removed, and the behavior of `NDBCLUSTER` is now in line with that of other transactional storage engines (such as `InnoDB`) that can roll back individual statements.

- Prior to MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, the maximum number of attributes allowed per table was 128; beginning with MySQL Cluster NDB 7.0.15 and MySQL Cluster NDB 7.1.4, this limit is increased to 512. Attribute names cannot be any longer than 31 characters. For each table, the maximum combined length of the table and database names is 122 characters.

- Previous to MySL Cluster NDB 7.0, the maximum size for a table row was 8 kilobytes, not counting `BLOB` values. MySQL Cluster NDB 7.0 and later support a maximum row length of 14 KB (also not including `BLOB` values).

  There is no set limit for the number of rows per `NDB` table. Limits on table size depend on a number of factors, in particular on the amount of RAM available to each data node.

- The `NDBCLUSTER` engine does not support foreign key constraints. As with `MyISAM` tables, if these are specified in a `CREATE TABLE` or `ALTER TABLE` statement, they are ignored.

For a complete listing of limitations in MySQL Cluster, see Section 17.1.6, "Known Limitations of MySQL Cluster". See also Section 17.1.6.11, "Previous MySQL Cluster Issues Resolved in MySQL 5.1, MySQL Cluster NDB 6.x, and MySQL Cluster NDB 7.x".

A.10.27. Does MySQL Cluster support foreign keys?

MySQL Cluster NDB 7.1 and earlier MySQL Cluster releases do not support foreign key constraints, and ignore foreign keys in `CREATE TABLE` statements (similarly to how `MyISAM` treats foreign key syntax).

Foreign key support comparable to that found in the `InnoDB` storage engine is provided by `NDB` beginning with MySQL Cluster NDB 7.3. Applications requiring foreign support key should use MySQL Cluster NDB 7.3 or later.

A.10.28. How do I import an existing MySQL database into a MySQL Cluster?

You can import databases into MySQL Cluster much as you would with any other version of MySQL. Other than the limitations mentioned elsewhere in this FAQ, the only other special requirement is that any tables to be included in the cluster must use the `NDB` storage engine. This means that the tables must be created with `ENGINE=NDB` or `ENGINE=NDBCLUSTER`.

It is also possible to convert existing tables that use other storage engines to `NDBCLUSTER` using one or more `ALTER TABLE` statement. However, the definition of the table must be compatible with the `NDBCLUSTER` storage engine prior to making the conversion. In MySQL 5.1, an additional workaround is also required; see Section 17.1.6, "Known Limitations of MySQL Cluster", for details.

A.10.29. How do MySQL Cluster nodes communicate with one another?

Cluster nodes can communicate through any of three different transport mechanisms: TCP/IP, SHM (shared memory), and SCI (Scalable Coherent Interface). Where available, SHM is used by default between nodes residing on the same cluster host; however, this is considered experimental. SCI is a high-speed (1 gigabit per second and higher), high-availability protocol used in building scalable multi-processor systems; it requires special hardware and drivers. See Section 17.3.4, "Using High-Speed Interconnects with MySQL Cluster", for more about using SCI as a transport mechanism for MySQL Cluster.

A.10.30 What is an *arbitrator*?

If one or more data nodes in a cluster fail, it is possible that not all cluster data nodes will be able to "see" one another. In fact, it is possible that two sets of data nodes might become isolated from one another in a network partitioning, also known as a "split-brain" scenario. This type of situation is undesirable because each set of data nodes tries to behave as though it is the entire cluster. An arbitrator is required to decide between the competing sets of data nodes.

When all data nodes in at least one node group are alive, network partitioning is not an issue, because no single subset of the cluster can form a functional cluster on its own. The real problem arises when no single node group has all its nodes alive, in which case network partitioning (the "split-brain" scenario) becomes possible. Then an arbitrator is required. All cluster nodes recognize the same node as the arbitrator, which is normally the management server; however, it is possible to configure any of the MySQL Servers in the cluster to act as the arbitrator instead. The arbitrator accepts the first set of cluster nodes to contact it, and tells the remaining set to shut down. Arbitrator selection is controlled by the `ArbitrationRank` configuration parameter for MySQL Server and management server nodes. In MySQL Cluster NDB 7.0.7 and later, you can also use the `ArbitrationRank` configuration parameter to control the arbitrator selection process. For more information about these parameters, see Section 17.3.3.5, "Defining a MySQL Cluster Management Server".

The role of arbitrator does not in and of itself impose any heavy demands upon the host so designated, and thus the arbitrator host does not need to be particularly fast or to have extra memory especially for this purpose.

A.10.31 What data types are supported by MySQL Cluster?

MySQL Cluster supports all of the usual MySQL data types, including those associated with MySQL's spatial extensions; however, the `NDB` storage engine does not support spatial indexes. (Spatial indexes are supported only by `MyISAM`; see Section 11.5, "Extensions for Spatial Data", for more information.) In addition, there are some differences with regard to indexes when used with `NDB` tables.

> **Note**
>
> MySQL Cluster Disk Data tables (that is, tables created with `TABLESPACE ... STORAGE DISK ENGINE=NDB` or `TABLESPACE ... STORAGE DISK ENGINE=NDBCLUSTER`) have only fixed-width rows. This means that (for example) each Disk Data table record containing a `VARCHAR(255)` column requires space for 255 characters (as required for the character set and collation being used for the table), regardless of the actual number of characters stored therein.

See Section 17.1.6, "Known Limitations of MySQL Cluster", for more information about these issues.

A.10.32 How do I start and stop MySQL Cluster?

It is necessary to start each node in the cluster separately, in the following order:

1. Start the management node, using the `ndb_mgmd` command.

   You must include the `-f` or `--config-file` option to tell the management node where its configuration file can be found.

2. Start each data node with the `ndbd` command.

   Each data node must be started with the `-c` or `--ndb-connectstring` option so that the data node knows how to connect to the management server.

3. Start each MySQL Server (SQL node) using your preferred startup script, such as `mysqld_safe`.

   Each MySQL Server must be started with the `--ndbcluster` and `--ndb-connectstring` options. These options cause mysqld to enable `NDBCLUSTER` storage engine support and how to connect to the management server.

Each of these commands must be run from a system shell on the machine housing the affected node. (You do not have to be physically present at the machine—a remote login shell can be used for this purpose.) You can verify that the cluster is running by starting the `NDB` management client `ndb_mgm` on the machine housing the management node and issuing the `SHOW` or `ALL STATUS` command.

To shut down a running cluster, issue the command `SHUTDOWN` in the management client. Alternatively, you may enter the following command in a system shell:

```
shell> ndb_mgm -e "SHUTDOWN"
```

(The quotation marks in this example are optional, since there are no spaces in the command string following the `-e` option; in addition, the `SHUTDOWN` command, like other management client commands, is not case-sensitive.)

Either of these commands causes the `ndb_mgm`, `ndb_mgm`, and any `ndbd` processes to terminate gracefully. MySQL servers running as SQL nodes can be stopped using `mysqladmin shutdown`.

For more information, see Section 17.5.2, "Commands in the MySQL Cluster Management Client", and Section 17.2.6, "Safe Shutdown and Restart of MySQL Cluster".

A.10.33 What happens to MySQL Cluster data when the MySQL Cluster is shut down?

The data that was held in memory by the cluster's data nodes is written to disk, and is reloaded into memory the next time that the cluster is started.

A.10.34 Is it a good idea to have more than one management node for a MySQL Cluster?

It can be helpful as a fail-safe. Only one management node controls the cluster at any given time, but it is possible to configure one management node as primary, and one or more additional management nodes to take over in the event that the primary management node fails.

See Section 17.3.3, "MySQL Cluster Configuration Files", for information on how to configure MySQL Cluster management nodes.

A.10.35 Can I mix different kinds of hardware and operating systems in one MySQL Cluster?

Yes, as long as all machines and operating systems have the same "endianness" (all big-endian or all little-endian).

It is also possible to use software from different MySQL Cluster releases on different nodes. However, we support this only as part of a rolling upgrade procedure (see Section 17.5.5, "Performing a Rolling Restart of a MySQL Cluster").

A.10.36. Can I run two data nodes on a single host? Two SQL nodes?

Yes, it is possible to do this. In the case of multiple data nodes, it is advisable (but not required) for each node to use a different data directory. If you want to run multiple SQL nodes on one machine, each instance of `mysqld` must use a different TCP/IP port. However, in MySQL 5.1, running more than one cluster node of a given type per machine is generally not encouraged or supported for production use.

We also advise against running data nodes and SQL nodes together on the same host, since the `ndbd` and `mysqld` processes may compete for memory.

A.10.37. Can I use host names with MySQL Cluster?

Yes, it is possible to use DNS and DHCP for cluster hosts. However, if your application requires "five nines" availability, you should use fixed (numeric) IP addresses, since making communication between Cluster hosts dependent on services such as DNS and DHCP introduces additional potential points of failure.

A.10.38. Does MySQL Cluster support IPv6?

MySQL Cluster NDB 7.0 and later support IPv6 for connections between SQL nodes (MySQL servers). However, connections between all other types of nodes must use IPv4.

In practical terms, this means that you can use IPv6 for replication between MySQL Clusters, but connections between nodes in the same MySQL Cluster must use IPv4. For more information, see Section 17.6.3, "Known Issues in MySQL Cluster Replication".

A.10.39. How do I handle MySQL users in a MySQL Cluster having multiple MySQL servers?

MySQL user accounts and privileges are *not* automatically propagated between different MySQL servers accessing the same MySQL Cluster. Therefore, you must make sure that these are copied between the SQL nodes yourself. You can do this manually, or automate the task with scripts.

> **Warning**
>
> Do not attempt to work around this issue by converting the MySQL system tables to use the `NDBCLUSTER` storage engine. Only the `MyISAM` storage engine is supported for these tables.

A.10.40. How do I continue to send queries in the event that one of the SQL nodes fails?

MySQL Cluster does not provide any sort of automatic failover between SQL nodes. Your application must be prepared to handle the loss of SQL nodes and to fail over between them.

A.10.41. How do I back up and restore a MySQL Cluster?

You can use the NDB native backup and restore functionality in the MySQL Cluster management client and the `ndb_restore` program. See Section 17.5.3, "Online Backup of MySQL Cluster", and Section 17.4.20, "`ndb_restore` — Restore a MySQL Cluster Backup".

You can also use the traditional functionality provided for this purpose in `mysqldump` and the MySQL server. See Section 4.5.4, "`mysqldump` — A Database Backup Program", for more information.

A.10.42 What is an "angel process"?

This process monitors and, if necessary, attempts to restart the data node process. If you check the list of active processes on your system after starting `ndbd`, you can see that there are actually 2 processes running by that name, as shown here (we omit the output from `ndb_mgmd` and `ndbd` for brevity):

```
shell> ./ndb_mgmd

shell> ps aux | grep ndb
me       23002  0.0  0.0 122948  3104 ?        Ssl  14:14   0:00 ./ndb_mgmd
me       23025  0.0  0.0   5284   820 pts/2    S+   14:14   0:00 grep ndb

shell> ./ndbd -c 127.0.0.1 --initial

shell> ps aux | grep ndb
me       23002  0.0  0.0 123080  3356 ?        Ssl  14:14   0:00 ./ndb_mgmd
me       23096  0.0  0.0  35876  2036 ?        Ss   14:14   0:00 ./ndbd -c 127.0.0.1 --initial
me       23097  1.0  2.4 524116 91096 ?        Sl   14:14   0:00 ./ndbd -c 127.0.0.1 --initial
me       23168  0.0  0.0   5284   812 pts/2    R+   14:15   0:00 grep ndb
```

The `ndbd` process showing 0 memory and CPU usage is the angel process. It actually does use a very small amount of each, of course. It simply checks to see if the main `ndbd` process (the primary data node process that actually handles the data) is running. If permitted to do so (for example, if the `StopOnError` configuration parameter is set to false—see Section 17.3.2.1, "MySQL Cluster Data Node Configuration Parameters"), the angel process tries to restart the primary data node process.

A.11 MySQL 5.1 FAQ: MySQL Chinese, Japanese, and Korean Character Sets

This set of Frequently Asked Questions derives from the experience of MySQL's Support and Development groups in handling many inquiries about CJK (Chinese-Japanese-Korean) issues.

A.11.1 What CJK character sets are available in MySQL?

The list of CJK character sets may vary depending on your MySQL version. For example, the `gb18030` character set was not supported prior to MySQL 5.7.4. However, since the name of the applicable language appears in the `DESCRIPTION` column for every entry in the `INFORMATION_SCHEMA.CHARACTER_SETS` table, you can obtain a current list of all the non-Unicode CJK character sets using this query:

```
mysql> SELECT CHARACTER_SET_NAME, DESCRIPTION
    -> FROM INFORMATION_SCHEMA.CHARACTER_SETS
    -> WHERE DESCRIPTION LIKE '%Chin%'
    -> OR DESCRIPTION LIKE '%Japanese%'
    -> OR DESCRIPTION LIKE '%Korean%'
    -> ORDER BY CHARACTER_SET_NAME;
+--------------------+-------------------------------+
| CHARACTER_SET_NAME | DESCRIPTION                   |
+--------------------+-------------------------------+
| big5               | Big5 Traditional Chinese      |
| cp932              | SJIS for Windows Japanese     |
| eucjpms            | UJIS for Windows Japanese     |
| euckr              | EUC-KR Korean                 |
| gb18030            | China National Standard GB18030 |
| gb2312             | GB2312 Simplified Chinese     |
| gbk                | GBK Simplified Chinese        |
| sjis               | Shift-JIS Japanese            |
| ujis               | EUC-JP Japanese               |
+--------------------+-------------------------------+
9 rows in set (0.01 sec)
```

(See Section 20.1, "The INFORMATION_SCHEMA CHARACTER_SETS Table", for more information.)

MySQL supports three variants of the *GB* (*Guojia Biaozhun*, or *National Standard*, or *Simplified Chinese*) character sets which are official in the People's Republic of China: `gb2312`, `gbk`, and `gb18030` (added in MySQL 5.7.4).

Sometimes people try to insert `gbk` characters into `gb2312`, and it works most of the time because `gbk` is a superset of `gb2312`—but eventually they try to insert a rarer Chinese character and it doesn't work. (See Bug #16072 for an example).

Here, we try to clarify exactly what characters are legitimate in `gb2312` or `gbk`, with reference to the official documents. Please check these references before reporting `gb2312` or `gbk` bugs.

- For a complete listing of the `gb2312` characters, ordered according to the `gb2312_chinese_ci` collation: gb2312

- MySQL's `gbk` is in reality "Microsoft code page 936". This differs from the official `gbk` for characters `A1A4` (middle dot), `A1AA` (em dash), `A6E0-A6F5`, and `A8BB-A8C0`.

- For a listing of `gbk`/Unicode mappings, see http://www.unicode.org/Public/MAPPINGS/VENDORS/MICSFT/WINDOWS/CP936.TXT.

- For MySQL's listing of `gbk` characters, see gbk.

A.11.2 I have inserted CJK characters into my table. Why does `SELECT` display them as "?" characters?

This problem is usually due to a setting in MySQL that doesn't match the settings for the application program or the operating system. Here are some common steps for correcting these types of issues:

- *Be certain of what MySQL version you are using.*

  Use the statement `SELECT VERSION();` to determine this.

- *Make sure that the database is actually using the desired character set.*

  People often think that the client character set is always the same as either the server character set or the character set used for display purposes. However, both of these are false assumptions. You can make sure by checking the result of `SHOW CREATE TABLE tablename` or—better yet —by using this statement:

  ```
  SELECT character_set_name, collation_name
      FROM information_schema.columns
      WHERE table_schema = your_database_name
          AND table_name = your_table_name
          AND column_name = your_column_name;
  ```

- *Determine the hexadecimal value of the character or characters that are not being displayed correctly.*

  You can obtain this information for a column `column_name` in the table `table_name` using the following query:

  ```
  SELECT HEX(column_name)
  FROM table_name;
  ```

  `3F` is the encoding for the `?` character; this means that `?` is the character actually stored in the column. This most often happens because of a problem converting a particular character from your client character set to the target character set.

- *Make sure that a round trip possible—that is, when you select `literal` (or `_introducer hexadecimal-value`), you obtain `literal` as a result.*

  For example, the Japanese Katakana character *Pe* (ペ) exists in all CJK character sets, and has the code point value (hexadecimal coding) `0x30da`. To test a round trip for this character, use this query:

  ```
  SELECT 'ペ' AS `ペ`;          /* or SELECT _ucs2 0x30da; */
  ```

  If the result is not also ペ, then the round trip has failed.

  For bug reports regarding such failures, we might ask you to follow up with `SELECT HEX('ペ');`. Then we can determine whether the client encoding is correct.

- *Make sure that the problem is not with the browser or other application, rather than with MySQL.*

  Use the `mysql` client program (on Windows: `mysql.exe`) to accomplish this task. If `mysql` displays correctly but your application doesn't, then your problem is probably due to system settings.

To find out what your settings are, use the `SHOW VARIABLES` statement, whose output should resemble what is shown here:

```
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+----------------------------------------+
| Variable_name            | Value                                  |
+--------------------------+----------------------------------------+
| character_set_client     | utf8                                   |
| character_set_connection | utf8                                   |
| character_set_database   | latin1                                 |
| character_set_filesystem | binary                                 |
| character_set_results    | utf8                                   |
| character_set_server     | latin1                                 |
| character_set_system     | utf8                                   |
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/ |
+--------------------------+----------------------------------------+
8 rows in set (0.03 sec)
```

These are typical character-set settings for an international-oriented client (notice the use of `utf8` Unicode) connected to a server in the West (`latin1` is a West Europe character set and a default for MySQL).

Although Unicode (usually the `utf8` variant on Unix, and the `ucs2` variant on Windows) is preferable to Latin, it is often not what your operating system utilities support best. Many Windows users find that a Microsoft character set, such as `cp932` for Japanese Windows, is suitable.

If you cannot control the server settings, and you have no idea what your underlying computer is, then try changing to a common character set for the country that you're in (`euckr` = Korea; `gb18030`, `gb2312` or `gbk` = People's Republic of China; `big5` = Taiwan; `sjis`, `ujis`, `cp932`, or `eucjpms` = Japan; `ucs2` or `utf8` = anywhere). Usually it is necessary to change only the client and connection and results settings. There is a simple statement which changes all three at once: `SET NAMES`. For example:

```
SET NAMES 'big5';
```

Once the setting is correct, you can make it permanent by editing `my.cnf` or `my.ini`. For example you might add lines looking like these:

```
[mysqld]
character-set-server=big5
[client]
default-character-set=big5
```

It is also possible that there are issues with the API configuration setting being used in your application; see *Why does my GUI front end or browser not display CJK characters correctly...?* for more information.

A.11.3. What problems should I be aware of when working with the Big5 Chinese character set?

MySQL supports the Big5 character set which is common in Hong Kong and Taiwan (Republic of China). MySQL's `big5` is in reality Microsoft code page 950, which is very similar to the original `big5` character set. We changed to this character set starting with MySQL version 4.1.16 / 5.0.16 (as a result of Bug #12476). For example, the following statements work in current versions of MySQL, but not in old versions:

```
mysql> CREATE TABLE big5 (BIG5 CHAR(1) CHARACTER SET BIG5);
```

```
Query OK, 0 rows affected (0.13 sec)

mysql> INSERT INTO big5 VALUES (0xf9dc);
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM big5;
+------+
| big5 |
+------+
| 爛   |
+------+
1 row in set (0.02 sec)
```

A feature request for adding HKSCS extensions has been filed. People who need this extension may find the suggested patch for Bug #13577 to be of interest.

A.11.4. Why do Japanese character set conversions fail?

MySQL supports the sjis, ujis, cp932, and eucjpms character sets, as well as Unicode. A common need is to convert between character sets. For example, there might be a Unix server (typically with sjis or ujis) and a Windows client (typically with cp932).

In the following conversion table, the ucs2 column represents the source, and the sjis, cp932, ujis, and eucjpms columns represent the destinations—that is, the last 4 columns provide the hexadecimal result when we use CONVERT(ucs2) or we assign a ucs2 column containing the value to an sjis, cp932, ujis, or eucjpms column.

Character Name	ucs2	sjis	cp932	ujis	eucjpms
BROKEN BAR	00A6	3F	3F	8FA2C3	3F
FULLWIDTH BROKEN BAR	FFE4	3F	FA55	3F	8FA2
YEN SIGN	00A5	3F	3F	20	3F
FULLWIDTH YEN SIGN	FFE5	818F	818F	A1EF	3F
TILDE	007E	7E	7E	7E	7E
OVERLINE	203E	3F	3F	20	3F
HORIZONTAL BAR	2015	815C	815C	A1BD	A1BD
EM DASH	2014	3F	3F	3F	3F
REVERSE SOLIDUS	005C	815F	5C	5C	5C
FULLWIDTH ""	FF3C	3F	815F	3F	A1C0
WAVE DASH	301C	8160	3F	A1C1	3F
FULLWIDTH TILDE	FF5E	3F	8160	3F	A1C1
DOUBLE VERTICAL LINE	2016	8161	3F	A1C2	3F
PARALLEL TO	2225	3F	8161	3F	A1C2
MINUS SIGN	2212	817C	3F	A1DD	3F
FULLWIDTH HYPHEN-MINUS	FF0D	3F	817C	3F	A1DD
CENT SIGN	00A2	8191	3F	A1F1	3F
FULLWIDTH CENT SIGN	FFE0	3F	8191	3F	A1F1
POUND SIGN	00A3	8192	3F	A1F2	3F
FULLWIDTH POUND SIGN	FFE1	3F	8192	3F	A1F2
NOT SIGN	00AC	81CA	3F	A2CC	3F

Character Name	ucs2	sjis	cp932	ujis	eucjpms
FULLWIDTH NOT SIGN	FFE2	3F	81CA	3F	A2CC

Now consider the following portion of the table.

	ucs2	sjis	cp932
NOT SIGN	00AC	81CA	3F
FULLWIDTH NOT SIGN	FFE2	3F	81CA

This means that MySQL converts the `NOT SIGN` (Unicode `U+00AC`) to `sjis` code point `0x81CA` and to `cp932` code point `3F`. (`3F` is the question mark ("?")—this is what is always used when the conversion cannot be performed.

A.11.5. What should I do if I want to convert SJIS `81CA` to `cp932`?

Our answer is: "?". There are serious complaints about this: many people would prefer a "loose" conversion, so that `81CA (NOT SIGN)` in `sjis` becomes `81CA (FULLWIDTH NOT SIGN)` in `cp932`. We are considering a change to this behavior.

A.11.6. How does MySQL represent the Yen (¥) sign?

A problem arises because some versions of Japanese character sets (both `sjis` and `euc`) treat `5C` as a *reverse solidus* (\—also known as a backslash), and others treat it as a yen sign (¥).

MySQL follows only one version of the JIS (Japanese Industrial Standards) standard description. In MySQL, *`5C` is always the reverse solidus (\ )*.

A.11.7. Does MySQL plan to make a separate character set where `5C` is the Yen sign, as at least one other major DBMS does?

This is one possible solution to the Yen sign issue; however, this will not happen in MySQL 5.1 or 6.0.

A.11.8. Of what issues should I be aware when working with Korean character sets in MySQL?

In theory, while there have been several versions of the `euckr` (*Extended Unix Code Korea*) character set, only one problem has been noted.

We use the "ASCII" variant of EUC-KR, in which the code point `0x5c` is REVERSE SOLIDUS, that is \, instead of the "KS-Roman" variant of EUC-KR, in which the code point `0x5c` is `WON SIGN`(₩). This means that you cannot convert Unicode `U+20A9` to `euckr`:

```
mysql> SELECT
    ->     CONVERT('₩' USING euckr) AS euckr,
    ->     HEX(CONVERT('₩' USING euckr)) AS hexeuckr;
+-------+----------+
| euckr | hexeuckr |
+-------+----------+
| ?     | 3F       |
+-------+----------+
1 row in set (0.00 sec)
```

MySQL's graphic Korean chart is here: euckr.

A.11.9. Why do I get `Incorrect string value` error messages?

For illustration, we'll create a table with one Unicode (`ucs2`) column and one Chinese (`gb2312`) column.

```
mysql> CREATE TABLE ch
    -> (ucs2 CHAR(3) CHARACTER SET ucs2,
    -> gb2312 CHAR(3) CHARACTER SET gb2312);
Query OK, 0 rows affected (0.05 sec)
```

We'll try to place the rare character 㳅 in both columns.

```
mysql> INSERT INTO ch VALUES ('A㳅B','A㳅B');
Query OK, 1 row affected, 1 warning (0.00 sec)
```

Ah, there is a warning. Use the following statement to see what it is:

```
mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1366
Message: Incorrect string value: '\xE6\xB1\x8CB' for column 'gb2312' at row 1
1 row in set (0.00 sec)
```

So it is a warning about the `gb2312` column only.

```
mysql> SELECT ucs2,HEX(ucs2),gb2312,HEX(gb2312) FROM ch;
+-------+--------------+--------+-------------+
| ucs2  | HEX(ucs2)    | gb2312 | HEX(gb2312) |
+-------+--------------+--------+-------------+
| A㳅B  | 00416C4C0042 | A?B    | 413F42      |
+-------+--------------+--------+-------------+
1 row in set (0.00 sec)
```

Several things need explanation here:

1. The fact that it is a "warning" rather than an "error" is characteristic of MySQL. We like to try to do what we can, to get the best fit, rather than give up.

2. The 㳅 character is not in the `gb2312` character set. We described that problem earlier.

3. If you are using an old version of MySQL, you will probably see a different message.

4. With `sql_mode=TRADITIONAL`, there would be an error message, rather than a warning.

A.11.10 Why does my GUI front end or browser not display CJK characters correctly in my application using Access, PHP, or another API?

Obtain a direct connection to the server using the `mysql` client (Windows: `mysql.exe`), and try the same query there. If `mysql` responds correctly, then the trouble may be that your application interface requires initialization. Use `mysql` to tell you what character set or sets it uses with the statement `SHOW VARIABLES LIKE 'char%';`. If you are using Access, then you are most likely connecting with Connector/ODBC. In this case, you should check Configuring Connector/ODBC. If, for instance, you use `big5`, you would enter `SET NAMES 'big5'`. (Note that no `;` is required in this case). If you are using ASP, you might need to add `SET NAMES` in the code. Here is an example that has worked in the past:

```
<%
```

```
Session.CodePage=0
Dim strConnection
Dim Conn
strConnection="driver={MySQL ODBC 3.51 Driver};server=server;uid=username;" \
             & "pwd=password;database=database;stmt=SET NAMES 'big5';"
Set Conn = Server.CreateObject("ADODB.Connection")
Conn.Open strConnection
%>
```

In much the same way, if you are using any character set other than `latin1` with Connector/Net, then you must specify the character set in the connection string. See Connecting to MySQL Using Connector/Net, for more information.

If you are using PHP, try this:

```
<?php
  $link = new mysqli($host, $usr, $pwd, $db);

  if( mysqli_connect_errno() )
  {
    printf("Connect failed: %s\n", mysqli_connect_error());
    exit();
  }

  $link->query("SET NAMES 'utf8'");
?>
```

In this case, we used `SET NAMES` to change `character_set_client` and `character_set_connection` and `character_set_results`.

Another issue often encountered in PHP applications has to do with assumptions made by the browser. Sometimes adding or changing a `<meta>` tag suffices to correct the problem: for example, to insure that the user agent interprets page content as `UTF-8`, you should include `<meta http-equiv="Content-Type" content="text/html; charset=utf-8">` in the `<head>` of the HTML page.

If you are using Connector/J, see Using Character Sets and Unicode.

A.11.11 I've upgraded to MySQL 5.1. How can I revert to behavior like that in MySQL 4.0 with regard to character sets?

In MySQL Version 4.0, there was a single "global" character set for both server and client, and the decision as to which character to use was made by the server administrator. This changed starting with MySQL Version 4.1. What happens now is a "handshake", as described in Section 10.1.4, "Connection Character Sets and Collations":

> When a client connects, it sends to the server the name of the character set that it wants to use. The server uses the name to set the `character_set_client`, `character_set_results`, and `character_set_connection` system variables. In effect, the server performs a `SET NAMES` operation using the character set name.

The effect of this is that you cannot control the client character set by starting `mysqld` with `--character-set-server=utf8`. However, some of our Asian customers have said that they prefer the MySQL 4.0 behavior. To make it possible to retain this behavior, we added a `mysqld` switch, `--character-set-client-handshake`, which can be turned off with `--skip-character-set-client-handshake`. If you start `mysqld` with `--skip-character-set-`

`client-handshake`, then, when a client connects, it sends to the server the name of the character set that it wants to use—however, *the server ignores this request from the client*.

By way of example, suppose that your favorite server character set is `latin1` (unlikely in a CJK area, but this is the default value). Suppose further that the client uses `utf8` because this is what the client's operating system supports. Now, start the server with `latin1` as its default character set:

```
mysqld --character-set-server=latin1
```

And then start the client with the default character set `utf8`:

```
mysql --default-character-set=utf8
```

The current settings can be seen by viewing the output of `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+------------------------------------+
| Variable_name            | Value                              |
+--------------------------+------------------------------------+
| character_set_client     | utf8                               |
| character_set_connection | utf8                               |
| character_set_database   | latin1                             |
| character_set_filesystem | binary                             |
| character_set_results    | utf8                               |
| character_set_server     | latin1                             |
| character_set_system     | utf8                               |
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/ |
+--------------------------+------------------------------------+
8 rows in set (0.01 sec)
```

Now stop the client, and then stop the server using `mysqladmin`. Then start the server again, but this time tell it to skip the handshake like so:

```
mysqld --character-set-server=utf8 --skip-character-set-client-handshake
```

Start the client with `utf8` once again as the default character set, then display the current settings:

```
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+------------------------------------+
| Variable_name            | Value                              |
+--------------------------+------------------------------------+
| character_set_client     | latin1                             |
| character_set_connection | latin1                             |
| character_set_database   | latin1                             |
| character_set_filesystem | binary                             |
| character_set_results    | latin1                             |
| character_set_server     | latin1                             |
| character_set_system     | utf8                               |
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/ |
+--------------------------+------------------------------------+
8 rows in set (0.01 sec)
```

As you can see by comparing the differing results from `SHOW VARIABLES`, the server ignores the client's initial settings if the `--skip-character-set-client-handshake` is used.

A.11.12. Why do some `LIKE` and `FULLTEXT` searches with CJK characters fail?

There is a very simple problem with `LIKE` searches on `BINARY` and `BLOB` columns: we need to know the end of a character. With multibyte character sets, different characters might have different octet lengths. For example, in `utf8`, A requires one byte but 서 requires three bytes, as shown here:

```
+------------------------+--------------------------+
| OCTET_LENGTH(_utf8 'A') | OCTET_LENGTH(_utf8 '서') |
+------------------------+--------------------------+
|                      1 |                        3 |
+------------------------+--------------------------+
1 row in set (0.00 sec)
```

If we don't know where the first character ends, then we don't know where the second character begins, in which case even very simple searches such as `LIKE '_A%'` fail. The solution is to use a regular CJK character set in the first place, or to convert to a CJK character set before comparing.

This is one reason why MySQL cannot allow encodings of nonexistent characters. If it is not strict about rejecting bad input, then it has no way of knowing where characters end.

For `FULLTEXT` searches, we need to know where words begin and end. With Western languages, this is rarely a problem because most (if not all) of these use an easy-to-identify word boundary— the space character. However, this is not usually the case with Asian writing. We could use arbitrary halfway measures, like assuming that all Han characters represent words, or (for Japanese) depending on changes from Katakana to Hiragana due to grammatical endings. However, the only sure solution requires a comprehensive word list, which means that we would have to include a dictionary in the server for each Asian language supported. This is simply not feasible.

A.11.13 How do I know whether character X is available in all character sets?

The majority of simplified Chinese and basic nonhalfwidth Japanese Kana characters appear in all CJK character sets. This stored procedure accepts a `UCS-2` Unicode character, converts it to all other character sets, and displays the results in hexadecimal.

```
DELIMITER //

CREATE PROCEDURE p_convert(ucs2_char CHAR(1) CHARACTER SET ucs2)
BEGIN

CREATE TABLE tj
            (ucs2 CHAR(1) character set ucs2,
             utf8 CHAR(1) character set utf8,
             big5 CHAR(1) character set big5,
             cp932 CHAR(1) character set cp932,
             eucjpms CHAR(1) character set eucjpms,
             euckr CHAR(1) character set euckr,
             gb2312 CHAR(1) character set gb2312,
             gbk CHAR(1) character set gbk,
             sjis CHAR(1) character set sjis,
             ujis CHAR(1) character set ujis);

INSERT INTO tj (ucs2) VALUES (ucs2_char);

UPDATE tj SET utf8=ucs2,
             big5=ucs2,
             cp932=ucs2,
             eucjpms=ucs2,
             euckr=ucs2,
             gb2312=ucs2,
             gbk=ucs2,
             sjis=ucs2,
             ujis=ucs2;
```

```
/* If there is a conversion problem, UPDATE will produce a warning. */

SELECT hex(ucs2) AS ucs2,
       hex(utf8) AS utf8,
       hex(big5) AS big5,
       hex(cp932) AS cp932,
       hex(eucjpms) AS eucjpms,
       hex(euckr) AS euckr,
       hex(gb2312) AS gb2312,
       hex(gbk) AS gbk,
       hex(sjis) AS sjis,
       hex(ujis) AS ujis
FROM tj;

DROP TABLE tj;

END//
```

The input can be any single `ucs2` character, or it can be the code point value (hexadecimal representation) of that character. For example, from Unicode's list of `ucs2` encodings and names (http://www.unicode.org/Public/UNIDATA/UnicodeData.txt), we know that the Katakana character *Pe* appears in all CJK character sets, and that its code point value is `0x30da`. If we use this value as the argument to `p_convert()`, the result is as shown here:

```
mysql> CALL p_convert(0x30da)//
+------+--------+------+-------+---------+-------+--------+------+------+------+
| ucs2 | utf8   | big5 | cp932 | eucjpms | euckr | gb2312 | gbk  | sjis | ujis |
+------+--------+------+-------+---------+-------+--------+------+------+------+
| 30DA | E3839A | C772 | 8379  | A5DA    | ABDA  | A5DA   | A5DA | 8379 | A5DA |
+------+--------+------+-------+---------+-------+--------+------+------+------+
1 row in set (0.04 sec)
```

Since none of the column values is `3F`—that is, the question mark character (`?`)—we know that every conversion worked.

A.11.14 Why do CJK strings sort incorrectly in Unicode? (I)

Sometimes people observe that the result of a `utf8_unicode_ci` or `ucs2_unicode_ci` search, or of an `ORDER BY` sort is not what they think a native would expect. Although we never rule out the possibility that there is a bug, we have found in the past that many people do not read correctly the standard table of weights for the Unicode Collation Algorithm. MySQL uses the table found at http://www.unicode.org/Public/UCA/4.0.0/allkeys-4.0.0.txt. This is not the first table you will find by navigating from the `unicode.org` home page, because MySQL uses the older 4.0.0 "allkeys" table, rather than the more recent 4.1.0 table. (The newer `'520'` collations in MySQL 5.6 use the 5.2 "allkeys" table.) This is because we are very wary about changing ordering which affects indexes, lest we bring about situations such as that reported in Bug #16526, illustrated as follows:

```
mysql< CREATE TABLE tj (s1 CHAR(1) CHARACTER SET utf8 COLLATE utf8_unicode_ci);
Query OK, 0 rows affected (0.05 sec)

mysql> INSERT INTO tj VALUES ('が'),('か');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM tj WHERE s1 = 'か';
+------+
| s1   |
+------+
| が   |
```

```
| か   |
+------+
2 rows in set (0.00 sec)
```

The character in the first result row is not the one that we searched for. Why did MySQL retrieve it? First we look for the Unicode code point value, which is possible by reading the hexadecimal number for the `ucs2` version of the characters:

```
mysql> SELECT s1, HEX(CONVERT(s1 USING ucs2)) FROM tj;
+------+----------------------------+
| s1   | HEX(CONVERT(s1 USING ucs2)) |
+------+----------------------------+
| が   | 304C                       |
| か   | 304B                       |
+------+----------------------------+
2 rows in set (0.03 sec)
```

Now we search for `304B` and `304C` in the `4.0.0 allkeys` table, and find these lines:

```
304B  ; [.1E57.0020.000E.304B] # HIRAGANA LETTER KA
304C  ; [.1E57.0020.000E.304B][.0000.0140.0002.3099] # HIRAGANA LETTER GA; QQCM
```

The official Unicode names (following the "#" mark) tell us the Japanese syllabary (Hiragana), the informal classification (letter, digit, or punctuation mark), and the Western identifier (`KA` or `GA`, which happen to be voiced and unvoiced components of the same letter pair). More importantly, the *primary weight* (the first hexadecimal number inside the square brackets) is `1E57` on both lines. For comparisons in both searching and sorting, MySQL pays attention to the primary weight only, ignoring all the other numbers. This means that we are sorting が and か correctly according to the Unicode specification. If we wanted to distinguish them, we'd have to use a non-UCA (Unicode Collation Algorithm) collation (`utf8_bin` or `utf8_general_ci`), or to compare the `HEX()` values, or use `ORDER BY CONVERT(s1 USING sjis)`. Being correct "according to Unicode" isn't enough, of course: the person who submitted the bug was equally correct. We plan to add another collation for Japanese according to the JIS X 4061 standard, in which voiced/unvoiced letter pairs like `KA`/`GA` are distinguishable for ordering purposes.

A.11.15: Why do CJK strings sort incorrectly in Unicode? (II)

If you are using Unicode (`ucs2` or `utf8`), and you know what the Unicode sort order is (see Section A.11, "MySQL 5.1 FAQ: MySQL Chinese, Japanese, and Korean Character Sets"), but MySQL still seems to sort your table incorrectly, then you should first verify the table character set:

```
mysql> SHOW CREATE TABLE t\G
******************** 1. row *******************
Table: t
Create Table: CREATE TABLE `t` (
`s1` char(1) CHARACTER SET ucs2 DEFAULT NULL
) ENGINE=MyISAM DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

Since the character set appears to be correct, let's see what information the `INFORMATION_SCHEMA.COLUMNS` table can provide about this column:

```
mysql> SELECT COLUMN_NAME, CHARACTER_SET_NAME, COLLATION_NAME
    -> FROM INFORMATION_SCHEMA.COLUMNS
    -> WHERE COLUMN_NAME = 's1'
    -> AND TABLE_NAME = 't';
+-------------+--------------------+-----------------+
```

```
| COLUMN_NAME | CHARACTER_SET_NAME | COLLATION_NAME  |
+-------------+--------------------+-----------------+
| s1          | ucs2               | ucs2_general_ci |
+-------------+--------------------+-----------------+
1 row in set (0.01 sec)
```

(See Section 20.4, "The INFORMATION_SCHEMA COLUMNS Table", for more information.)

You can see that the collation is `ucs2_general_ci` instead of `ucs2_unicode_ci`. The reason why this is so can be found using `SHOW CHARSET`, as shown here:

```
mysql> SHOW CHARSET LIKE 'ucs2%';
+---------+---------------+-------------------+--------+
| Charset | Description   | Default collation | Maxlen |
+---------+---------------+-------------------+--------+
| ucs2    | UCS-2 Unicode | ucs2_general_ci   |      2 |
+---------+---------------+-------------------+--------+
1 row in set (0.00 sec)
```

For `ucs2` and `utf8`, the default collation is "general". To specify a Unicode collation, use `COLLATE ucs2_unicode_ci`.

A.11.16. Why are my supplementary characters rejected by MySQL?

Before MySQL 5.5.3, MySQL does not support supplementary characters—that is, characters which need more than 3 bytes—for `UTF-8`. We support only what Unicode calls the *Basic Multilingual Plane / Plane 0*. Only a few very rare Han characters are supplementary; support for them is uncommon. This has led to reports such as that found in Bug #12600, which we rejected as "not a bug". With `utf8`, we must truncate an input string when we encounter bytes that we don't understand. Otherwise, we wouldn't know how long the bad multibyte character is.

One possible workaround is to use `ucs2` instead of `utf8`, in which case the "bad" characters are changed to question marks; however, no truncation takes place. You can also change the data type to `BLOB` or `BINARY`, which perform no validity checking.

As of MySQL 5.5.3, Unicode support is extended to include supplementary characters by means of additional Unicode character sets: `utf16`, `utf32`, and 4-byte `utf8mb4`. These character sets support supplementary Unicode characters outside the Basic Multilingual Plane (BMP).

A.11.17. Shouldn't it be "CJKV"?

No. The term "CJKV" (*Chinese Japanese Korean Vietnamese*) refers to Vietnamese character sets which contain Han (originally Chinese) characters. MySQL has no plan to support the old Vietnamese script using Han characters. MySQL does of course support the modern Vietnamese script with Western characters.

As of MySQL 5.6, there are Vietnamese collations for Unicode character sets, as described in Section 10.1.13.1, "Unicode Character Sets".

A.11.18. Does MySQL allow CJK characters to be used in database and table names?

This issue is fixed in MySQL 5.1, by automatically rewriting the names of the corresponding directories and files.

For example, if you create a database named 楮 on a server whose operating system does not support CJK in directory names, MySQL creates a directory named `@0w@00a5@00ae`, which is just a fancy way of encoding `E6A5AE`—that is, the Unicode hexadecimal representation for the 楮

character. However, if you run a `SHOW DATABASES` statement, you can see that the database is listed as 楮.

A.11.19 Where can I find translations of the MySQL Manual into Chinese, Japanese, and Korean?

The Japanese translation of the MySQL 5.6 manual can be downloaded from http://dev.mysql.com/doc/.

A.11.20 Where can I get help with CJK and related issues in MySQL?

The following resources are available:

- A listing of MySQL user groups can be found at https://wikis.oracle.com/display/mysql/List+of+MySQL+User+Groups.

- View feature requests relating to character set issues at http://tinyurl.com/y6xcuf.

- Visit the MySQL Character Sets, Collation, Unicode Forum. http://forums.mysql.com/ also provides foreign-language forums.

A.12 MySQL 5.1 FAQ: Connectors & APIs

For common questions, issues, and answers relating to the MySQL Connectors and other APIs, see the following areas of the Manual:

- Section 21.8.14, "Common Questions and Problems When Using the C API"

- Common Problems with MySQL and PHP

- Connector/ODBC Notes and Tips

- Connector/Net Programming

- MySQL Connector/J 5.1 Developer Guide

A.13 MySQL 5.1 FAQ: Replication

In the following section, we provide answers to questions that are most frequently asked about MySQL Replication.

A.13.1 Must the slave be connected to the master all the time?

No, it does not. The slave can go down or stay disconnected for hours or even days, and then reconnect and catch up on updates. For example, you can set up a master/slave relationship over a dial-up link where the link is up only sporadically and for short periods of time. The implication of this is that, at any given time, the slave is not guaranteed to be in synchrony with the master unless you take some special measures.

To ensure that catchup can occur for a slave that has been disconnected, you must not remove binary log files from the master that contain information that has not yet been replicated to the slaves. Asynchronous replication can work only if the slave is able to continue reading the binary log from the point where it last read events.

A.13.2 Must I enable networking on my master and slave to enable replication?

Yes, networking must be enabled on the master and slave. If networking is not enabled, the slave cannot connect to the master and transfer the binary log. Check that the `skip-networking` option has not been enabled in the configuration file for either server.

A.13.3 How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave?

Check the `Seconds_Behind_Master` column in the output from `SHOW SLAVE STATUS`. See Section 16.1.4.1, "Checking Replication Status".

When the slave SQL thread executes an event read from the master, it modifies its own time to the event timestamp. (This is why `TIMESTAMP` is well replicated.) In the `Time` column in the output of `SHOW PROCESSLIST`, the number of seconds displayed for the slave SQL thread is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. You can use this to determine the date of the last replicated event. Note that if your slave has been disconnected from the master for one hour, and then reconnects, you may immediately see large `Time` values such as 3600 for the slave SQL thread in `SHOW PROCESSLIST`. This is because the slave is executing statements that are one hour old. See Section 16.2.1, "Replication Implementation Details".

A.13.4 How do I force the master to block updates until the slave catches up?

Use the following procedure:

1. On the master, execute these statements:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SHOW MASTER STATUS;
```

Record the replication coordinates (the current binary log file name and position) from the output of the `SHOW` statement.

2. On the slave, issue the following statement, where the arguments to the `MASTER_POS_WAIT()` function are the replication coordinate values obtained in the previous step:

```
mysql> SELECT MASTER_POS_WAIT('log_name', log_pos);
```

The `SELECT` statement blocks until the slave reaches the specified log file and position. At that point, the slave is in synchrony with the master and the statement returns.

3. On the master, issue the following statement to enable the master to begin processing updates again:

```
mysql> UNLOCK TABLES;
```

A.13.5. What issues should I be aware of when setting up two-way replication?

MySQL replication currently does not support any locking protocol between master and slave to guarantee the atomicity of a distributed (cross-server) update. In other words, it is possible for client A to make an update to co-master 1, and in the meantime, before it propagates to co-master 2, client B could make an update to co-master 2 that makes the update of client A work differently than it did on co-master 1. Thus, when the update of client A makes it to co-master 2, it produces tables that are different from what you have on co-master 1, even after all the updates from co-master 2 have also propagated. This means that you should not chain two servers together in a two-way replication relationship unless you are sure that your updates can safely happen in any order, or unless you take care of mis-ordered updates somehow in the client code.

You should also realize that two-way replication actually does not improve performance very much (if at all) as far as updates are concerned. Each server must do the same number of updates, just as you would have a single server do. The only difference is that there is a little less lock contention because the updates originating on another server are serialized in one slave thread. Even this benefit might be offset by network delays.

A.13.6. How can I use replication to improve performance of my system?

Set up one server as the master and direct all writes to it. Then configure as many slaves as you have the budget and rackspace for, and distribute the reads among the master and the slaves. You can also start the slaves with the `--skip-innodb`, `--low-priority-updates`, and `--delay-key-write=ALL` options to get speed improvements on the slave end. In this case, the slave uses nontransactional `MyISAM` tables instead of `InnoDB` tables to get more speed by eliminating transactional overhead.

A.13.7. What should I do to prepare client code in my own applications to use performance-enhancing replication?

See the guide to using replication as a scale-out solution, Section 16.3.3, "Using Replication for Scale-Out".

A.13.8. When and how much can MySQL replication improve the performance of my system?

MySQL replication is most beneficial for a system that processes frequent reads and infrequent writes. In theory, by using a single-master/multiple-slave setup, you can scale the system by adding more slaves until you either run out of network bandwidth, or your update load grows to the point that the master cannot handle it.

To determine how many slaves you can use before the added benefits begin to level out, and how much you can improve performance of your site, you must know your query patterns, and determine empirically by benchmarking the relationship between the throughput for reads and writes on a typical master and a typical slave. The example here shows a rather simplified calculation of what you can get with replication for a hypothetical system. Let `reads` and `writes` denote the number of reads and writes per second, respectively.

Let's say that system load consists of 10% writes and 90% reads, and we have determined by benchmarking that `reads` is 1200 - 2 * `writes`. In other words, the system can do 1,200 reads per second with no writes, the average write is twice as slow as the average read, and the relationship

is linear. Suppose that the master and each slave have the same capacity, and that we have one master and N slaves. Then we have for each server (master or slave):

`reads` = 1200 - 2 * `writes`

`reads` = 9 * `writes` / (N + 1) (reads are split, but writes replicated to all slaves)

9 * `writes` / (N + 1) + 2 * `writes` = 1200

`writes` = 1200 / (2 + 9/(N + 1))

The last equation indicates the maximum number of writes for N slaves, given a maximum possible read rate of 1,200 per second and a ratio of nine reads per write.

This analysis yields the following conclusions:

- If N = 0 (which means we have no replication), our system can handle about 1200/11 = 109 writes per second.

- If N = 1, we get up to 184 writes per second.

- If N = 8, we get up to 400 writes per second.

- If N = 17, we get up to 480 writes per second.

- Eventually, as N approaches infinity (and our budget negative infinity), we can get very close to 600 writes per second, increasing system throughput about 5.5 times. However, with only eight servers, we increase it nearly four times.

These computations assume infinite network bandwidth and neglect several other factors that could be significant on your system. In many cases, you may not be able to perform a computation similar to the one just shown that accurately predicts what will happen on your system if you add N replication slaves. However, answering the following questions should help you decide whether and by how much replication will improve the performance of your system:

- What is the read/write ratio on your system?

- How much more write load can one server handle if you reduce the reads?

- For how many slaves do you have bandwidth available on your network?

A.13.9 How can I use replication to provide redundancy or high availability?

How you implement redundancy is entirely dependent on your application and circumstances. High-availability solutions (with automatic failover) require active monitoring and either custom scripts or third party tools to provide the failover support from the original MySQL server to the slave.

To handle the process manually, you should be able to switch from a failed master to a pre-configured slave by altering your application to talk to the new server or by adjusting the DNS for the MySQL server from the failed server to the new server.

For more information and some example solutions, see Section 16.3.6, "Switching Masters During Failover".

A.13.10 How do I tell whether a master server is using statement-based or row-based binary logging format?

Check the value of the `binlog_format` system variable:

```
mysql> SHOW VARIABLES LIKE 'binlog_format';
```

The value shown will be one of `STATEMENT`, `ROW`, or `MIXED`. For `MIXED` mode, statement-based logging is used by default but replication switches automatically to row-based logging under certain conditions, such as unsafe statements. For information about when this may occur, see Section 5.4.4.3, "Mixed Binary Logging Format".

A.13.11 How do I tell a slave to use row-based replication?

Slaves automatically know which format to use.

A.13.12 How do I prevent `GRANT` and `REVOKE` statements from replicating to slave machines?

Start the server with the `--replicate-wild-ignore-table=mysql.%` option to ignore replication for tables in the `mysql` database.

A.13.13 Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on OS X and Windows)?

Yes.

A.13.14 Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)?

Yes.

Appendix B Errors, Error Codes, and Common Problems

Table of Contents

This appendix lists common problems and errors that may occur and potential resolutions, in addition to listing the errors that may appear when you call MySQL from any host language. The first section covers problems and resolutions. Detailed information on errors is provided: One list displays server error messages. Another list displays client program messages.

B.1 Sources of Error Information

There are several sources of error information in MySQL:

- Each SQL statement executed results in an error code, an SQLSTATE value, and an error message, as described in Section B.2, "Types of Error Values". These errors are returned from the server side; see Section B.3, "Server Error Codes and Messages".

- Errors can occur on the client side, usually involving problems communicating with the server; see Section B.4, "Client Error Codes and Messages".

- SQL statement warning and error information is available through the SHOW WARNINGS and SHOW ERRORS statements. The warning_count system variable indicates the number of errors, warnings, and notes. The error_count system variable indicates the number of errors. Its value excludes warnings and notes.

- SHOW SLAVE STATUS statement output includes information about replication errors occurring on the slave side.

- SHOW ENGINE INNODB STATUS statement output includes information about the most recent foreign key error if a CREATE TABLE statement for an InnoDB table fails.

- The perror program provides information from the command line about error numbers. See Section 4.8.1, "perror — Explain Error Codes".

Descriptions of server and client errors are provided later in this Appendix. For information about errors related to InnoDB, see Section 14.6.12.4, "InnoDB Error Handling".

B.2 Types of Error Values

When an error occurs in MySQL, the server returns two types of error values:

- A MySQL-specific error code. This value is numeric. It is not portable to other database systems.

- An SQLSTATE value. The value is a five-character string (for example, `'42S02'`). The values are taken from ANSI SQL and ODBC and are more standardized.

A message string that provides a textual description of the error is also available.

When an error occurs, the MySQL error code, SQLSTATE value, and message string are available using C API functions:

- MySQL error code: Call `mysql_errno()`

- SQLSTATE value: Call `mysql_sqlstate()`

- Error message: Call `mysql_error()`

For prepared statements, the corresponding error functions are `mysql_stmt_errno()`, `mysql_stmt_sqlstate()`, and `mysql_stmt_error()`. All error functions are described in Section 21.8, "MySQL C API".

The number of errors, warnings, and notes for the previous statement can be obtained by calling `mysql_warning_count()`. See Section 21.8.7.72, "mysql_warning_count()".

The first two characters of an SQLSTATE value indicate the error class:

- Class = `'00'` indicates success.

- Class = `'01'` indicates a warning.

- Class = `'02'` indicates "not found." This is relevant within the context of cursors and is used to control what happens when a cursor reaches the end of a data set. This condition also occurs for `SELECT ... INTO var_list` statements that retrieve no rows.

- Class > `'02'` indicates an exception.

B.3 Server Error Codes and Messages

MySQL programs have access to several types of error information when the server returns an error. For example, the `mysql` client program displays errors using the following format:

```
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

The message displayed contains three types of information:

- A numeric error code (`1146`). This number is MySQL-specific and is not portable to other database systems.

- A five-character SQLSTATE value (`'42S02'`). The values are taken from ANSI SQL and ODBC and are more standardized. Not all MySQL error numbers have corresponding SQLSTATE values. In these cases, `'HY000'` (general error) is used.

- A message string that provides a textual description of the error.

For error checking, use error codes, not error messages. Error messages do not change often, but it is possible. Also if the database administrator changes the language setting, that affects the language of error messages.

Error codes are stable across GA releases of a given MySQL series. Before a series reaches GA status, new codes may still be under development and subject to change.

Server error information comes from the following source files. For details about the way that error information is defined, see the MySQL Internals Manual.

- Error message information is listed in the `share/errmsg.txt` file. `%d` and `%s` represent numbers and strings, respectively, that are substituted into the Message values when they are displayed.

- The Error values listed in `share/errmsg.txt` are used to generate the definitions in the `include/mysqld_error.h` and `include/mysqld_ername.h` MySQL source files.

- The SQLSTATE values listed in `share/errmsg.txt` are used to generate the definitions in the `include/sql_state.h` MySQL source file.

Because updates are frequent, it is possible that those files will contain additional error information not listed here.

- Error: `1000` SQLSTATE: `HY000` (`ER_HASHCHK`)

  Message: hashchk

  Unused.

- Error: `1001` SQLSTATE: `HY000` (`ER_NISAMCHK`)

  Message: isamchk

  Unused.

- Error: `1002` SQLSTATE: `HY000` (`ER_NO`)

  Message: NO

  Used in the construction of other messages.

- Error: `1003` SQLSTATE: `HY000` (`ER_YES`)

  Message: YES

  Used in the construction of other messages.

  Extended `EXPLAIN` format generates Note messages. `ER_YES` is used in the `Code` column for these messages in subsequent `SHOW WARNINGS` output.

- Error: `1004` SQLSTATE: `HY000` (`ER_CANT_CREATE_FILE`)

  Message: Can't create file '%s' (errno: %d)

  Occurs for failure to copy an `.frm` file to a new location, during execution of a `CREATE TABLE dst LIKE src` statement when the server tries to copy the source table `.frm` file to the destination table `.frm` file.

  Possible causes: Permissions problem for source `.frm` file; destination `.frm` file already exists but is not writeable.

- Error: `1005` SQLSTATE: `HY000` (`ER_CANT_CREATE_TABLE`)

  Message: Can't create table '%s' (errno: %d)

  `InnoDB` reports this error when a table cannot be created. If the error message refers to error 150, table creation failed because a foreign key constraint was not correctly formed. If the error message refers

to error −1, table creation probably failed because the table includes a column name that matched the name of an internal `InnoDB` table.

- Error: `1006` SQLSTATE: `HY000` (`ER_CANT_CREATE_DB`)

  Message: Can't create database '%s' (errno: %d)

- Error: `1007` SQLSTATE: `HY000` (`ER_DB_CREATE_EXISTS`)

  Message: Can't create database '%s'; database exists

  An attempt to create a database failed because the database already exists.

  Drop the database first if you really want to replace an existing database, or add an `IF NOT EXISTS` clause to the `CREATE DATABASE` statement if to retain an existing database without having the statement produce an error.

- Error: `1008` SQLSTATE: `HY000` (`ER_DB_DROP_EXISTS`)

  Message: Can't drop database '%s'; database doesn't exist

- Error: `1009` SQLSTATE: `HY000` (`ER_DB_DROP_DELETE`)

  Message: Error dropping database (can't delete '%s', errno: %d)

- Error: `1010` SQLSTATE: `HY000` (`ER_DB_DROP_RMDIR`)

  Message: Error dropping database (can't rmdir '%s', errno: %d)

- Error: `1011` SQLSTATE: `HY000` (`ER_CANT_DELETE_FILE`)

  Message: Error on delete of '%s' (errno: %d)

- Error: `1012` SQLSTATE: `HY000` (`ER_CANT_FIND_SYSTEM_REC`)

  Message: Can't read record in system table

  Returned by `InnoDB` for attempts to access `InnoDB INFORMATION_SCHEMA` tables when `InnoDB` is unavailable.

- Error: `1013` SQLSTATE: `HY000` (`ER_CANT_GET_STAT`)

  Message: Can't get status of '%s' (errno: %d)

- Error: `1014` SQLSTATE: `HY000` (`ER_CANT_GET_WD`)

  Message: Can't get working directory (errno: %d)

- Error: `1015` SQLSTATE: `HY000` (`ER_CANT_LOCK`)

  Message: Can't lock file (errno: %d)

- Error: `1016` SQLSTATE: `HY000` (`ER_CANT_OPEN_FILE`)

  Message: Can't open file: '%s' (errno: %d)

  `InnoDB` reports this error when the table from the `InnoDB` data files cannot be found, even though the `.frm` file for the table exists. See Section 14.6.12.3, "Troubleshooting InnoDB Data Dictionary Operations".

- Error: `1017` SQLSTATE: `HY000` (`ER_FILE_NOT_FOUND`)

  Message: Can't find file: '%s' (errno: %d)

- Error: `1018` SQLSTATE: `HY000` (`ER_CANT_READ_DIR`)

  Message: Can't read dir of '%s' (errno: %d)

- Error: `1019` SQLSTATE: `HY000` (`ER_CANT_SET_WD`)

  Message: Can't change dir to '%s' (errno: %d)

- Error: `1020` SQLSTATE: `HY000` (`ER_CHECKREAD`)

  Message: Record has changed since last read in table '%s'

- Error: `1021` SQLSTATE: `HY000` (`ER_DISK_FULL`)

  Message: Disk full (%s); waiting for someone to free some space...

- Error: `1022` SQLSTATE: `23000` (`ER_DUP_KEY`)

  Message: Can't write; duplicate key in table '%s'

- Error: `1023` SQLSTATE: `HY000` (`ER_ERROR_ON_CLOSE`)

  Message: Error on close of '%s' (errno: %d)

- Error: `1024` SQLSTATE: `HY000` (`ER_ERROR_ON_READ`)

  Message: Error reading file '%s' (errno: %d)

- Error: `1025` SQLSTATE: `HY000` (`ER_ERROR_ON_RENAME`)

  Message: Error on rename of '%s' to '%s' (errno: %d)

  `InnoDB` reports this error if you attempt to drop the last index that can enforce a particular referential constraint. As of MySQL 5.5, this error message is replaced by `ERROR 1553`.

- Error: `1026` SQLSTATE: `HY000` (`ER_ERROR_ON_WRITE`)

  Message: Error writing file '%s' (errno: %d)

- Error: `1027` SQLSTATE: `HY000` (`ER_FILE_USED`)

  Message: '%s' is locked against change

- Error: `1028` SQLSTATE: `HY000` (`ER_FILSORT_ABORT`)

  Message: Sort aborted

- Error: `1029` SQLSTATE: `HY000` (`ER_FORM_NOT_FOUND`)

  Message: View '%s' doesn't exist for '%s'

- Error: `1030` SQLSTATE: `HY000` (`ER_GET_ERRNO`)

  Message: Got error %d from storage engine

  Check the `%d` value to see what the OS error means. For example, 28 indicates that you have run out of disk space.

- Error: `1031` SQLSTATE: `HY000` (`ER_ILLEGAL_HA`)

  Message: Table storage engine for '%s' doesn't have this option

- Error: `1032` SQLSTATE: `HY000` (`ER_KEY_NOT_FOUND`)

  Message: Can't find record in '%s'

- Error: `1033` SQLSTATE: `HY000` (`ER_NOT_FORM_FILE`)

  Message: Incorrect information in file: '%s'

- Error: `1034` SQLSTATE: `HY000` (`ER_NOT_KEYFILE`)

  Message: Incorrect key file for table '%s'; try to repair it

- Error: `1035` SQLSTATE: `HY000` (`ER_OLD_KEYFILE`)

  Message: Old key file for table '%s'; repair it!

- Error: `1036` SQLSTATE: `HY000` (`ER_OPEN_AS_READONLY`)

  Message: Table '%s' is read only

- Error: `1037` SQLSTATE: `HY001` (`ER_OUTOFMEMORY`)

  Message: Out of memory; restart server and try again (needed %d bytes)

- Error: `1038` SQLSTATE: `HY001` (`ER_OUT_OF_SORTMEMORY`)

  Message: Out of sort memory; increase server sort buffer size

- Error: `1039` SQLSTATE: `HY000` (`ER_UNEXPECTED_EOF`)

  Message: Unexpected EOF found when reading file '%s' (errno: %d)

- Error: `1040` SQLSTATE: `08004` (`ER_CON_COUNT_ERROR`)

  Message: Too many connections

- Error: `1041` SQLSTATE: `HY000` (`ER_OUT_OF_RESOURCES`)

  Message: Out of memory; check if mysqld or some other process uses all available memory; if not, you may have to use 'ulimit' to allow mysqld to use more memory or you can add more swap space

- Error: `1042` SQLSTATE: `08S01` (`ER_BAD_HOST_ERROR`)

  Message: Can't get hostname for your address

- Error: `1043` SQLSTATE: `08S01` (`ER_HANDSHAKE_ERROR`)

  Message: Bad handshake

- Error: `1044` SQLSTATE: `42000` (`ER_DBACCESS_DENIED_ERROR`)

  Message: Access denied for user '%s'@'%s' to database '%s'

- Error: `1045` SQLSTATE: `28000` (`ER_ACCESS_DENIED_ERROR`)

  Message: Access denied for user '%s'@'%s' (using password: %s)

- Error: `1046` SQLSTATE: `3D000` (`ER_NO_DB_ERROR`)

  Message: No database selected

- Error: `1047` SQLSTATE: `08S01` (`ER_UNKNOWN_COM_ERROR`)

  Message: Unknown command

- Error: `1048` SQLSTATE: `23000` (`ER_BAD_NULL_ERROR`)

  Message: Column '%s' cannot be null

- Error: `1049` SQLSTATE: `42000` (`ER_BAD_DB_ERROR`)

  Message: Unknown database '%s'

- Error: `1050` SQLSTATE: `42S01` (`ER_TABLE_EXISTS_ERROR`)

  Message: Table '%s' already exists

- Error: `1051` SQLSTATE: `42S02` (`ER_BAD_TABLE_ERROR`)

  Message: Unknown table '%s'

- Error: `1052` SQLSTATE: `23000` (`ER_NON_UNIQ_ERROR`)

  Message: Column '%s' in %s is ambiguous

  ```
  %s = column name
  %s = location of column (for example, "field list")
  ```

  Likely cause: A column appears in a query without appropriate qualification, such as in a select list or ON clause.

  Examples:

  ```
  mysql> SELECT i FROM t INNER JOIN t AS t2;
  ERROR 1052 (23000): Column 'i' in field list is ambiguous

  mysql> SELECT * FROM t LEFT JOIN t AS t2 ON i = i;
  ERROR 1052 (23000): Column 'i' in on clause is ambiguous
  ```

  Resolution:

  - Qualify the column with the appropriate table name:

    ```
    mysql> SELECT t2.i FROM t INNER JOIN t AS t2;
    ```

  - Modify the query to avoid the need for qualification:

    ```
    mysql> SELECT * FROM t LEFT JOIN t AS t2 USING (i);
    ```

- Error: `1053` SQLSTATE: `08S01` (`ER_SERVER_SHUTDOWN`)

  Message: Server shutdown in progress

- Error: `1054` SQLSTATE: `42S22` (`ER_BAD_FIELD_ERROR`)

Message: Unknown column '%s' in '%s'

- Error: `1055` SQLSTATE: `42000` (`ER_WRONG_FIELD_WITH_GROUP`)

  Message: '%s' isn't in GROUP BY

- Error: `1056` SQLSTATE: `42000` (`ER_WRONG_GROUP_FIELD`)

  Message: Can't group on '%s'

- Error: `1057` SQLSTATE: `42000` (`ER_WRONG_SUM_SELECT`)

  Message: Statement has sum functions and columns in same statement

- Error: `1058` SQLSTATE: `21S01` (`ER_WRONG_VALUE_COUNT`)

  Message: Column count doesn't match value count

- Error: `1059` SQLSTATE: `42000` (`ER_TOO_LONG_IDENT`)

  Message: Identifier name '%s' is too long

- Error: `1060` SQLSTATE: `42S21` (`ER_DUP_FIELDNAME`)

  Message: Duplicate column name '%s'

- Error: `1061` SQLSTATE: `42000` (`ER_DUP_KEYNAME`)

  Message: Duplicate key name '%s'

- Error: `1062` SQLSTATE: `23000` (`ER_DUP_ENTRY`)

  Message: Duplicate entry '%s' for key %d

  From 5.1.20: The message returned with this error uses the format string for
  `ER_DUP_ENTRY_WITH_KEY_NAME`.

- Error: `1063` SQLSTATE: `42000` (`ER_WRONG_FIELD_SPEC`)

  Message: Incorrect column specifier for column '%s'

- Error: `1064` SQLSTATE: `42000` (`ER_PARSE_ERROR`)

  Message: %s near '%s' at line %d

- Error: `1065` SQLSTATE: `42000` (`ER_EMPTY_QUERY`)

  Message: Query was empty

- Error: `1066` SQLSTATE: `42000` (`ER_NONUNIQ_TABLE`)

  Message: Not unique table/alias: '%s'

- Error: `1067` SQLSTATE: `42000` (`ER_INVALID_DEFAULT`)

  Message: Invalid default value for '%s'

- Error: `1068` SQLSTATE: `42000` (`ER_MULTIPLE_PRI_KEY`)

  Message: Multiple primary key defined

- Error: `1069` SQLSTATE: `42000` (`ER_TOO_MANY_KEYS`)

  Message: Too many keys specified; max %d keys allowed

- Error: `1070` SQLSTATE: `42000` (`ER_TOO_MANY_KEY_PARTS`)

  Message: Too many key parts specified; max %d parts allowed

- Error: `1071` SQLSTATE: `42000` (`ER_TOO_LONG_KEY`)

  Message: Specified key was too long; max key length is %d bytes

- Error: `1072` SQLSTATE: `42000` (`ER_KEY_COLUMN_DOES_NOT_EXITS`)

  Message: Key column '%s' doesn't exist in table

- Error: `1073` SQLSTATE: `42000` (`ER_BLOB_USED_AS_KEY`)

  Message: BLOB column '%s' can't be used in key specification with the used table type

- Error: `1074` SQLSTATE: `42000` (`ER_TOO_BIG_FIELDLENGTH`)

  Message: Column length too big for column '%s' (max = %lu); use BLOB or TEXT instead

- Error: `1075` SQLSTATE: `42000` (`ER_WRONG_AUTO_KEY`)

  Message: Incorrect table definition; there can be only one auto column and it must be defined as a key

- Error: `1076` SQLSTATE: `HY000` (`ER_READY`)

  Message: %s: ready for connections. Version: '%s' socket: '%s' port: %d

- Error: `1077` SQLSTATE: `HY000` (`ER_NORMAL_SHUTDOWN`)

  Message: %s: Normal shutdown

- Error: `1078` SQLSTATE: `HY000` (`ER_GOT_SIGNAL`)

  Message: %s: Got signal %d. Aborting!

- Error: `1079` SQLSTATE: `HY000` (`ER_SHUTDOWN_COMPLETE`)

  Message: %s: Shutdown complete

- Error: `1080` SQLSTATE: `08S01` (`ER_FORCING_CLOSE`)

  Message: %s: Forcing close of thread %ld user: '%s'

- Error: `1081` SQLSTATE: `08S01` (`ER_IPSOCK_ERROR`)

  Message: Can't create IP socket

- Error: `1082` SQLSTATE: `42S12` (`ER_NO_SUCH_INDEX`)

  Message: Table '%s' has no index like the one used in CREATE INDEX; recreate the table

- Error: `1083` SQLSTATE: `42000` (`ER_WRONG_FIELD_TERMINATORS`)

  Message: Field separator argument is not what is expected; check the manual

- Error: `1084` SQLSTATE: `42000` (`ER_BLOBS_AND_NO_TERMINATED`)

  Message: You can't use fixed rowlength with BLOBs; please use 'fields terminated by'

- Error: `1085` SQLSTATE: `HY000` (`ER_TEXTFILE_NOT_READABLE`)

  Message: The file '%s' must be in the database directory or be readable by all

- Error: `1086` SQLSTATE: `HY000` (`ER_FILE_EXISTS_ERROR`)

  Message: File '%s' already exists

- Error: `1087` SQLSTATE: `HY000` (`ER_LOAD_INFO`)

  Message: Records: %ld Deleted: %ld Skipped: %ld Warnings: %ld

- Error: `1088` SQLSTATE: `HY000` (`ER_ALTER_INFO`)

  Message: Records: %ld Duplicates: %ld

- Error: `1089` SQLSTATE: `HY000` (`ER_WRONG_SUB_KEY`)

  Message: Incorrect prefix key; the used key part isn't a string, the used length is longer than the key part, or the storage engine doesn't support unique prefix keys

- Error: `1090` SQLSTATE: `42000` (`ER_CANT_REMOVE_ALL_FIELDS`)

  Message: You can't delete all columns with ALTER TABLE; use DROP TABLE instead

- Error: `1091` SQLSTATE: `42000` (`ER_CANT_DROP_FIELD_OR_KEY`)

  Message: Can't DROP '%s'; check that column/key exists

- Error: `1092` SQLSTATE: `HY000` (`ER_INSERT_INFO`)

  Message: Records: %ld Duplicates: %ld Warnings: %ld

- Error: `1093` SQLSTATE: `HY000` (`ER_UPDATE_TABLE_USED`)

  Message: You can't specify target table '%s' for update in FROM clause

  This error occurs for attempts to select from and modify the same table within a single statement.

- Error: `1094` SQLSTATE: `HY000` (`ER_NO_SUCH_THREAD`)

  Message: Unknown thread id: %lu

- Error: `1095` SQLSTATE: `HY000` (`ER_KILL_DENIED_ERROR`)

  Message: You are not owner of thread %lu

- Error: `1096` SQLSTATE: `HY000` (`ER_NO_TABLES_USED`)

  Message: No tables used

- Error: `1097` SQLSTATE: `HY000` (`ER_TOO_BIG_SET`)

  Message: Too many strings for column %s and SET

- Error: `1098` SQLSTATE: `HY000` (`ER_NO_UNIQUE_LOGFILE`)

Message: Can't generate a unique log-filename %s.(1-999)

- Error: `1099` SQLSTATE: `HY000` (`ER_TABLE_NOT_LOCKED_FOR_WRITE`)

  Message: Table '%s' was locked with a READ lock and can't be updated

- Error: `1100` SQLSTATE: `HY000` (`ER_TABLE_NOT_LOCKED`)

  Message: Table '%s' was not locked with LOCK TABLES

- Error: `1101` SQLSTATE: `42000` (`ER_BLOB_CANT_HAVE_DEFAULT`)

  Message: BLOB/TEXT column '%s' can't have a default value

- Error: `1102` SQLSTATE: `42000` (`ER_WRONG_DB_NAME`)

  Message: Incorrect database name '%s'

- Error: `1103` SQLSTATE: `42000` (`ER_WRONG_TABLE_NAME`)

  Message: Incorrect table name '%s'

- Error: `1104` SQLSTATE: `42000` (`ER_TOO_BIG_SELECT`)

  Message: The SELECT would examine more than MAX_JOIN_SIZE rows; check your WHERE and use SET SQL_BIG_SELECTS=1 or SET MAX_JOIN_SIZE=# if the SELECT is okay

- Error: `1105` SQLSTATE: `HY000` (`ER_UNKNOWN_ERROR`)

  Message: Unknown error

- Error: `1106` SQLSTATE: `42000` (`ER_UNKNOWN_PROCEDURE`)

  Message: Unknown procedure '%s'

- Error: `1107` SQLSTATE: `42000` (`ER_WRONG_PARAMCOUNT_TO_PROCEDURE`)

  Message: Incorrect parameter count to procedure '%s'

- Error: `1108` SQLSTATE: `HY000` (`ER_WRONG_PARAMETERS_TO_PROCEDURE`)

  Message: Incorrect parameters to procedure '%s'

- Error: `1109` SQLSTATE: `42S02` (`ER_UNKNOWN_TABLE`)

  Message: Unknown table '%s' in %s

- Error: `1110` SQLSTATE: `42000` (`ER_FIELD_SPECIFIED_TWICE`)

  Message: Column '%s' specified twice

- Error: `1111` SQLSTATE: `HY000` (`ER_INVALID_GROUP_FUNC_USE`)

  Message: Invalid use of group function

- Error: `1112` SQLSTATE: `42000` (`ER_UNSUPPORTED_EXTENSION`)

  Message: Table '%s' uses an extension that doesn't exist in this MySQL version

- Error: `1113` SQLSTATE: `42000` (`ER_TABLE_MUST_HAVE_COLUMNS`)

Message: A table must have at least 1 column

- Error: `1114` SQLSTATE: `HY000` (`ER_RECORD_FILE_FULL`)

Message: The table '%s' is full

`InnoDB` reports this error when the system tablespace runs out of free space. Reconfigure the system tablespace to add a new data file.

- Error: `1115` SQLSTATE: `42000` (`ER_UNKNOWN_CHARACTER_SET`)

Message: Unknown character set: '%s'

- Error: `1116` SQLSTATE: `HY000` (`ER_TOO_MANY_TABLES`)

Message: Too many tables; MySQL can only use %d tables in a join

- Error: `1117` SQLSTATE: `HY000` (`ER_TOO_MANY_FIELDS`)

Message: Too many columns

- Error: `1118` SQLSTATE: `42000` (`ER_TOO_BIG_ROWSIZE`)

Message: Row size too large. The maximum row size for the used table type, not counting BLOBs, is %ld. You have to change some columns to TEXT or BLOBs

- Error: `1119` SQLSTATE: `HY000` (`ER_STACK_OVERRUN`)

Message: Thread stack overrun: Used: %ld of a %ld stack. Use 'mysqld -O thread_stack=#' to specify a bigger stack if needed

- Error: `1120` SQLSTATE: `42000` (`ER_WRONG_OUTER_JOIN`)

Message: Cross dependency found in OUTER JOIN; examine your ON conditions

- Error: `1121` SQLSTATE: `42000` (`ER_NULL_COLUMN_IN_INDEX`)

Message: Table handler doesn't support NULL in given index. Please change column '%s' to be NOT NULL or use another handler

- Error: `1122` SQLSTATE: `HY000` (`ER_CANT_FIND_UDF`)

Message: Can't load function '%s'

- Error: `1123` SQLSTATE: `HY000` (`ER_CANT_INITIALIZE_UDF`)

Message: Can't initialize function '%s'; %s

- Error: `1124` SQLSTATE: `HY000` (`ER_UDF_NO_PATHS`)

Message: No paths allowed for shared library

- Error: `1125` SQLSTATE: `HY000` (`ER_UDF_EXISTS`)

Message: Function '%s' already exists

- Error: `1126` SQLSTATE: `HY000` (`ER_CANT_OPEN_LIBRARY`)

Message: Can't open shared library '%s' (errno: %d %s)

- Error: `1127` SQLSTATE: `HY000` (`ER_CANT_FIND_DL_ENTRY`)

  Message: Can't find symbol '%s' in library

- Error: `1128` SQLSTATE: `HY000` (`ER_FUNCTION_NOT_DEFINED`)

  Message: Function '%s' is not defined

- Error: `1129` SQLSTATE: `HY000` (`ER_HOST_IS_BLOCKED`)

  Message: Host '%s' is blocked because of many connection errors; unblock with 'mysqladmin flush-hosts'

- Error: `1130` SQLSTATE: `HY000` (`ER_HOST_NOT_PRIVILEGED`)

  Message: Host '%s' is not allowed to connect to this MySQL server

- Error: `1131` SQLSTATE: `42000` (`ER_PASSWORD_ANONYMOUS_USER`)

  Message: You are using MySQL as an anonymous user and anonymous users are not allowed to change passwords

- Error: `1132` SQLSTATE: `42000` (`ER_PASSWORD_NOT_ALLOWED`)

  Message: You must have privileges to update tables in the mysql database to be able to change passwords for others

- Error: `1133` SQLSTATE: `42000` (`ER_PASSWORD_NO_MATCH`)

  Message: Can't find any matching row in the user table

- Error: `1134` SQLSTATE: `HY000` (`ER_UPDATE_INFO`)

  Message: Rows matched: %ld Changed: %ld Warnings: %ld

- Error: `1135` SQLSTATE: `HY000` (`ER_CANT_CREATE_THREAD`)

  Message: Can't create a new thread (errno %d); if you are not out of available memory, you can consult the manual for a possible OS-dependent bug

- Error: `1136` SQLSTATE: `21S01` (`ER_WRONG_VALUE_COUNT_ON_ROW`)

  Message: Column count doesn't match value count at row %ld

- Error: `1137` SQLSTATE: `HY000` (`ER_CANT_REOPEN_TABLE`)

  Message: Can't reopen table: '%s'

- Error: `1138` SQLSTATE: `22004` (`ER_INVALID_USE_OF_NULL`)

  Message: Invalid use of NULL value

- Error: `1139` SQLSTATE: `42000` (`ER_REGEXP_ERROR`)

  Message: Got error '%s' from regexp

- Error: `1140` SQLSTATE: `42000` (`ER_MIX_OF_GROUP_FUNC_AND_FIELDS`)

  Message: Mixing of GROUP columns (MIN(),MAX(),COUNT(),...) with no GROUP columns is illegal if there is no GROUP BY clause

- Error: `1141` SQLSTATE: `42000` (`ER_NONEXISTING_GRANT`)

  Message: There is no such grant defined for user '%s' on host '%s'

- Error: `1142` SQLSTATE: `42000` (`ER_TABLEACCESS_DENIED_ERROR`)

  Message: %s command denied to user '%s'@'%s' for table '%s'

- Error: `1143` SQLSTATE: `42000` (`ER_COLUMNACCESS_DENIED_ERROR`)

  Message: %s command denied to user '%s'@'%s' for column '%s' in table '%s'

- Error: `1144` SQLSTATE: `42000` (`ER_ILLEGAL_GRANT_FOR_TABLE`)

  Message: Illegal GRANT/REVOKE command; please consult the manual to see which privileges can be used

- Error: `1145` SQLSTATE: `42000` (`ER_GRANT_WRONG_HOST_OR_USER`)

  Message: The host or user argument to GRANT is too long

- Error: `1146` SQLSTATE: `42S02` (`ER_NO_SUCH_TABLE`)

  Message: Table '%s.%s' doesn't exist

- Error: `1147` SQLSTATE: `42000` (`ER_NONEXISTING_TABLE_GRANT`)

  Message: There is no such grant defined for user '%s' on host '%s' on table '%s'

- Error: `1148` SQLSTATE: `42000` (`ER_NOT_ALLOWED_COMMAND`)

  Message: The used command is not allowed with this MySQL version

- Error: `1149` SQLSTATE: `42000` (`ER_SYNTAX_ERROR`)

  Message: You have an error in your SQL syntax; check the manual that corresponds to your MySQL server version for the right syntax to use

- Error: `1150` SQLSTATE: `HY000` (`ER_DELAYED_CANT_CHANGE_LOCK`)

  Message: Delayed insert thread couldn't get requested lock for table %s

- Error: `1151` SQLSTATE: `HY000` (`ER_TOO_MANY_DELAYED_THREADS`)

  Message: Too many delayed threads in use

- Error: `1152` SQLSTATE: `08S01` (`ER_ABORTING_CONNECTION`)

  Message: Aborted connection %ld to db: '%s' user: '%s' (%s)

- Error: `1153` SQLSTATE: `08S01` (`ER_NET_PACKET_TOO_LARGE`)

  Message: Got a packet bigger than 'max_allowed_packet' bytes

- Error: `1154` SQLSTATE: `08S01` (`ER_NET_READ_ERROR_FROM_PIPE`)

  Message: Got a read error from the connection pipe

- Error: `1155` SQLSTATE: `08S01` (`ER_NET_FCNTL_ERROR`)

  Message: Got an error from fcntl()

- Error: `1156` SQLSTATE: `08S01` (`ER_NET_PACKETS_OUT_OF_ORDER`)

  Message: Got packets out of order

- Error: `1157` SQLSTATE: `08S01` (`ER_NET_UNCOMPRESS_ERROR`)

  Message: Couldn't uncompress communication packet

- Error: `1158` SQLSTATE: `08S01` (`ER_NET_READ_ERROR`)

  Message: Got an error reading communication packets

- Error: `1159` SQLSTATE: `08S01` (`ER_NET_READ_INTERRUPTED`)

  Message: Got timeout reading communication packets

- Error: `1160` SQLSTATE: `08S01` (`ER_NET_ERROR_ON_WRITE`)

  Message: Got an error writing communication packets

- Error: `1161` SQLSTATE: `08S01` (`ER_NET_WRITE_INTERRUPTED`)

  Message: Got timeout writing communication packets

- Error: `1162` SQLSTATE: `42000` (`ER_TOO_LONG_STRING`)

  Message: Result string is longer than 'max_allowed_packet' bytes

- Error: `1163` SQLSTATE: `42000` (`ER_TABLE_CANT_HANDLE_BLOB`)

  Message: The used table type doesn't support BLOB/TEXT columns

- Error: `1164` SQLSTATE: `42000` (`ER_TABLE_CANT_HANDLE_AUTO_INCREMENT`)

  Message: The used table type doesn't support AUTO_INCREMENT columns

- Error: `1165` SQLSTATE: `HY000` (`ER_DELAYED_INSERT_TABLE_LOCKED`)

  Message: INSERT DELAYED can't be used with table '%s' because it is locked with LOCK TABLES

- Error: `1166` SQLSTATE: `42000` (`ER_WRONG_COLUMN_NAME`)

  Message: Incorrect column name '%s'

- Error: `1167` SQLSTATE: `42000` (`ER_WRONG_KEY_COLUMN`)

  Message: The used storage engine can't index column '%s'

- Error: `1168` SQLSTATE: `HY000` (`ER_WRONG_MRG_TABLE`)

  Message: Unable to open underlying table which is differently defined or of non-MyISAM type or doesn't exist

- Error: `1169` SQLSTATE: `23000` (`ER_DUP_UNIQUE`)

  Message: Can't write, because of unique constraint, to table '%s'

- Error: `1170` SQLSTATE: `42000` (`ER_BLOB_KEY_WITHOUT_LENGTH`)

  Message: BLOB/TEXT column '%s' used in key specification without a key length

- Error: `1171` SQLSTATE: `42000` (`ER_PRIMARY_CANT_HAVE_NULL`)

  Message: All parts of a PRIMARY KEY must be NOT NULL; if you need NULL in a key, use UNIQUE instead

- Error: `1172` SQLSTATE: `42000` (`ER_TOO_MANY_ROWS`)

  Message: Result consisted of more than one row

- Error: `1173` SQLSTATE: `42000` (`ER_REQUIRES_PRIMARY_KEY`)

  Message: This table type requires a primary key

  `InnoDB` reports this error when you attempt to drop an implicit clustered index (the first `UNIQUE NOT NULL` index) if the table did not contain a PRIMARY KEY.

  `InnoDB` should no longer report this error as of MySQL 5.5. For tables without an explicit `PRIMARY KEY`, `InnoDB` creates an implicit clustered index using the first columns of the table that are declared `UNIQUE` and `NOT NULL`. When you drop such an index, `InnoDB` now automatically copies the table and rebuilds the index using a different `UNIQUE NOT NULL` group of columns or a system-generated key. Since this operation changes the primary key, it uses the slow method of copying the table and re-creating the index, rather than the Fast Index Creation technique from Implementation Details of Fast Index Creation.

- Error: `1174` SQLSTATE: `HY000` (`ER_NO_RAID_COMPILED`)

  Message: This version of MySQL is not compiled with RAID support

- Error: `1175` SQLSTATE: `HY000` (`ER_UPDATE_WITHOUT_KEY_IN_SAFE_MODE`)

  Message: You are using safe update mode and you tried to update a table without a WHERE that uses a KEY column

- Error: `1176` SQLSTATE: `42000` (`ER_KEY_DOES_NOT_EXITS`)

  Message: Key '%s' doesn't exist in table '%s'

- Error: `1177` SQLSTATE: `42000` (`ER_CHECK_NO_SUCH_TABLE`)

  Message: Can't open table

- Error: `1178` SQLSTATE: `42000` (`ER_CHECK_NOT_IMPLEMENTED`)

  Message: The storage engine for the table doesn't support %s

- Error: `1179` SQLSTATE: `25000` (`ER_CANT_DO_THIS_DURING_AN_TRANSACTION`)

  Message: You are not allowed to execute this command in a transaction

- Error: `1180` SQLSTATE: `HY000` (`ER_ERROR_DURING_COMMIT`)

  Message: Got error %d during COMMIT

- Error: `1181` SQLSTATE: `HY000` (`ER_ERROR_DURING_ROLLBACK`)

  Message: Got error %d during ROLLBACK

- Error: `1182` SQLSTATE: `HY000` (`ER_ERROR_DURING_FLUSH_LOGS`)

Message: Got error %d during FLUSH_LOGS

- Error: `1183` SQLSTATE: `HY000` (`ER_ERROR_DURING_CHECKPOINT`)

  Message: Got error %d during CHECKPOINT

- Error: `1184` SQLSTATE: `08S01` (`ER_NEW_ABORTING_CONNECTION`)

  Message: Aborted connection %ld to db: '%s' user: '%s' host: '%s' (%s)

- Error: `1185` SQLSTATE: `HY000` (`ER_DUMP_NOT_IMPLEMENTED`)

  Message: The storage engine for the table does not support binary table dump

- Error: `1186` SQLSTATE: `HY000` (`ER_FLUSH_MASTER_BINLOG_CLOSED`)

  Message: Binlog closed, cannot RESET MASTER

- Error: `1187` SQLSTATE: `HY000` (`ER_INDEX_REBUILD`)

  Message: Failed rebuilding the index of dumped table '%s'

- Error: `1188` SQLSTATE: `HY000` (`ER_MASTER`)

  Message: Error from master: '%s'

- Error: `1189` SQLSTATE: `08S01` (`ER_MASTER_NET_READ`)

  Message: Net error reading from master

- Error: `1190` SQLSTATE: `08S01` (`ER_MASTER_NET_WRITE`)

  Message: Net error writing to master

- Error: `1191` SQLSTATE: `HY000` (`ER_FT_MATCHING_KEY_NOT_FOUND`)

  Message: Can't find FULLTEXT index matching the column list

- Error: `1192` SQLSTATE: `HY000` (`ER_LOCK_OR_ACTIVE_TRANSACTION`)

  Message: Can't execute the given command because you have active locked tables or an active transaction

- Error: `1193` SQLSTATE: `HY000` (`ER_UNKNOWN_SYSTEM_VARIABLE`)

  Message: Unknown system variable '%s'

- Error: `1194` SQLSTATE: `HY000` (`ER_CRASHED_ON_USAGE`)

  Message: Table '%s' is marked as crashed and should be repaired

- Error: `1195` SQLSTATE: `HY000` (`ER_CRASHED_ON_REPAIR`)

  Message: Table '%s' is marked as crashed and last (automatic?) repair failed

- Error: `1196` SQLSTATE: `HY000` (`ER_WARNING_NOT_COMPLETE_ROLLBACK`)

  Message: Some non-transactional changed tables couldn't be rolled back

- Error: `1197` SQLSTATE: `HY000` (`ER_TRANS_CACHE_FULL`)

Message: Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage; increase this mysqld variable and try again

- Error: `1198` SQLSTATE: `HY000` (`ER_SLAVE_MUST_STOP`)

Message: This operation cannot be performed with a running slave; run STOP SLAVE first

- Error: `1199` SQLSTATE: `HY000` (`ER_SLAVE_NOT_RUNNING`)

Message: This operation requires a running slave; configure slave and do START SLAVE

- Error: `1200` SQLSTATE: `HY000` (`ER_BAD_SLAVE`)

Message: The server is not configured as slave; fix in config file or with CHANGE MASTER TO

- Error: `1201` SQLSTATE: `HY000` (`ER_MASTER_INFO`)

Message: Could not initialize master info structure; more error messages can be found in the MySQL error log

- Error: `1202` SQLSTATE: `HY000` (`ER_SLAVE_THREAD`)

Message: Could not create slave thread; check system resources

- Error: `1203` SQLSTATE: `42000` (`ER_TOO_MANY_USER_CONNECTIONS`)

Message: User %s already has more than 'max_user_connections' active connections

- Error: `1204` SQLSTATE: `HY000` (`ER_SET_CONSTANTS_ONLY`)

Message: You may only use constant expressions with SET

- Error: `1205` SQLSTATE: `HY000` (`ER_LOCK_WAIT_TIMEOUT`)

Message: Lock wait timeout exceeded; try restarting transaction

`InnoDB` reports this error when lock wait timeout expires. The statement that waited too long was rolled back (not the entire transaction). You can increase the value of the `innodb_lock_wait_timeout` configuration option if SQL statements should wait longer for other transactions to complete, or decrease it if too many long-running transactions are causing locking problems and reducing concurrency on a busy system.

- Error: `1206` SQLSTATE: `HY000` (`ER_LOCK_TABLE_FULL`)

Message: The total number of locks exceeds the lock table size

`InnoDB` reports this error when the total number of locks exceeds the amount of memory devoted to managing locks. To avoid this error, increase the value of `innodb_buffer_pool_size`. Within an individual application, a workaround may be to break a large operation into smaller pieces. For example, if the error occurs for a large `INSERT`, perform several smaller `INSERT` operations.

- Error: `1207` SQLSTATE: `25000` (`ER_READ_ONLY_TRANSACTION`)

Message: Update locks cannot be acquired during a READ UNCOMMITTED transaction

- Error: `1208` SQLSTATE: `HY000` (`ER_DROP_DB_WITH_READ_LOCK`)

Message: DROP DATABASE not allowed while thread is holding global read lock

- Error: `1209` SQLSTATE: `HY000` (`ER_CREATE_DB_WITH_READ_LOCK`)

  Message: CREATE DATABASE not allowed while thread is holding global read lock

- Error: `1210` SQLSTATE: `HY000` (`ER_WRONG_ARGUMENTS`)

  Message: Incorrect arguments to %s

- Error: `1211` SQLSTATE: `42000` (`ER_NO_PERMISSION_TO_CREATE_USER`)

  Message: '%s'@'%s' is not allowed to create new users

- Error: `1212` SQLSTATE: `HY000` (`ER_UNION_TABLES_IN_DIFFERENT_DIR`)

  Message: Incorrect table definition; all MERGE tables must be in the same database

- Error: `1213` SQLSTATE: `40001` (`ER_LOCK_DEADLOCK`)

  Message: Deadlock found when trying to get lock; try restarting transaction

  `InnoDB` reports this error when a transaction encounters a deadlock and is automatically rolled back so that your application can take corrective action. To recover from this error, run all the operations in this transaction again. A deadlock occurs when requests for locks arrive in inconsistent order between transactions. The transaction that was rolled back released all its locks, and the other transaction can now get all the locks it requested. Thus, when you re-run the transaction that was rolled back, it might have to wait for other transactions to complete, but typically the deadlock does not recur. If you encounter frequent deadlocks, make the sequence of locking operations (`LOCK TABLES`, `SELECT ... FOR UPDATE`, and so on) consistent between the different transactions or applications that experience the issue. See Section 14.6.4.9, "How to Cope with Deadlocks" for details.

- Error: `1214` SQLSTATE: `HY000` (`ER_TABLE_CANT_HANDLE_FT`)

  Message: The used table type doesn't support FULLTEXT indexes

- Error: `1215` SQLSTATE: `HY000` (`ER_CANNOT_ADD_FOREIGN`)

  Message: Cannot add foreign key constraint

- Error: `1216` SQLSTATE: `23000` (`ER_NO_REFERENCED_ROW`)

  Message: Cannot add or update a child row: a foreign key constraint fails

  `InnoDB` reports this error when you try to add a row but there is no parent row, and a foreign key constraint fails. Add the parent row first.

- Error: `1217` SQLSTATE: `23000` (`ER_ROW_IS_REFERENCED`)

  Message: Cannot delete or update a parent row: a foreign key constraint fails

  `InnoDB` reports this error when you try to delete a parent row that has children, and a foreign key constraint fails. Delete the children first.

- Error: `1218` SQLSTATE: `08S01` (`ER_CONNECT_TO_MASTER`)

  Message: Error connecting to master: %s

- Error: `1219` SQLSTATE: `HY000` (`ER_QUERY_ON_MASTER`)

  Message: Error running query on master: %s

- Error: `1220` SQLSTATE: `HY000` (`ER_ERROR_WHEN_EXECUTING_COMMAND`)

  Message: Error when executing command %s: %s

- Error: `1221` SQLSTATE: `HY000` (`ER_WRONG_USAGE`)

  Message: Incorrect usage of %s and %s

- Error: `1222` SQLSTATE: `21000` (`ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT`)

  Message: The used SELECT statements have a different number of columns

- Error: `1223` SQLSTATE: `HY000` (`ER_CANT_UPDATE_WITH_READLOCK`)

  Message: Can't execute the query because you have a conflicting read lock

- Error: `1224` SQLSTATE: `HY000` (`ER_MIXING_NOT_ALLOWED`)

  Message: Mixing of transactional and non-transactional tables is disabled

- Error: `1225` SQLSTATE: `HY000` (`ER_DUP_ARGUMENT`)

  Message: Option '%s' used twice in statement

- Error: `1226` SQLSTATE: `42000` (`ER_USER_LIMIT_REACHED`)

  Message: User '%s' has exceeded the '%s' resource (current value: %ld)

- Error: `1227` SQLSTATE: `42000` (`ER_SPECIFIC_ACCESS_DENIED_ERROR`)

  Message: Access denied; you need the %s privilege for this operation

- Error: `1228` SQLSTATE: `HY000` (`ER_LOCAL_VARIABLE`)

  Message: Variable '%s' is a SESSION variable and can't be used with SET GLOBAL

- Error: `1229` SQLSTATE: `HY000` (`ER_GLOBAL_VARIABLE`)

  Message: Variable '%s' is a GLOBAL variable and should be set with SET GLOBAL

- Error: `1230` SQLSTATE: `42000` (`ER_NO_DEFAULT`)

  Message: Variable '%s' doesn't have a default value

- Error: `1231` SQLSTATE: `42000` (`ER_WRONG_VALUE_FOR_VAR`)

  Message: Variable '%s' can't be set to the value of '%s'

- Error: `1232` SQLSTATE: `42000` (`ER_WRONG_TYPE_FOR_VAR`)

  Message: Incorrect argument type to variable '%s'

- Error: `1233` SQLSTATE: `HY000` (`ER_VAR_CANT_BE_READ`)

  Message: Variable '%s' can only be set, not read

- Error: `1234` SQLSTATE: `42000` (`ER_CANT_USE_OPTION_HERE`)

  Message: Incorrect usage/placement of '%s'

- Error: `1235` SQLSTATE: `42000` (`ER_NOT_SUPPORTED_YET`)

  Message: This version of MySQL doesn't yet support '%s'

- Error: `1236` SQLSTATE: `HY000` (`ER_MASTER_FATAL_ERROR_READING_BINLOG`)

  Message: Got fatal error %d from master when reading data from binary log: '%s'

- Error: `1237` SQLSTATE: `HY000` (`ER_SLAVE_IGNORED_TABLE`)

  Message: Slave SQL thread ignored the query because of replicate-*-table rules

- Error: `1238` SQLSTATE: `HY000` (`ER_INCORRECT_GLOBAL_LOCAL_VAR`)

  Message: Variable '%s' is a %s variable

- Error: `1239` SQLSTATE: `42000` (`ER_WRONG_FK_DEF`)

  Message: Incorrect foreign key definition for '%s': %s

- Error: `1240` SQLSTATE: `HY000` (`ER_KEY_REF_DO_NOT_MATCH_TABLE_REF`)

  Message: Key reference and table reference don't match

- Error: `1241` SQLSTATE: `21000` (`ER_OPERAND_COLUMNS`)

  Message: Operand should contain %d column(s)

- Error: `1242` SQLSTATE: `21000` (`ER_SUBQUERY_NO_1_ROW`)

  Message: Subquery returns more than 1 row

- Error: `1243` SQLSTATE: `HY000` (`ER_UNKNOWN_STMT_HANDLER`)

  Message: Unknown prepared statement handler (%.*s) given to %s

- Error: `1244` SQLSTATE: `HY000` (`ER_CORRUPT_HELP_DB`)

  Message: Help database is corrupt or does not exist

- Error: `1245` SQLSTATE: `HY000` (`ER_CYCLIC_REFERENCE`)

  Message: Cyclic reference on subqueries

- Error: `1246` SQLSTATE: `HY000` (`ER_AUTO_CONVERT`)

  Message: Converting column '%s' from %s to %s

- Error: `1247` SQLSTATE: `42S22` (`ER_ILLEGAL_REFERENCE`)

  Message: Reference '%s' not supported (%s)

- Error: `1248` SQLSTATE: `42000` (`ER_DERIVED_MUST_HAVE_ALIAS`)

  Message: Every derived table must have its own alias

- Error: `1249` SQLSTATE: `01000` (`ER_SELECT_REDUCED`)

  Message: Select %u was reduced during optimization

- Error: `1250` SQLSTATE: `42000` (`ER_TABLENAME_NOT_ALLOWED_HERE`)

  Message: Table '%s' from one of the SELECTs cannot be used in %s

- Error: `1251` SQLSTATE: `08004` (`ER_NOT_SUPPORTED_AUTH_MODE`)

  Message: Client does not support authentication protocol requested by server; consider upgrading MySQL client

- Error: `1252` SQLSTATE: `42000` (`ER_SPATIAL_CANT_HAVE_NULL`)

  Message: All parts of a SPATIAL index must be NOT NULL

- Error: `1253` SQLSTATE: `42000` (`ER_COLLATION_CHARSET_MISMATCH`)

  Message: COLLATION '%s' is not valid for CHARACTER SET '%s'

- Error: `1254` SQLSTATE: `HY000` (`ER_SLAVE_WAS_RUNNING`)

  Message: Slave is already running

- Error: `1255` SQLSTATE: `HY000` (`ER_SLAVE_WAS_NOT_RUNNING`)

  Message: Slave already has been stopped

- Error: `1256` SQLSTATE: `HY000` (`ER_TOO_BIG_FOR_UNCOMPRESS`)

  Message: Uncompressed data size too large; the maximum size is %d (probably, length of uncompressed data was corrupted)

- Error: `1257` SQLSTATE: `HY000` (`ER_ZLIB_Z_MEM_ERROR`)

  Message: ZLIB: Not enough memory

- Error: `1258` SQLSTATE: `HY000` (`ER_ZLIB_Z_BUF_ERROR`)

  Message: ZLIB: Not enough room in the output buffer (probably, length of uncompressed data was corrupted)

- Error: `1259` SQLSTATE: `HY000` (`ER_ZLIB_Z_DATA_ERROR`)

  Message: ZLIB: Input data corrupted

- Error: `1260` SQLSTATE: `HY000` (`ER_CUT_VALUE_GROUP_CONCAT`)

  Message: %d line(s) were cut by GROUP_CONCAT()

- Error: `1261` SQLSTATE: `01000` (`ER_WARN_TOO_FEW_RECORDS`)

  Message: Row %ld doesn't contain data for all columns

- Error: `1262` SQLSTATE: `01000` (`ER_WARN_TOO_MANY_RECORDS`)

  Message: Row %ld was truncated; it contained more data than there were input columns

- Error: `1263` SQLSTATE: `22004` (`ER_WARN_NULL_TO_NOTNULL`)

  Message: Column set to default value; NULL supplied to NOT NULL column '%s' at row %ld

- Error: `1264` SQLSTATE: `22003` (`ER_WARN_DATA_OUT_OF_RANGE`)

Message: Out of range value for column '%s' at row %ld

- Error: `1265` SQLSTATE: `01000` (`WARN_DATA_TRUNCATED`)

Message: Data truncated for column '%s' at row %ld

- Error: `1266` SQLSTATE: `HY000` (`ER_WARN_USING_OTHER_HANDLER`)

Message: Using storage engine %s for table '%s'

- Error: `1267` SQLSTATE: `HY000` (`ER_CANT_AGGREGATE_2COLLATIONS`)

Message: Illegal mix of collations (%s,%s) and (%s,%s) for operation '%s'

- Error: `1268` SQLSTATE: `HY000` (`ER_DROP_USER`)

Message: Cannot drop one or more of the requested users

- Error: `1269` SQLSTATE: `HY000` (`ER_REVOKE_GRANTS`)

Message: Can't revoke all privileges for one or more of the requested users

- Error: `1270` SQLSTATE: `HY000` (`ER_CANT_AGGREGATE_3COLLATIONS`)

Message: Illegal mix of collations (%s,%s), (%s,%s), (%s,%s) for operation '%s'

- Error: `1271` SQLSTATE: `HY000` (`ER_CANT_AGGREGATE_NCOLLATIONS`)

Message: Illegal mix of collations for operation '%s'

- Error: `1272` SQLSTATE: `HY000` (`ER_VARIABLE_IS_NOT_STRUCT`)

Message: Variable '%s' is not a variable component (can't be used as XXXX.variable_name)

- Error: `1273` SQLSTATE: `HY000` (`ER_UNKNOWN_COLLATION`)

Message: Unknown collation: '%s'

- Error: `1274` SQLSTATE: `HY000` (`ER_SLAVE_IGNORED_SSL_PARAMS`)

Message: SSL parameters in CHANGE MASTER are ignored because this MySQL slave was compiled without SSL support; they can be used later if MySQL slave with SSL is started

- Error: `1275` SQLSTATE: `HY000` (`ER_SERVER_IS_IN_SECURE_AUTH_MODE`)

Message: Server is running in --secure-auth mode, but '%s'@'%s' has a password in the old format; please change the password to the new format

- Error: `1276` SQLSTATE: `HY000` (`ER_WARN_FIELD_RESOLVED`)

Message: Field or reference '%s%s%s%s%s' of SELECT #%d was resolved in SELECT #%d

- Error: `1277` SQLSTATE: `HY000` (`ER_BAD_SLAVE_UNTIL_COND`)

Message: Incorrect parameter or combination of parameters for START SLAVE UNTIL

- Error: `1278` SQLSTATE: `HY000` (`ER_MISSING_SKIP_SLAVE`)

Message: It is recommended to use --skip-slave-start when doing step-by-step replication with START SLAVE UNTIL; otherwise, you will get problems if you get an unexpected slave's mysqld restart

- Error: `1279` SQLSTATE: `HY000` (`ER_UNTIL_COND_IGNORED`)

  Message: SQL thread is not to be started so UNTIL options are ignored

- Error: `1280` SQLSTATE: `42000` (`ER_WRONG_NAME_FOR_INDEX`)

  Message: Incorrect index name '%s'

- Error: `1281` SQLSTATE: `42000` (`ER_WRONG_NAME_FOR_CATALOG`)

  Message: Incorrect catalog name '%s'

- Error: `1282` SQLSTATE: `HY000` (`ER_WARN_QC_RESIZE`)

  Message: Query cache failed to set size %lu; new query cache size is %lu

- Error: `1283` SQLSTATE: `HY000` (`ER_BAD_FT_COLUMN`)

  Message: Column '%s' cannot be part of FULLTEXT index

- Error: `1284` SQLSTATE: `HY000` (`ER_UNKNOWN_KEY_CACHE`)

  Message: Unknown key cache '%s'

- Error: `1285` SQLSTATE: `HY000` (`ER_WARN_HOSTNAME_WONT_WORK`)

  Message: MySQL is started in --skip-name-resolve mode; you must restart it without this switch for this grant to work

- Error: `1286` SQLSTATE: `42000` (`ER_UNKNOWN_STORAGE_ENGINE`)

  Message: Unknown table engine '%s'

- Error: `1287` SQLSTATE: `HY000` (`ER_UNUSED_1`)

  Message: '%s' is deprecated; use '%s' instead

  `ER_UNUSED_1` was added in 5.1.9, removed after 5.1.19.

- Error: `1287` SQLSTATE: `HY000` (`ER_WARN_DEPRECATED_SYNTAX`)

  Message: '%s' is deprecated and will be removed in a future release. Please use %s instead

  From 5.1.8 through 5.1.10: This error was temporarily unavailable.

  From 5.1.11 through 5.1.19: This error was temporarily numbered 1543.

- Error: `1288` SQLSTATE: `HY000` (`ER_NON_UPDATABLE_TABLE`)

  Message: The target table %s of the %s is not updatable

- Error: `1289` SQLSTATE: `HY000` (`ER_FEATURE_DISABLED`)

  Message: The '%s' feature is disabled; you need MySQL built with '%s' to have it working

- Error: `1290` SQLSTATE: `HY000` (`ER_OPTION_PREVENTS_STATEMENT`)

  Message: The MySQL server is running with the %s option so it cannot execute this statement

- Error: `1291` SQLSTATE: `HY000` (`ER_DUPLICATED_VALUE_IN_TYPE`)

Message: Column '%s' has duplicated value '%s' in %s

- Error: `1292` SQLSTATE: `22007` (`ER_TRUNCATED_WRONG_VALUE`)

Message: Truncated incorrect %s value: '%s'

- Error: `1293` SQLSTATE: `HY000` (`ER_TOO_MUCH_AUTO_TIMESTAMP_COLS`)

Message: Incorrect table definition; there can be only one TIMESTAMP column with CURRENT_TIMESTAMP in DEFAULT or ON UPDATE clause

- Error: `1294` SQLSTATE: `HY000` (`ER_INVALID_ON_UPDATE`)

Message: Invalid ON UPDATE clause for '%s' column

- Error: `1295` SQLSTATE: `HY000` (`ER_UNSUPPORTED_PS`)

Message: This command is not supported in the prepared statement protocol yet

- Error: `1296` SQLSTATE: `HY000` (`ER_GET_ERRMSG`)

Message: Got error %d '%s' from %s

- Error: `1297` SQLSTATE: `HY000` (`ER_GET_TEMPORARY_ERRMSG`)

Message: Got temporary error %d '%s' from %s

- Error: `1298` SQLSTATE: `HY000` (`ER_UNKNOWN_TIME_ZONE`)

Message: Unknown or incorrect time zone: '%s'

- Error: `1299` SQLSTATE: `HY000` (`ER_WARN_INVALID_TIMESTAMP`)

Message: Invalid TIMESTAMP value in column '%s' at row %ld

- Error: `1300` SQLSTATE: `HY000` (`ER_INVALID_CHARACTER_STRING`)

Message: Invalid %s character string: '%s'

- Error: `1301` SQLSTATE: `HY000` (`ER_WARN_ALLOWED_PACKET_OVERFLOWED`)

Message: Result of %s() was larger than max_allowed_packet (%ld) - truncated

- Error: `1302` SQLSTATE: `HY000` (`ER_CONFLICTING_DECLARATIONS`)

Message: Conflicting declarations: '%s%s' and '%s%s'

- Error: `1303` SQLSTATE: `2F003` (`ER_SP_NO_RECURSIVE_CREATE`)

Message: Can't create a %s from within another stored routine

- Error: `1304` SQLSTATE: `42000` (`ER_SP_ALREADY_EXISTS`)

Message: %s %s already exists

- Error: `1305` SQLSTATE: `42000` (`ER_SP_DOES_NOT_EXIST`)

Message: %s %s does not exist

- Error: `1306` SQLSTATE: `HY000` (`ER_SP_DROP_FAILED`)

Message: Failed to DROP %s %s

- Error: `1307` SQLSTATE: `HY000` (`ER_SP_STORE_FAILED`)

Message: Failed to CREATE %s %s

- Error: `1308` SQLSTATE: `42000` (`ER_SP_LILABEL_MISMATCH`)

Message: %s with no matching label: %s

- Error: `1309` SQLSTATE: `42000` (`ER_SP_LABEL_REDEFINE`)

Message: Redefining label %s

- Error: `1310` SQLSTATE: `42000` (`ER_SP_LABEL_MISMATCH`)

Message: End-label %s without match

- Error: `1311` SQLSTATE: `01000` (`ER_SP_UNINIT_VAR`)

Message: Referring to uninitialized variable %s

- Error: `1312` SQLSTATE: `0A000` (`ER_SP_BADSELECT`)

Message: PROCEDURE %s can't return a result set in the given context

- Error: `1313` SQLSTATE: `42000` (`ER_SP_BADRETURN`)

Message: RETURN is only allowed in a FUNCTION

- Error: `1314` SQLSTATE: `0A000` (`ER_SP_BADSTATEMENT`)

Message: %s is not allowed in stored procedures

- Error: `1315` SQLSTATE: `42000` (`ER_UPDATE_LOG_DEPRECATED_IGNORED`)

Message: The update log is deprecated and replaced by the binary log; SET SQL_LOG_UPDATE has been ignored. This option will be removed in MySQL 5.6.

- Error: `1316` SQLSTATE: `42000` (`ER_UPDATE_LOG_DEPRECATED_TRANSLATED`)

Message: The update log is deprecated and replaced by the binary log; SET SQL_LOG_UPDATE has been translated to SET SQL_LOG_BIN. This option will be removed in MySQL 5.6.

- Error: `1317` SQLSTATE: `70100` (`ER_QUERY_INTERRUPTED`)

Message: Query execution was interrupted

- Error: `1318` SQLSTATE: `42000` (`ER_SP_WRONG_NO_OF_ARGS`)

Message: Incorrect number of arguments for %s %s; expected %u, got %u

- Error: `1319` SQLSTATE: `42000` (`ER_SP_COND_MISMATCH`)

Message: Undefined CONDITION: %s

- Error: `1320` SQLSTATE: `42000` (`ER_SP_NORETURN`)

Message: No RETURN found in FUNCTION %s

- Error: `1321` SQLSTATE: `2F005` (`ER_SP_NORETURNEND`)

  Message: FUNCTION %s ended without RETURN

- Error: `1322` SQLSTATE: `42000` (`ER_SP_BAD_CURSOR_QUERY`)

  Message: Cursor statement must be a SELECT

- Error: `1323` SQLSTATE: `42000` (`ER_SP_BAD_CURSOR_SELECT`)

  Message: Cursor SELECT must not have INTO

- Error: `1324` SQLSTATE: `42000` (`ER_SP_CURSOR_MISMATCH`)

  Message: Undefined CURSOR: %s

- Error: `1325` SQLSTATE: `24000` (`ER_SP_CURSOR_ALREADY_OPEN`)

  Message: Cursor is already open

- Error: `1326` SQLSTATE: `24000` (`ER_SP_CURSOR_NOT_OPEN`)

  Message: Cursor is not open

- Error: `1327` SQLSTATE: `42000` (`ER_SP_UNDECLARED_VAR`)

  Message: Undeclared variable: %s

- Error: `1328` SQLSTATE: `HY000` (`ER_SP_WRONG_NO_OF_FETCH_ARGS`)

  Message: Incorrect number of FETCH variables

- Error: `1329` SQLSTATE: `02000` (`ER_SP_FETCH_NO_DATA`)

  Message: No data - zero rows fetched, selected, or processed

- Error: `1330` SQLSTATE: `42000` (`ER_SP_DUP_PARAM`)

  Message: Duplicate parameter: %s

- Error: `1331` SQLSTATE: `42000` (`ER_SP_DUP_VAR`)

  Message: Duplicate variable: %s

- Error: `1332` SQLSTATE: `42000` (`ER_SP_DUP_COND`)

  Message: Duplicate condition: %s

- Error: `1333` SQLSTATE: `42000` (`ER_SP_DUP_CURS`)

  Message: Duplicate cursor: %s

- Error: `1334` SQLSTATE: `HY000` (`ER_SP_CANT_ALTER`)

  Message: Failed to ALTER %s %s

- Error: `1335` SQLSTATE: `0A000` (`ER_SP_SUBSELECT_NYI`)

  Message: Subquery value not supported

- Error: `1336` SQLSTATE: `0A000` (`ER_STMT_NOT_ALLOWED_IN_SF_OR_TRG`)

  Message: %s is not allowed in stored function or trigger

- Error: `1337` SQLSTATE: `42000` (`ER_SP_VARCOND_AFTER_CURSHNDLR`)

  Message: Variable or condition declaration after cursor or handler declaration

- Error: `1338` SQLSTATE: `42000` (`ER_SP_CURSOR_AFTER_HANDLER`)

  Message: Cursor declaration after handler declaration

- Error: `1339` SQLSTATE: `20000` (`ER_SP_CASE_NOT_FOUND`)

  Message: Case not found for CASE statement

- Error: `1340` SQLSTATE: `HY000` (`ER_FPARSER_TOO_BIG_FILE`)

  Message: Configuration file '%s' is too big

- Error: `1341` SQLSTATE: `HY000` (`ER_FPARSER_BAD_HEADER`)

  Message: Malformed file type header in file '%s'

- Error: `1342` SQLSTATE: `HY000` (`ER_FPARSER_EOF_IN_COMMENT`)

  Message: Unexpected end of file while parsing comment '%s'

- Error: `1343` SQLSTATE: `HY000` (`ER_FPARSER_ERROR_IN_PARAMETER`)

  Message: Error while parsing parameter '%s' (line: '%s')

- Error: `1344` SQLSTATE: `HY000` (`ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER`)

  Message: Unexpected end of file while skipping unknown parameter '%s'

- Error: `1345` SQLSTATE: `HY000` (`ER_VIEW_NO_EXPLAIN`)

  Message: EXPLAIN/SHOW can not be issued; lacking privileges for underlying table

- Error: `1346` SQLSTATE: `HY000` (`ER_FRM_UNKNOWN_TYPE`)

  Message: File '%s' has unknown type '%s' in its header

- Error: `1347` SQLSTATE: `HY000` (`ER_WRONG_OBJECT`)

  Message: '%s.%s' is not %s

- Error: `1348` SQLSTATE: `HY000` (`ER_NONUPDATEABLE_COLUMN`)

  Message: Column '%s' is not updatable

- Error: `1349` SQLSTATE: `HY000` (`ER_VIEW_SELECT_DERIVED`)

  Message: View's SELECT contains a subquery in the FROM clause

- Error: `1350` SQLSTATE: `HY000` (`ER_VIEW_SELECT_CLAUSE`)

  Message: View's SELECT contains a '%s' clause

- Error: `1351` SQLSTATE: `HY000` (`ER_VIEW_SELECT_VARIABLE`)

  Message: View's SELECT contains a variable or parameter

- Error: `1352` SQLSTATE: `HY000` (`ER_VIEW_SELECT_TMPTABLE`)

  Message: View's SELECT refers to a temporary table '%s'

- Error: `1353` SQLSTATE: `HY000` (`ER_VIEW_WRONG_LIST`)

  Message: View's SELECT and view's field list have different column counts

- Error: `1354` SQLSTATE: `HY000` (`ER_WARN_VIEW_MERGE`)

  Message: View merge algorithm can't be used here for now (assumed undefined algorithm)

- Error: `1355` SQLSTATE: `HY000` (`ER_WARN_VIEW_WITHOUT_KEY`)

  Message: View being updated does not have complete key of underlying table in it

- Error: `1356` SQLSTATE: `HY000` (`ER_VIEW_INVALID`)

  Message: View '%s.%s' references invalid table(s) or column(s) or function(s) or definer/invoker of view lack rights to use them

- Error: `1357` SQLSTATE: `HY000` (`ER_SP_NO_DROP_SP`)

  Message: Can't drop or alter a %s from within another stored routine

- Error: `1358` SQLSTATE: `HY000` (`ER_SP_GOTO_IN_HNDLR`)

  Message: GOTO is not allowed in a stored procedure handler

- Error: `1359` SQLSTATE: `HY000` (`ER_TRG_ALREADY_EXISTS`)

  Message: Trigger already exists

- Error: `1360` SQLSTATE: `HY000` (`ER_TRG_DOES_NOT_EXIST`)

  Message: Trigger does not exist

- Error: `1361` SQLSTATE: `HY000` (`ER_TRG_ON_VIEW_OR_TEMP_TABLE`)

  Message: Trigger's '%s' is view or temporary table

- Error: `1362` SQLSTATE: `HY000` (`ER_TRG_CANT_CHANGE_ROW`)

  Message: Updating of %s row is not allowed in %strigger

- Error: `1363` SQLSTATE: `HY000` (`ER_TRG_NO_SUCH_ROW_IN_TRG`)

  Message: There is no %s row in %s trigger

- Error: `1364` SQLSTATE: `HY000` (`ER_NO_DEFAULT_FOR_FIELD`)

  Message: Field '%s' doesn't have a default value

- Error: `1365` SQLSTATE: `22012` (`ER_DIVISION_BY_ZERO`)

  Message: Division by 0

- Error: `1366` SQLSTATE: `HY000` (`ER_TRUNCATED_WRONG_VALUE_FOR_FIELD`)

  Message: Incorrect %s value: '%s' for column '%s' at row %ld

- Error: `1367` SQLSTATE: `22007` (`ER_ILLEGAL_VALUE_FOR_TYPE`)

  Message: Illegal %s '%s' value found during parsing

- Error: `1368` SQLSTATE: `HY000` (`ER_VIEW_NONUPD_CHECK`)

  Message: CHECK OPTION on non-updatable view '%s.%s'

- Error: `1369` SQLSTATE: `HY000` (`ER_VIEW_CHECK_FAILED`)

  Message: CHECK OPTION failed '%s.%s'

- Error: `1370` SQLSTATE: `42000` (`ER_PROCACCESS_DENIED_ERROR`)

  Message: %s command denied to user '%s'@'%s' for routine '%s'

- Error: `1371` SQLSTATE: `HY000` (`ER_RELAY_LOG_FAIL`)

  Message: Failed purging old relay logs: %s

- Error: `1372` SQLSTATE: `HY000` (`ER_PASSWD_LENGTH`)

  Message: Password hash should be a %d-digit hexadecimal number

- Error: `1373` SQLSTATE: `HY000` (`ER_UNKNOWN_TARGET_BINLOG`)

  Message: Target log not found in binlog index

- Error: `1374` SQLSTATE: `HY000` (`ER_IO_ERR_LOG_INDEX_READ`)

  Message: I/O error reading log index file

- Error: `1375` SQLSTATE: `HY000` (`ER_BINLOG_PURGE_PROHIBITED`)

  Message: Server configuration does not permit binlog purge

- Error: `1376` SQLSTATE: `HY000` (`ER_FSEEK_FAIL`)

  Message: Failed on fseek()

- Error: `1377` SQLSTATE: `HY000` (`ER_BINLOG_PURGE_FATAL_ERR`)

  Message: Fatal error during log purge

- Error: `1378` SQLSTATE: `HY000` (`ER_LOG_IN_USE`)

  Message: A purgeable log is in use, will not purge

- Error: `1379` SQLSTATE: `HY000` (`ER_LOG_PURGE_UNKNOWN_ERR`)

  Message: Unknown error during log purge

- Error: `1380` SQLSTATE: `HY000` (`ER_RELAY_LOG_INIT`)

  Message: Failed initializing relay log position: %s

- Error: `1381` SQLSTATE: `HY000` (`ER_NO_BINARY_LOGGING`)

  Message: You are not using binary logging

- Error: `1382` SQLSTATE: `HY000` (`ER_RESERVED_SYNTAX`)

  Message: The '%s' syntax is reserved for purposes internal to the MySQL server

- Error: `1383` SQLSTATE: `HY000` (`ER_WSAS_FAILED`)

  Message: WSAStartup Failed

- Error: `1384` SQLSTATE: `HY000` (`ER_DIFF_GROUPS_PROC`)

  Message: Can't handle procedures with different groups yet

- Error: `1385` SQLSTATE: `HY000` (`ER_NO_GROUP_FOR_PROC`)

  Message: Select must have a group with this procedure

- Error: `1386` SQLSTATE: `HY000` (`ER_ORDER_WITH_PROC`)

  Message: Can't use ORDER clause with this procedure

- Error: `1387` SQLSTATE: `HY000` (`ER_LOGGING_PROHIBIT_CHANGING_OF`)

  Message: Binary logging and replication forbid changing the global server %s

- Error: `1388` SQLSTATE: `HY000` (`ER_NO_FILE_MAPPING`)

  Message: Can't map file: %s, errno: %d

- Error: `1389` SQLSTATE: `HY000` (`ER_WRONG_MAGIC`)

  Message: Wrong magic in %s

- Error: `1390` SQLSTATE: `HY000` (`ER_PS_MANY_PARAM`)

  Message: Prepared statement contains too many placeholders

- Error: `1391` SQLSTATE: `HY000` (`ER_KEY_PART_0`)

  Message: Key part '%s' length cannot be 0

- Error: `1392` SQLSTATE: `HY000` (`ER_VIEW_CHECKSUM`)

  Message: View text checksum failed

- Error: `1393` SQLSTATE: `HY000` (`ER_VIEW_MULTIUPDATE`)

  Message: Can not modify more than one base table through a join view '%s.%s'

- Error: `1394` SQLSTATE: `HY000` (`ER_VIEW_NO_INSERT_FIELD_LIST`)

  Message: Can not insert into join view '%s.%s' without fields list

- Error: `1395` SQLSTATE: `HY000` (`ER_VIEW_DELETE_MERGE_VIEW`)

  Message: Can not delete from join view '%s.%s'

- Error: `1396` SQLSTATE: `HY000` (`ER_CANNOT_USER`)

  Message: Operation %s failed for %s

- Error: `1397` SQLSTATE: `XAE04` (`ER_XAER_NOTA`)

  Message: XAER_NOTA: Unknown XID

- Error: `1398` SQLSTATE: `XAE05` (`ER_XAER_INVAL`)

  Message: XAER_INVAL: Invalid arguments (or unsupported command)

- Error: `1399` SQLSTATE: `XAE07` (`ER_XAER_RMFAIL`)

  Message: XAER_RMFAIL: The command cannot be executed when global transaction is in the %s state

- Error: `1400` SQLSTATE: `XAE09` (`ER_XAER_OUTSIDE`)

  Message: XAER_OUTSIDE: Some work is done outside global transaction

- Error: `1401` SQLSTATE: `XAE03` (`ER_XAER_RMERR`)

  Message: XAER_RMERR: Fatal error occurred in the transaction branch - check your data for consistency

- Error: `1402` SQLSTATE: `XA100` (`ER_XA_RBROLLBACK`)

  Message: XA_RBROLLBACK: Transaction branch was rolled back

- Error: `1403` SQLSTATE: `42000` (`ER_NONEXISTING_PROC_GRANT`)

  Message: There is no such grant defined for user '%s' on host '%s' on routine '%s'

- Error: `1404` SQLSTATE: `HY000` (`ER_PROC_AUTO_GRANT_FAIL`)

  Message: Failed to grant EXECUTE and ALTER ROUTINE privileges

- Error: `1405` SQLSTATE: `HY000` (`ER_PROC_AUTO_REVOKE_FAIL`)

  Message: Failed to revoke all privileges to dropped routine

- Error: `1406` SQLSTATE: `22001` (`ER_DATA_TOO_LONG`)

  Message: Data too long for column '%s' at row %ld

- Error: `1407` SQLSTATE: `42000` (`ER_SP_BAD_SQLSTATE`)

  Message: Bad SQLSTATE: '%s'

- Error: `1408` SQLSTATE: `HY000` (`ER_STARTUP`)

  Message: %s: ready for connections. Version: '%s' socket: '%s' port: %d %s

- Error: `1409` SQLSTATE: `HY000` (`ER_LOAD_FROM_FIXED_SIZE_ROWS_TO_VAR`)

  Message: Can't load value from file with fixed size rows to variable

- Error: `1410` SQLSTATE: `42000` (`ER_CANT_CREATE_USER_WITH_GRANT`)

  Message: You are not allowed to create a user with GRANT

- Error: `1411` SQLSTATE: `HY000` (`ER_WRONG_VALUE_FOR_TYPE`)

  Message: Incorrect %s value: '%s' for function %s

- Error: `1412` SQLSTATE: `HY000` (`ER_TABLE_DEF_CHANGED`)

  Message: Table definition has changed, please retry transaction

- Error: `1413` SQLSTATE: `42000` (`ER_SP_DUP_HANDLER`)

  Message: Duplicate handler declared in the same block

- Error: `1414` SQLSTATE: `42000` (`ER_SP_NOT_VAR_ARG`)

  Message: OUT or INOUT argument %d for routine %s is not a variable or NEW pseudo-variable in BEFORE trigger

- Error: `1415` SQLSTATE: `0A000` (`ER_SP_NO_RETSET`)

  Message: Not allowed to return a result set from a %s

- Error: `1416` SQLSTATE: `22003` (`ER_CANT_CREATE_GEOMETRY_OBJECT`)

  Message: Cannot get geometry object from data you send to the GEOMETRY field

- Error: `1417` SQLSTATE: `HY000` (`ER_FAILED_ROUTINE_BREAK_BINLOG`)

  Message: A routine failed and has neither NO SQL nor READS SQL DATA in its declaration and binary logging is enabled; if non-transactional tables were updated, the binary log will miss their changes

- Error: `1418` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_ROUTINE`)

  Message: This function has none of DETERMINISTIC, NO SQL, or READS SQL DATA in its declaration and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)

- Error: `1419` SQLSTATE: `HY000` (`ER_BINLOG_CREATE_ROUTINE_NEED_SUPER`)

  Message: You do not have the SUPER privilege and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)

- Error: `1420` SQLSTATE: `HY000` (`ER_EXEC_STMT_WITH_OPEN_CURSOR`)

  Message: You can't execute a prepared statement which has an open cursor associated with it. Reset the statement to re-execute it.

- Error: `1421` SQLSTATE: `HY000` (`ER_STMT_HAS_NO_OPEN_CURSOR`)

  Message: The statement (%lu) has no open cursor.

- Error: `1422` SQLSTATE: `HY000` (`ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG`)

  Message: Explicit or implicit commit is not allowed in stored function or trigger.

- Error: `1423` SQLSTATE: `HY000` (`ER_NO_DEFAULT_FOR_VIEW_FIELD`)

  Message: Field of view '%s.%s' underlying table doesn't have a default value

- Error: `1424` SQLSTATE: `HY000` (`ER_SP_NO_RECURSION`)

Message: Recursive stored functions and triggers are not allowed.

- Error: `1425` SQLSTATE: `42000` (`ER_TOO_BIG_SCALE`)

Message: Too big scale %d specified for column '%s'. Maximum is %lu.

- Error: `1426` SQLSTATE: `42000` (`ER_TOO_BIG_PRECISION`)

Message: Too big precision %d specified for column '%s'. Maximum is %lu.

- Error: `1427` SQLSTATE: `42000` (`ER_M_BIGGER_THAN_D`)

Message: For float(M,D), double(M,D) or decimal(M,D), M must be >= D (column '%s').

- Error: `1428` SQLSTATE: `HY000` (`ER_WRONG_LOCK_OF_SYSTEM_TABLE`)

Message: You can't combine write-locking of system tables with other tables or lock types

- Error: `1429` SQLSTATE: `HY000` (`ER_CONNECT_TO_FOREIGN_DATA_SOURCE`)

Message: Unable to connect to foreign data source: %s

- Error: `1430` SQLSTATE: `HY000` (`ER_QUERY_ON_FOREIGN_DATA_SOURCE`)

Message: There was a problem processing the query on the foreign data source. Data source error: %s

- Error: `1431` SQLSTATE: `HY000` (`ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST`)

Message: The foreign data source you are trying to reference does not exist. Data source error: %s

- Error: `1432` SQLSTATE: `HY000` (`ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE`)

Message: Can't create federated table. The data source connection string '%s' is not in the correct format

- Error: `1433` SQLSTATE: `HY000` (`ER_FOREIGN_DATA_STRING_INVALID`)

Message: The data source connection string '%s' is not in the correct format

- Error: `1434` SQLSTATE: `HY000` (`ER_CANT_CREATE_FEDERATED_TABLE`)

Message: Can't create federated table. Foreign data src error: %s

- Error: `1435` SQLSTATE: `HY000` (`ER_TRG_IN_WRONG_SCHEMA`)

Message: Trigger in wrong schema

- Error: `1436` SQLSTATE: `HY000` (`ER_STACK_OVERRUN_NEED_MORE`)

Message: Thread stack overrun: %ld bytes used of a %ld byte stack, and %ld bytes needed. Use 'mysqld -O thread_stack=#' to specify a bigger stack.

- Error: `1437` SQLSTATE: `42000` (`ER_TOO_LONG_BODY`)

Message: Routine body for '%s' is too long

- Error: `1438` SQLSTATE: `HY000` (`ER_WARN_CANT_DROP_DEFAULT_KEYCACHE`)

Message: Cannot drop default keycache

- Error: `1439` SQLSTATE: `42000` (`ER_TOO_BIG_DISPLAYWIDTH`)

  Message: Display width out of range for column '%s' (max = %lu)

- Error: `1440` SQLSTATE: `XAE08` (`ER_XAER_DUPID`)

  Message: XAER_DUPID: The XID already exists

- Error: `1441` SQLSTATE: `22008` (`ER_DATETIME_FUNCTION_OVERFLOW`)

  Message: Datetime function: %s field overflow

- Error: `1442` SQLSTATE: `HY000` (`ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG`)

  Message: Can't update table '%s' in stored function/trigger because it is already used by statement which invoked this stored function/trigger.

- Error: `1443` SQLSTATE: `HY000` (`ER_VIEW_PREVENT_UPDATE`)

  Message: The definition of table '%s' prevents operation %s on table '%s'.

- Error: `1444` SQLSTATE: `HY000` (`ER_PS_NO_RECURSION`)

  Message: The prepared statement contains a stored routine call that refers to that same statement. It's not allowed to execute a prepared statement in such a recursive manner

- Error: `1445` SQLSTATE: `HY000` (`ER_SP_CANT_SET_AUTOCOMMIT`)

  Message: Not allowed to set autocommit from a stored function or trigger

- Error: `1446` SQLSTATE: `HY000` (`ER_MALFORMED_DEFINER`)

  Message: Definer is not fully qualified

- Error: `1447` SQLSTATE: `HY000` (`ER_VIEW_FRM_NO_USER`)

  Message: View '%s'.'%s' has no definer information (old table format). Current user is used as definer. Please recreate the view!

- Error: `1448` SQLSTATE: `HY000` (`ER_VIEW_OTHER_USER`)

  Message: You need the SUPER privilege for creation view with '%s'@'%s' definer

- Error: `1449` SQLSTATE: `HY000` (`ER_NO_SUCH_USER`)

  Message: The user specified as a definer ('%s'@'%s') does not exist

- Error: `1450` SQLSTATE: `HY000` (`ER_FORBID_SCHEMA_CHANGE`)

  Message: Changing schema from '%s' to '%s' is not allowed.

- Error: `1451` SQLSTATE: `23000` (`ER_ROW_IS_REFERENCED_2`)

  Message: Cannot delete or update a parent row: a foreign key constraint fails (%s)

- Error: `1452` SQLSTATE: `23000` (`ER_NO_REFERENCED_ROW_2`)

  Message: Cannot add or update a child row: a foreign key constraint fails (%s)

- Error: `1453` SQLSTATE: `42000` (`ER_SP_BAD_VAR_SHADOW`)

Message: Variable '%s' must be quoted with `...`, or renamed

- Error: `1454` SQLSTATE: `HY000` (`ER_TRG_NO_DEFINER`)

Message: No definer attribute for trigger '%s'.'%s'. The trigger will be activated under the authorization of the invoker, which may have insufficient privileges. Please recreate the trigger.

- Error: `1455` SQLSTATE: `HY000` (`ER_OLD_FILE_FORMAT`)

Message: '%s' has an old format, you should re-create the '%s' object(s)

- Error: `1456` SQLSTATE: `HY000` (`ER_SP_RECURSION_LIMIT`)

Message: Recursive limit %d (as set by the max_sp_recursion_depth variable) was exceeded for routine %s

- Error: `1457` SQLSTATE: `HY000` (`ER_SP_PROC_TABLE_CORRUPT`)

Message: Failed to load routine %s. The table mysql.proc is missing, corrupt, or contains bad data (internal code %d)

`ER_SP_PROC_TABLE_CORRUPT` was added in 5.1.4.

- Error: `1458` SQLSTATE: `42000` (`ER_SP_WRONG_NAME`)

Message: Incorrect routine name '%s'

`ER_SP_WRONG_NAME` was added in 5.1.7.

- Error: `1459` SQLSTATE: `HY000` (`ER_TABLE_NEEDS_UPGRADE`)

Message: Table upgrade required. Please do "REPAIR TABLE `%s`" or dump/reload to fix it!

`ER_TABLE_NEEDS_UPGRADE` was added in 5.1.7.

- Error: `1460` SQLSTATE: `42000` (`ER_SP_NO_AGGREGATE`)

Message: AGGREGATE is not supported for stored functions

`ER_SP_NO_AGGREGATE` was added in 5.1.9.

- Error: `1461` SQLSTATE: `42000` (`ER_MAX_PREPARED_STMT_COUNT_REACHED`)

Message: Can't create more than max_prepared_stmt_count statements (current value: %lu)

`ER_MAX_PREPARED_STMT_COUNT_REACHED` was added in 5.1.11.

- Error: `1462` SQLSTATE: `HY000` (`ER_VIEW_RECURSIVE`)

Message: `%s`.`%s` contains view recursion

`ER_VIEW_RECURSIVE` was added in 5.1.11.

- Error: `1463` SQLSTATE: `42000` (`ER_NON_GROUPING_FIELD_USED`)

Message: non-grouping field '%s' is used in %s clause

`ER_NON_GROUPING_FIELD_USED` was added in 5.1.11.

- Error: `1464` SQLSTATE: `HY000` (`ER_TABLE_CANT_HANDLE_SPKEYS`)

  Message: The used table type doesn't support SPATIAL indexes

  `ER_TABLE_CANT_HANDLE_SPKEYS` was added in 5.1.11.

- Error: `1465` SQLSTATE: `HY000` (`ER_NO_TRIGGERS_ON_SYSTEM_SCHEMA`)

  Message: Triggers can not be created on system tables

  `ER_NO_TRIGGERS_ON_SYSTEM_SCHEMA` was added in 5.1.12.

- Error: `1466` SQLSTATE: `HY000` (`ER_REMOVED_SPACES`)

  Message: Leading spaces are removed from name '%s'

  `ER_REMOVED_SPACES` was added in 5.1.12.

- Error: `1467` SQLSTATE: `HY000` (`ER_AUTOINC_READ_FAILED`)

  Message: Failed to read auto-increment value from storage engine

  `ER_AUTOINC_READ_FAILED` was added in 5.1.12.

- Error: `1468` SQLSTATE: `HY000` (`ER_USERNAME`)

  Message: user name

  `ER_USERNAME` was added in 5.1.12.

- Error: `1469` SQLSTATE: `HY000` (`ER_HOSTNAME`)

  Message: host name

  `ER_HOSTNAME` was added in 5.1.12.

- Error: `1470` SQLSTATE: `HY000` (`ER_WRONG_STRING_LENGTH`)

  Message: String '%s' is too long for %s (should be no longer than %d)

  `ER_WRONG_STRING_LENGTH` was added in 5.1.12.

- Error: `1471` SQLSTATE: `HY000` (`ER_NON_INSERTABLE_TABLE`)

  Message: The target table %s of the %s is not insertable-into

  `ER_NON_INSERTABLE_TABLE` was added in 5.1.12.

- Error: `1472` SQLSTATE: `HY000` (`ER_ADMIN_WRONG_MRG_TABLE`)

  Message: Table '%s' is differently defined or of non-MyISAM type or doesn't exist

  `ER_ADMIN_WRONG_MRG_TABLE` was added in 5.1.20.

- Error: `1473` SQLSTATE: `HY000` (`ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT`)

  Message: Too high level of nesting for select

  `ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT` was added in 5.1.23.

- Error: `1474` SQLSTATE: `HY000` (`ER_NAME_BECOMES_EMPTY`)

  Message: Name '%s' has become ''

  `ER_NAME_BECOMES_EMPTY` was added in 5.1.23.

- Error: `1475` SQLSTATE: `HY000` (`ER_AMBIGUOUS_FIELD_TERM`)

  Message: First character of the FIELDS TERMINATED string is ambiguous; please use non-optional and non-empty FIELDS ENCLOSED BY

  `ER_AMBIGUOUS_FIELD_TERM` was added in 5.1.23.

- Error: `1476` SQLSTATE: `HY000` (`ER_FOREIGN_SERVER_EXISTS`)

  Message: The foreign server, %s, you are trying to create already exists.

  `ER_FOREIGN_SERVER_EXISTS` was added in 5.1.15.

- Error: `1477` SQLSTATE: `HY000` (`ER_FOREIGN_SERVER_DOESNT_EXIST`)

  Message: The foreign server name you are trying to reference does not exist. Data source error: %s

  `ER_FOREIGN_SERVER_DOESNT_EXIST` was added in 5.1.15.

- Error: `1478` SQLSTATE: `HY000` (`ER_ILLEGAL_HA_CREATE_OPTION`)

  Message: Table storage engine '%s' does not support the create option '%s'

  `ER_ILLEGAL_HA_CREATE_OPTION` was added in 5.1.7.

- Error: `1479` SQLSTATE: `HY000` (`ER_PARTITION_REQUIRES_VALUES_ERROR`)

  Message: Syntax error: %s PARTITIONING requires definition of VALUES %s for each partition

- Error: `1480` SQLSTATE: `HY000` (`ER_PARTITION_WRONG_VALUES_ERROR`)

  Message: Only %s PARTITIONING can use VALUES %s in partition definition

- Error: `1481` SQLSTATE: `HY000` (`ER_CHAR_SET_IN_PART_FIELD_ERROR`)

  Message: VARCHAR only allowed if binary collation for partition functions

  `ER_CHAR_SET_IN_PART_FIELD_ERROR` was removed after 5.1.5.

- Error: `1481` SQLSTATE: `HY000` (`ER_PARTITION_MAXVALUE_ERROR`)

  Message: MAXVALUE can only be used in last partition definition

- Error: `1482` SQLSTATE: `HY000` (`ER_PARTITION_SUBPARTITION_ERROR`)

  Message: Subpartitions can only be hash partitions and by key

- Error: `1483` SQLSTATE: `HY000` (`ER_PARTITION_SUBPART_MIX_ERROR`)

  Message: Must define subpartitions on all partitions if on one partition

  `ER_PARTITION_SUBPART_MIX_ERROR` was added in 5.1.9.

- Error: `1484` SQLSTATE: `HY000` (`ER_PARTITION_WRONG_NO_PART_ERROR`)

Message: Wrong number of partitions defined, mismatch with previous setting

- Error: `1485` SQLSTATE: `HY000` (`ER_PARTITION_WRONG_NO_SUBPART_ERROR`)

Message: Wrong number of subpartitions defined, mismatch with previous setting

- Error: `1486` SQLSTATE: `HY000` (`ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR`)

Message: Constant/Random expression in (sub)partitioning function is not allowed

In 5.1.43: `ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR` was renamed to `ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR`.

`ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR` was removed after 5.1.42.

- Error: `1486` SQLSTATE: `HY000` (`ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR`)

Message: Constant, random or timezone-dependent expressions in (sub)partitioning function are not allowed

In 5.1.43: `ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR` was renamed to `ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR`.

`ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR` was added in 5.1.43.

- Error: `1487` SQLSTATE: `HY000` (`ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR`)

Message: Expression in RANGE/LIST VALUES must be constant

- Error: `1488` SQLSTATE: `HY000` (`ER_FIELD_NOT_FOUND_PART_ERROR`)

Message: Field in list of fields for partition function not found in table

- Error: `1489` SQLSTATE: `HY000` (`ER_LIST_OF_FIELDS_ONLY_IN_HASH_ERROR`)

Message: List of fields is only allowed in KEY partitions

- Error: `1490` SQLSTATE: `HY000` (`ER_INCONSISTENT_PARTITION_INFO_ERROR`)

Message: The partition info in the frm file is not consistent with what can be written into the frm file

- Error: `1491` SQLSTATE: `HY000` (`ER_PARTITION_FUNC_NOT_ALLOWED_ERROR`)

Message: The %s function returns the wrong type

- Error: `1492` SQLSTATE: `HY000` (`ER_PARTITIONS_MUST_BE_DEFINED_ERROR`)

Message: For %s partitions each partition must be defined

- Error: `1493` SQLSTATE: `HY000` (`ER_RANGE_NOT_INCREASING_ERROR`)

Message: VALUES LESS THAN value must be strictly increasing for each partition

- Error: `1494` SQLSTATE: `HY000` (`ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR`)

Message: VALUES value must be of same type as partition function

- Error: `1495` SQLSTATE: `HY000` (`ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR`)

Message: Multiple definition of same constant in list partitioning

- Error: `1496` SQLSTATE: `HY000` (`ER_DROP_PARTITION_FAILURE`)

Message: Drop partition not supported in this version for this handler

`ER_DROP_PARTITION_FAILURE` was removed after 5.1.5.

- Error: `1496` SQLSTATE: `HY000` (`ER_PARTITION_ENTRY_ERROR`)

Message: Partitioning can not be used stand-alone in query

- Error: `1497` SQLSTATE: `HY000` (`ER_DROP_PARTITION_WHEN_FK_DEFINED`)

Message: Cannot drop a partition when a foreign key constraint is defined on the table

`ER_DROP_PARTITION_WHEN_FK_DEFINED` was removed after 5.1.5.

- Error: `1497` SQLSTATE: `HY000` (`ER_MIX_HANDLER_ERROR`)

Message: The mix of handlers in the partitions is not allowed in this version of MySQL

- Error: `1498` SQLSTATE: `HY000` (`ER_PARTITION_NOT_DEFINED_ERROR`)

Message: For the partitioned engine it is necessary to define all %s

- Error: `1499` SQLSTATE: `HY000` (`ER_TOO_MANY_PARTITIONS_ERROR`)

Message: Too many partitions (including subpartitions) were defined

- Error: `1500` SQLSTATE: `HY000` (`ER_SUBPARTITION_ERROR`)

Message: It is only possible to mix RANGE/LIST partitioning with HASH/KEY partitioning for subpartitioning

- Error: `1501` SQLSTATE: `HY000` (`ER_CANT_CREATE_HANDLER_FILE`)

Message: Failed to create specific handler file

- Error: `1502` SQLSTATE: `HY000` (`ER_BLOB_FIELD_IN_PART_FUNC_ERROR`)

Message: A BLOB field is not allowed in partition function

- Error: `1503` SQLSTATE: `HY000` (`ER_UNIQUE_KEY_NEED_ALL_FIELDS_IN_PF`)

Message: A %s must include all columns in the table's partitioning function

- Error: `1504` SQLSTATE: `HY000` (`ER_NO_PARTS_ERROR`)

Message: Number of %s = 0 is not an allowed value

- Error: `1505` SQLSTATE: `HY000` (`ER_TABLESPACE_OPTION_ONLY_ONCE`)

Message: It is not allowed to specify %s more than once

`ER_TABLESPACE_OPTION_ONLY_ONCE` was added in 5.1.6, removed after 5.1.6.

- Error: `1505` SQLSTATE: `HY000` (`ER_PARTITION_MGMT_ON_NONPARTITIONED`)

Message: Partition management on a not partitioned table is not possible

- Error: `1506` SQLSTATE: `HY000` (`ER_CREATE_TABLESPACE_FAILED`)

  Message: Failed to create %s

  `ER_CREATE_TABLESPACE_FAILED` was added in 5.1.6, removed after 5.1.6.

- Error: `1506` SQLSTATE: `HY000` (`ER_FOREIGN_KEY_ON_PARTITIONED`)

  Message: Foreign key clause is not yet supported in conjunction with partitioning

  `ER_FOREIGN_KEY_ON_PARTITIONED` was added in 5.1.6.

- Error: `1507` SQLSTATE: `HY000` (`ER_DROP_TABLESPACE_FAILED`)

  Message: Failed to drop %s

  `ER_DROP_TABLESPACE_FAILED` was added in 5.1.6, removed after 5.1.6.

- Error: `1507` SQLSTATE: `HY000` (`ER_DROP_PARTITION_NON_EXISTENT`)

  Message: Error in list of partitions to %s

- Error: `1508` SQLSTATE: `HY000` (`ER_DROP_LAST_PARTITION`)

  Message: Cannot remove all partitions, use DROP TABLE instead

- Error: `1509` SQLSTATE: `HY000` (`ER_COALESCE_ONLY_ON_HASH_PARTITION`)

  Message: COALESCE PARTITION can only be used on HASH/KEY partitions

- Error: `1510` SQLSTATE: `HY000` (`ER_REORG_HASH_ONLY_ON_SAME_NO`)

  Message: REORGANIZE PARTITION can only be used to reorganize partitions not to change their numbers

  `ER_REORG_HASH_ONLY_ON_SAME_NO` was added in 5.1.6.

- Error: `1511` SQLSTATE: `HY000` (`ER_ALTER_TABLESPACE_FAILED`)

  Message: Failed to alter: %s

  `ER_ALTER_TABLESPACE_FAILED` was added in 5.1.6, removed after 5.1.6.

- Error: `1511` SQLSTATE: `HY000` (`ER_REORG_NO_PARAM_ERROR`)

  Message: REORGANIZE PARTITION without parameters can only be used on auto-partitioned tables using HASH PARTITIONs

  `ER_REORG_NO_PARAM_ERROR` was added in 5.1.6.

- Error: `1512` SQLSTATE: `HY000` (`ER_ONLY_ON_RANGE_LIST_PARTITION`)

  Message: %s PARTITION can only be used on RANGE/LIST partitions

- Error: `1513` SQLSTATE: `HY000` (`ER_ADD_PARTITION_SUBPART_ERROR`)

  Message: Trying to Add partition(s) with wrong number of subpartitions

- Error: `1514` SQLSTATE: `HY000` (`ER_ADD_PARTITION_NO_NEW_PARTITION`)

  Message: At least one partition must be added

- Error: `1515` SQLSTATE: `HY000` (`ER_COALESCE_PARTITION_NO_PARTITION`)

  Message: At least one partition must be coalesced

- Error: `1516` SQLSTATE: `HY000` (`ER_REORG_PARTITION_NOT_EXIST`)

  Message: More partitions to reorganize than there are partitions

- Error: `1517` SQLSTATE: `HY000` (`ER_SAME_NAME_PARTITION`)

  Message: Duplicate partition name %s

- Error: `1518` SQLSTATE: `HY000` (`ER_NO_BINLOG_ERROR`)

  Message: It is not allowed to shut off binlog on this command

  `ER_NO_BINLOG_ERROR` was added in 5.1.6.

- Error: `1519` SQLSTATE: `HY000` (`ER_CONSECUTIVE_REORG_PARTITIONS`)

  Message: When reorganizing a set of partitions they must be in consecutive order

- Error: `1520` SQLSTATE: `HY000` (`ER_REORG_OUTSIDE_RANGE`)

  Message: Reorganize of range partitions cannot change total ranges except for last partition where it can extend the range

- Error: `1521` SQLSTATE: `HY000` (`ER_PARTITION_FUNCTION_FAILURE`)

  Message: Partition function not supported in this version for this handler

  `ER_PARTITION_FUNCTION_FAILURE` was added in 5.1.6.

- Error: `1522` SQLSTATE: `HY000` (`ER_PART_STATE_ERROR`)

  Message: Partition state cannot be defined from CREATE/ALTER TABLE

  `ER_PART_STATE_ERROR` was added in 5.1.6.

- Error: `1523` SQLSTATE: `HY000` (`ER_LIMITED_PART_RANGE`)

  Message: The %s handler only supports 32 bit integers in VALUES

  `ER_LIMITED_PART_RANGE` was added in 5.1.6.

- Error: `1524` SQLSTATE: `HY000` (`ER_PLUGIN_IS_NOT_LOADED`)

  Message: Plugin '%s' is not loaded

- Error: `1525` SQLSTATE: `HY000` (`ER_EVENT_COL_COUNT_DOESNT_MATCH`)

  Message: Column count of %s.%s is wrong. Table probably corrupted

  `ER_EVENT_COL_COUNT_DOESNT_MATCH` was added in 5.1.6, removed after 5.1.6.

- Error: `1525` SQLSTATE: `HY000` (`ER_WRONG_VALUE`)

Message: Incorrect %s value: '%s'

`ER_WRONG_VALUE` was added in 5.1.4.

- Error: `1526` SQLSTATE: `HY000` (`ER_EVENT_CANNOT_LOAD_FROM_TABLE`)

Message: Cannot load from mysql.%s. Table probably corrupted. See error log.

`ER_EVENT_CANNOT_LOAD_FROM_TABLE` was added in 5.1.6, removed after 5.1.7.

- Error: `1526` SQLSTATE: `HY000` (`ER_NO_PARTITION_FOR_GIVEN_VALUE`)

Message: Table has no partition for value %s

`ER_NO_PARTITION_FOR_GIVEN_VALUE` was added in 5.1.4.

- Error: `1527` SQLSTATE: `HY000` (`ER_FILEGROUP_OPTION_ONLY_ONCE`)

Message: It is not allowed to specify %s more than once

`ER_FILEGROUP_OPTION_ONLY_ONCE` was added in 5.1.7.

- Error: `1528` SQLSTATE: `HY000` (`ER_CREATE_FILEGROUP_FAILED`)

Message: Failed to create %s

`ER_CREATE_FILEGROUP_FAILED` was added in 5.1.7.

- Error: `1529` SQLSTATE: `HY000` (`ER_DROP_FILEGROUP_FAILED`)

Message: Failed to drop %s

`ER_DROP_FILEGROUP_FAILED` was added in 5.1.7.

- Error: `1530` SQLSTATE: `HY000` (`ER_TABLESPACE_AUTO_EXTEND_ERROR`)

Message: The handler doesn't support autoextend of tablespaces

`ER_TABLESPACE_AUTO_EXTEND_ERROR` was added in 5.1.6.

- Error: `1531` SQLSTATE: `HY000` (`ER_WRONG_SIZE_NUMBER`)

Message: A size parameter was incorrectly specified, either number or on the form 10M

`ER_WRONG_SIZE_NUMBER` was added in 5.1.6.

- Error: `1532` SQLSTATE: `HY000` (`ER_SIZE_OVERFLOW_ERROR`)

Message: The size number was correct but we don't allow the digit part to be more than 2 billion

`ER_SIZE_OVERFLOW_ERROR` was added in 5.1.6.

- Error: `1533` SQLSTATE: `HY000` (`ER_ALTER_FILEGROUP_FAILED`)

Message: Failed to alter: %s

`ER_ALTER_FILEGROUP_FAILED` was added in 5.1.7.

- Error: `1534` SQLSTATE: `HY000` (`ER_BINLOG_ROW_LOGGING_FAILED`)

Message: Writing one row to the row-based binary log failed

`ER_BINLOG_ROW_LOGGING_FAILED` was added in 5.1.5.

- Error: `1535` SQLSTATE: `HY000` (`ER_BINLOG_ROW_WRONG_TABLE_DEF`)

Message: Table definition on master and slave does not match: %s

`ER_BINLOG_ROW_WRONG_TABLE_DEF` was added in 5.1.5.

- Error: `1536` SQLSTATE: `HY000` (`ER_BINLOG_ROW_RBR_TO_SBR`)

Message: Slave running with --log-slave-updates must use row-based binary logging to be able to replicate row-based binary log events

`ER_BINLOG_ROW_RBR_TO_SBR` was added in 5.1.5.

- Error: `1537` SQLSTATE: `HY000` (`ER_EVENT_ALREADY_EXISTS`)

Message: Event '%s' already exists

`ER_EVENT_ALREADY_EXISTS` was added in 5.1.6.

- Error: `1538` SQLSTATE: `HY000` (`ER_EVENT_STORE_FAILED`)

Message: Failed to store event %s. Error code %d from storage engine.

`ER_EVENT_STORE_FAILED` was added in 5.1.6.

- Error: `1539` SQLSTATE: `HY000` (`ER_EVENT_DOES_NOT_EXIST`)

Message: Unknown event '%s'

`ER_EVENT_DOES_NOT_EXIST` was added in 5.1.6.

- Error: `1540` SQLSTATE: `HY000` (`ER_WARN_DEPRECATED_STATEMENT`)

Message: The '%s' statement is deprecated and will be removed in MySQL %s. Please use client programs (e.g. %s) instead.

`ER_WARN_DEPRECATED_STATEMENT` was added in 5.1.7, removed after 5.1.7.

- Error: `1540` SQLSTATE: `HY000` (`ER_EVENT_CANT_ALTER`)

Message: Failed to alter event '%s'

`ER_EVENT_CANT_ALTER` was added in 5.1.6.

- Error: `1541` SQLSTATE: `HY000` (`ER_WARN_DEPRECATED`)

Message: The syntax '%s' is deprecated and will be removed in MySQL %s. Please use %s instead.

`ER_WARN_DEPRECATED` was added in 5.1.9, removed after 5.1.9.

- Error: `1541` SQLSTATE: `HY000` (`ER_EVENT_DROP_FAILED`)

Message: Failed to drop %s

`ER_EVENT_DROP_FAILED` was added in 5.1.6.

- Error: `1542` SQLSTATE: `HY000` (`ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG`)

  Message: INTERVAL is either not positive or too big

  `ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG` was added in 5.1.6.

- Error: `1543` SQLSTATE: `HY000` (`ER_EVENT_ENDS_BEFORE_STARTS`)

  Message: ENDS is either invalid or before STARTS

  `ER_EVENT_ENDS_BEFORE_STARTS` was added in 5.1.6.

- Error: `1544` SQLSTATE: `HY000` (`ER_EVENT_EXEC_TIME_IN_THE_PAST`)

  Message: Event execution time is in the past. Event has been disabled

  `ER_EVENT_EXEC_TIME_IN_THE_PAST` was added in 5.1.6.

- Error: `1545` SQLSTATE: `HY000` (`ER_EVENT_OPEN_TABLE_FAILED`)

  Message: Failed to open mysql.event

  `ER_EVENT_OPEN_TABLE_FAILED` was added in 5.1.6.

- Error: `1546` SQLSTATE: `HY000` (`ER_EVENT_NEITHER_M_EXPR_NOR_M_AT`)

  Message: No datetime expression provided

  `ER_EVENT_NEITHER_M_EXPR_NOR_M_AT` was added in 5.1.6.

- Error: `1547` SQLSTATE: `HY000` (`ER_COL_COUNT_DOESNT_MATCH_CORRUPTED`)

  Message: Column count of mysql.%s is wrong. Expected %d, found %d. The table is probably corrupted

  `ER_COL_COUNT_DOESNT_MATCH_CORRUPTED` was added in 5.1.7.

- Error: `1548` SQLSTATE: `HY000` (`ER_CANNOT_LOAD_FROM_TABLE`)

  Message: Cannot load from mysql.%s. The table is probably corrupted

  `ER_CANNOT_LOAD_FROM_TABLE` was added in 5.1.9.

- Error: `1549` SQLSTATE: `HY000` (`ER_EVENT_CANNOT_DELETE`)

  Message: Failed to delete the event from mysql.event

  `ER_EVENT_CANNOT_DELETE` was added in 5.1.6.

- Error: `1550` SQLSTATE: `HY000` (`ER_EVENT_COMPILE_ERROR`)

  Message: Error during compilation of event's body

  `ER_EVENT_COMPILE_ERROR` was added in 5.1.6.

- Error: `1551` SQLSTATE: `HY000` (`ER_EVENT_SAME_NAME`)

  Message: Same old and new event name

  `ER_EVENT_SAME_NAME` was added in 5.1.6.

- Error: `1552` SQLSTATE: `HY000` (`ER_EVENT_DATA_TOO_LONG`)

  Message: Data for column '%s' too long

  `ER_EVENT_DATA_TOO_LONG` was added in 5.1.6.

- Error: `1553` SQLSTATE: `HY000` (`ER_CANT_READ_LOCK_LOG_TABLE`)

  Message: You can't use usual read lock with log tables. Try READ LOCAL instead

  `ER_CANT_READ_LOCK_LOG_TABLE` was added in 5.1.6, removed after 5.1.20.

- Error: `1553` SQLSTATE: `HY000` (`ER_DROP_INDEX_FK`)

  Message: Cannot drop index '%s': needed in a foreign key constraint

  `InnoDB` reports this error when you attempt to drop the last index that can enforce a particular referential constraint.

  For optimal performance with DML statements, `InnoDB` requires an index to exist on foreign key columns, so that `UPDATE` and `DELETE` operations on a parent table can easily check whether corresponding rows exist in the child table. MySQL creates or drops such indexes automatically when needed, as a side-effect of `CREATE TABLE`, `CREATE INDEX`, and `ALTER TABLE` statements.

  When you drop an index, `InnoDB` checks if the index is used for checking a foreign key constraint. It is still OK to drop the index if there is another index that can be used to enforce the same constraint. `InnoDB` prevents you from dropping the last index that can enforce a particular referential constraint.

  `ER_DROP_INDEX_FK` was added in 5.1.6.

- Error: `1554` SQLSTATE: `HY000` (`ER_WARN_DEPRECATED_SYNTAX_WITH_VER`)

  Message: The syntax '%s' is deprecated and will be removed in MySQL %s. Please use %s instead

  `ER_WARN_DEPRECATED_SYNTAX_WITH_VER` was added in 5.1.20.

- Error: `1555` SQLSTATE: `HY000` (`ER_CANT_WRITE_LOCK_LOG_TABLE`)

  Message: You can't write-lock a log table. Only read access is possible

  `ER_CANT_WRITE_LOCK_LOG_TABLE` was added in 5.1.6.

- Error: `1556` SQLSTATE: `HY000` (`ER_CANT_LOCK_LOG_TABLE`)

  Message: You can't use locks with log tables.

  `ER_CANT_LOCK_LOG_TABLE` was added in 5.1.21.

- Error: `1557` SQLSTATE: `23000` (`ER_FOREIGN_DUPLICATE_KEY`)

  Message: Upholding foreign key constraints for table '%s', entry '%s', key %d would lead to a duplicate entry

  `ER_FOREIGN_DUPLICATE_KEY` was added in 5.1.7.

- Error: `1558` SQLSTATE: `HY000` (`ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE`)

  Message: Column count of mysql.%s is wrong. Expected %d, found %d. Created with MySQL %d, now running %d. Please use mysql_upgrade to fix this error.

ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE was added in 5.1.7.

- Error: 1559 SQLSTATE: HY000 (ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR)

Message: Cannot switch out of the row-based binary log format when the session has open temporary tables

ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR was added in 5.1.9.

- Error: 1560 SQLSTATE: HY000 (ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT)

Message: Cannot change the binary logging format inside a stored function or trigger

ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT was added in 5.1.9.

- Error: 1561 SQLSTATE: HY000 (ER_NDB_CANT_SWITCH_BINLOG_FORMAT)

Message: The NDB cluster engine does not support changing the binlog format on the fly yet

ER_NDB_CANT_SWITCH_BINLOG_FORMAT was added in 5.1.9.

- Error: 1562 SQLSTATE: HY000 (ER_PARTITION_NO_TEMPORARY)

Message: Cannot create temporary table with partitions

ER_PARTITION_NO_TEMPORARY was added in 5.1.9.

- Error: 1563 SQLSTATE: HY000 (ER_PARTITION_CONST_DOMAIN_ERROR)

Message: Partition constant is out of partition function domain

ER_PARTITION_CONST_DOMAIN_ERROR was added in 5.1.12.

- Error: 1564 SQLSTATE: HY000 (ER_PARTITION_FUNCTION_IS_NOT_ALLOWED)

Message: This partition function is not allowed

ER_PARTITION_FUNCTION_IS_NOT_ALLOWED was added in 5.1.12.

- Error: 1565 SQLSTATE: HY000 (ER_DDL_LOG_ERROR)

Message: Error in DDL log

ER_DDL_LOG_ERROR was added in 5.1.11.

- Error: 1566 SQLSTATE: HY000 (ER_NULL_IN_VALUES_LESS_THAN)

Message: Not allowed to use NULL value in VALUES LESS THAN

ER_NULL_IN_VALUES_LESS_THAN was added in 5.1.11.

- Error: 1567 SQLSTATE: HY000 (ER_EVENT_RECURSIVITY_FORBIDDEN)

Message: Recursivity of EVENT DDL statements is forbidden when body is present

ER_EVENT_RECURSIVITY_FORBIDDEN was added in 5.1.12, removed after 5.1.17.

- Error: 1567 SQLSTATE: HY000 (ER_WRONG_PARTITION_NAME)

Message: Incorrect partition name

`ER_WRONG_PARTITION_NAME` was added in 5.1.11.

- Error: `1568` SQLSTATE: `25001` (`ER_CANT_CHANGE_TX_ISOLATION`)

Message: Transaction isolation level can't be changed while a transaction is in progress

`ER_CANT_CHANGE_TX_ISOLATION` was added in 5.1.7.

- Error: `1569` SQLSTATE: `HY000` (`ER_DUP_ENTRY_AUTOINCREMENT_CASE`)

Message: ALTER TABLE causes auto_increment resequencing, resulting in duplicate entry '%s' for key '%s'

`ER_DUP_ENTRY_AUTOINCREMENT_CASE` was added in 5.1.12.

- Error: `1570` SQLSTATE: `HY000` (`ER_EVENT_MODIFY_QUEUE_ERROR`)

Message: Internal scheduler error %d

`ER_EVENT_MODIFY_QUEUE_ERROR` was added in 5.1.11.

- Error: `1571` SQLSTATE: `HY000` (`ER_EVENT_SET_VAR_ERROR`)

Message: Error during starting/stopping of the scheduler. Error code %u

`ER_EVENT_SET_VAR_ERROR` was added in 5.1.11.

- Error: `1572` SQLSTATE: `HY000` (`ER_PARTITION_MERGE_ERROR`)

Message: Engine cannot be used in partitioned tables

`ER_PARTITION_MERGE_ERROR` was added in 5.1.12.

- Error: `1573` SQLSTATE: `HY000` (`ER_CANT_ACTIVATE_LOG`)

Message: Cannot activate '%s' log

`ER_CANT_ACTIVATE_LOG` was added in 5.1.12.

- Error: `1574` SQLSTATE: `HY000` (`ER_RBR_NOT_AVAILABLE`)

Message: The server was not built with row-based replication

`ER_RBR_NOT_AVAILABLE` was added in 5.1.12.

- Error: `1575` SQLSTATE: `HY000` (`ER_BASE64_DECODE_ERROR`)

Message: Decoding of base64 string failed

`ER_BASE64_DECODE_ERROR` was added in 5.1.12.

- Error: `1576` SQLSTATE: `HY000` (`ER_EVENT_RECURSION_FORBIDDEN`)

Message: Recursion of EVENT DDL statements is forbidden when body is present

`ER_EVENT_RECURSION_FORBIDDEN` was added in 5.1.18.

- Error: `1577` SQLSTATE: `HY000` (`ER_EVENTS_DB_ERROR`)

  Message: Cannot proceed because system tables used by Event Scheduler were found damaged at server start

  To address this issue, try running `mysql_upgrade`.

  `ER_EVENTS_DB_ERROR` was added in 5.1.12.

- Error: `1578` SQLSTATE: `HY000` (`ER_ONLY_INTEGERS_ALLOWED`)

  Message: Only integers allowed as number here

  `ER_ONLY_INTEGERS_ALLOWED` was added in 5.1.12.

- Error: `1579` SQLSTATE: `HY000` (`ER_UNSUPORTED_LOG_ENGINE`)

  Message: This storage engine cannot be used for log tables"

  `ER_UNSUPORTED_LOG_ENGINE` was added in 5.1.12.

- Error: `1580` SQLSTATE: `HY000` (`ER_BAD_LOG_STATEMENT`)

  Message: You cannot '%s' a log table if logging is enabled

  `ER_BAD_LOG_STATEMENT` was added in 5.1.12.

- Error: `1581` SQLSTATE: `HY000` (`ER_CANT_RENAME_LOG_TABLE`)

  Message: Cannot rename '%s'. When logging enabled, rename to/from log table must rename two tables: the log table to an archive table and another table back to '%s'

  `ER_CANT_RENAME_LOG_TABLE` was added in 5.1.13.

- Error: `1582` SQLSTATE: `42000` (`ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT`)

  Message: Incorrect parameter count in the call to native function '%s'

  `ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT` was added in 5.1.13.

- Error: `1583` SQLSTATE: `42000` (`ER_WRONG_PARAMETERS_TO_NATIVE_FCT`)

  Message: Incorrect parameters in the call to native function '%s'

  `ER_WRONG_PARAMETERS_TO_NATIVE_FCT` was added in 5.1.13.

- Error: `1584` SQLSTATE: `42000` (`ER_WRONG_PARAMETERS_TO_STORED_FCT`)

  Message: Incorrect parameters in the call to stored function '%s'

  `ER_WRONG_PARAMETERS_TO_STORED_FCT` was added in 5.1.14.

- Error: `1585` SQLSTATE: `HY000` (`ER_NATIVE_FCT_NAME_COLLISION`)

  Message: This function '%s' has the same name as a native function

  `ER_NATIVE_FCT_NAME_COLLISION` was added in 5.1.14.

- Error: `1586` SQLSTATE: `23000` (`ER_DUP_ENTRY_WITH_KEY_NAME`)

Message: Duplicate entry '%s' for key '%s'

From 5.1.20: The format string for this error is also used with `ER_DUP_ENTRY`.

`ER_DUP_ENTRY_WITH_KEY_NAME` was added in 5.1.15.

- Error: `1587` SQLSTATE: `HY000` (`ER_BINLOG_PURGE_EMFILE`)

Message: Too many files opened, please execute the command again

`ER_BINLOG_PURGE_EMFILE` was added in 5.1.14.

- Error: `1588` SQLSTATE: `HY000` (`ER_EVENT_CANNOT_CREATE_IN_THE_PAST`)

Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.

`ER_EVENT_CANNOT_CREATE_IN_THE_PAST` was added in 5.1.17.

- Error: `1589` SQLSTATE: `HY000` (`ER_EVENT_CANNOT_ALTER_IN_THE_PAST`)

Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.

`ER_EVENT_CANNOT_ALTER_IN_THE_PAST` was added in 5.1.17.

- Error: `1590` SQLSTATE: `HY000` (`ER_SLAVE_INCIDENT`)

Message: The incident %s occured on the master. Message: %s

`ER_SLAVE_INCIDENT` was added in 5.1.18.

- Error: `1591` SQLSTATE: `HY000` (`ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT`)

Message: Table has no partition for some existing values

`ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT` was added in 5.1.18.

- Error: `1592` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_STATEMENT`)

Message: Statement may not be safe to log in statement format.

`ER_BINLOG_UNSAFE_STATEMENT` was added in 5.1.20.

- Error: `1593` SQLSTATE: `HY000` (`ER_SLAVE_FATAL_ERROR`)

Message: Fatal error: %s

`ER_SLAVE_FATAL_ERROR` was added in 5.1.20.

- Error: `1594` SQLSTATE: `HY000` (`ER_SLAVE_RELAY_LOG_READ_FAILURE`)

Message: Relay log read failure: %s

`ER_SLAVE_RELAY_LOG_READ_FAILURE` was added in 5.1.20.

- Error: `1595` SQLSTATE: `HY000` (`ER_SLAVE_RELAY_LOG_WRITE_FAILURE`)

Message: Relay log write failure: %s

`ER_SLAVE_RELAY_LOG_WRITE_FAILURE` was added in 5.1.20.

- Error: `1596` SQLSTATE: `HY000` (`ER_SLAVE_CREATE_EVENT_FAILURE`)

  Message: Failed to create %s

  `ER_SLAVE_CREATE_EVENT_FAILURE` was added in 5.1.20.

- Error: `1597` SQLSTATE: `HY000` (`ER_SLAVE_MASTER_COM_FAILURE`)

  Message: Master command %s failed: %s

  `ER_SLAVE_MASTER_COM_FAILURE` was added in 5.1.20.

- Error: `1598` SQLSTATE: `HY000` (`ER_BINLOG_LOGGING_IMPOSSIBLE`)

  Message: Binary logging not possible. Message: %s

  `ER_BINLOG_LOGGING_IMPOSSIBLE` was added in 5.1.20.

- Error: `1599` SQLSTATE: `HY000` (`ER_VIEW_NO_CREATION_CTX`)

  Message: View `%s`.`%s` has no creation context

  `ER_VIEW_NO_CREATION_CTX` was added in 5.1.21.

- Error: `1600` SQLSTATE: `HY000` (`ER_VIEW_INVALID_CREATION_CTX`)

  Message: Creation context of view `%s`.`%s' is invalid

  `ER_VIEW_INVALID_CREATION_CTX` was added in 5.1.21.

- Error: `1601` SQLSTATE: `HY000` (`ER_SR_INVALID_CREATION_CTX`)

  Message: Creation context of stored routine `%s`.`%s` is invalid

  `ER_SR_INVALID_CREATION_CTX` was added in 5.1.21.

- Error: `1602` SQLSTATE: `HY000` (`ER_TRG_CORRUPTED_FILE`)

  Message: Corrupted TRG file for table `%s`.`%s`

  `ER_TRG_CORRUPTED_FILE` was added in 5.1.21.

- Error: `1603` SQLSTATE: `HY000` (`ER_TRG_NO_CREATION_CTX`)

  Message: Triggers for table `%s`.`%s` have no creation context

  `ER_TRG_NO_CREATION_CTX` was added in 5.1.21.

- Error: `1604` SQLSTATE: `HY000` (`ER_TRG_INVALID_CREATION_CTX`)

  Message: Trigger creation context of table `%s`.`%s` is invalid

  `ER_TRG_INVALID_CREATION_CTX` was added in 5.1.21.

- Error: `1605` SQLSTATE: `HY000` (`ER_EVENT_INVALID_CREATION_CTX`)

  Message: Creation context of event `%s`.`%s` is invalid

`ER_EVENT_INVALID_CREATION_CTX` was added in 5.1.21.

- Error: `1606` SQLSTATE: `HY000` (`ER_TRG_CANT_OPEN_TABLE`)

Message: Cannot open table for trigger `%s`.`%s`

`ER_TRG_CANT_OPEN_TABLE` was added in 5.1.21.

- Error: `1607` SQLSTATE: `HY000` (`ER_CANT_CREATE_SROUTINE`)

Message: Cannot create stored routine `%s`. Check warnings

`ER_CANT_CREATE_SROUTINE` was added in 5.1.23.

- Error: `1608` SQLSTATE: `HY000` (`ER_SLAVE_AMBIGOUS_EXEC_MODE`)

Message: Ambiguous slave modes combination. %s

`ER_SLAVE_AMBIGOUS_EXEC_MODE` was added in 5.1.24.

- Error: `1609` SQLSTATE: `HY000`
  (`ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT`)

Message: The BINLOG statement of type `%s` was not preceded by a format description BINLOG statement.

`ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT` was added in 5.1.24.

- Error: `1610` SQLSTATE: `HY000` (`ER_SLAVE_CORRUPT_EVENT`)

Message: Corrupted replication event was detected

`ER_SLAVE_CORRUPT_EVENT` was added in 5.1.24.

- Error: `1611` SQLSTATE: `HY000` (`ER_LOAD_DATA_INVALID_COLUMN`)

Message: Invalid column reference (%s) in LOAD DATA

`ER_LOAD_DATA_INVALID_COLUMN` was added in 5.1.24.

- Error: `1612` SQLSTATE: `HY000` (`ER_LOG_PURGE_NO_FILE`)

Message: Being purged log %s was not found

`ER_LOG_PURGE_NO_FILE` was added in 5.1.24.

- Error: `1613` SQLSTATE: `XA106` (`ER_XA_RBTIMEOUT`)

Message: XA_RBTIMEOUT: Transaction branch was rolled back: took too long

`ER_XA_RBTIMEOUT` was added in 5.1.30.

- Error: `1614` SQLSTATE: `XA102` (`ER_XA_RBDEADLOCK`)

Message: XA_RBDEADLOCK: Transaction branch was rolled back: deadlock was detected

`ER_XA_RBDEADLOCK` was added in 5.1.30.

- Error: `1615` SQLSTATE: `HY000` (`ER_NEED_REPREPARE`)

Message: Prepared statement needs to be re-prepared

`ER_NEED_REPREPARE` was added in 5.1.25.

- Error: `1616` SQLSTATE: `HY000` (`ER_DELAYED_NOT_SUPPORTED`)

Message: DELAYED option not supported for table '%s'

`ER_DELAYED_NOT_SUPPORTED` was added in 5.1.28.

- Error: `1617` SQLSTATE: `HY000` (`WARN_NO_MASTER_INFO`)

Message: The master info structure does not exist

`WARN_NO_MASTER_INFO` was added in 5.1.31.

- Error: `1618` SQLSTATE: `HY000` (`WARN_OPTION_IGNORED`)

Message: <%s> option ignored

`WARN_OPTION_IGNORED` was added in 5.1.31.

- Error: `1619` SQLSTATE: `HY000` (`WARN_PLUGIN_DELETE_BUILTIN`)

Message: Built-in plugins cannot be deleted

`WARN_PLUGIN_DELETE_BUILTIN` was added in 5.1.31.

- Error: `1620` SQLSTATE: `HY000` (`WARN_PLUGIN_BUSY`)

Message: Plugin is busy and will be uninstalled on shutdown

`WARN_PLUGIN_BUSY` was added in 5.1.31.

- Error: `1621` SQLSTATE: `HY000` (`ER_VARIABLE_IS_READONLY`)

Message: %s variable '%s' is read-only. Use SET %s to assign the value

`ER_VARIABLE_IS_READONLY` was added in 5.1.31.

- Error: `1622` SQLSTATE: `HY000` (`ER_WARN_ENGINE_TRANSACTION_ROLLBACK`)

Message: Storage engine %s does not support rollback for this statement. Transaction rolled back and must be restarted

`ER_WARN_ENGINE_TRANSACTION_ROLLBACK` was added in 5.1.33.

- Error: `1623` SQLSTATE: `HY000` (`ER_SLAVE_HEARTBEAT_FAILURE`)

Message: Unexpected master's heartbeat data: %s

`ER_SLAVE_HEARTBEAT_FAILURE` was added in 5.1.33.

- Error: `1624` SQLSTATE: `HY000` (`ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE`)

Message: The requested value for the heartbeat period %s %s

`ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE` was added in 5.1.33.

- Error: `1625` SQLSTATE: `HY000` (`ER_NDB_REPLICATION_SCHEMA_ERROR`)

  Message: Bad schema for mysql.ndb_replication table. Message: %s

  `ER_NDB_REPLICATION_SCHEMA_ERROR` was added in 5.1.33.

- Error: `1626` SQLSTATE: `HY000` (`ER_CONFLICT_FN_PARSE_ERROR`)

  Message: Error in parsing conflict function. Message: %s

  `ER_CONFLICT_FN_PARSE_ERROR` was added in 5.1.33.

- Error: `1627` SQLSTATE: `HY000` (`ER_EXCEPTIONS_WRITE_ERROR`)

  Message: Write to exceptions table failed. Message: %s"

  `ER_EXCEPTIONS_WRITE_ERROR` was added in 5.1.33.

- Error: `1628` SQLSTATE: `HY000` (`ER_TOO_LONG_TABLE_COMMENT`)

  Message: Comment for table '%s' is too long (max = %lu)

  `ER_TOO_LONG_TABLE_COMMENT` was added in 5.1.33.

- Error: `1629` SQLSTATE: `HY000` (`ER_TOO_LONG_FIELD_COMMENT`)

  Message: Comment for field '%s' is too long (max = %lu)

  `ER_TOO_LONG_FIELD_COMMENT` was added in 5.1.33.

- Error: `1630` SQLSTATE: `42000` (`ER_FUNC_INEXISTENT_NAME_COLLISION`)

  Message: FUNCTION %s does not exist. Check the 'Function Name Parsing and Resolution' section in the Reference Manual

  `ER_FUNC_INEXISTENT_NAME_COLLISION` was added in 5.1.36.

- Error: `1631` SQLSTATE: `HY000` (`ER_DATABASE_NAME`)

  Message: Database

  `ER_DATABASE_NAME` was added in 5.1.36.

- Error: `1632` SQLSTATE: `HY000` (`ER_TABLE_NAME`)

  Message: Table

  `ER_TABLE_NAME` was added in 5.1.36.

- Error: `1633` SQLSTATE: `HY000` (`ER_PARTITION_NAME`)

  Message: Partition

  `ER_PARTITION_NAME` was added in 5.1.36.

- Error: `1634` SQLSTATE: `HY000` (`ER_SUBPARTITION_NAME`)

  Message: Subpartition

  `ER_SUBPARTITION_NAME` was added in 5.1.36.

- Error: `1635` SQLSTATE: `HY000` (`ER_TEMPORARY_NAME`)

  Message: Temporary

  `ER_TEMPORARY_NAME` was added in 5.1.36.

- Error: `1636` SQLSTATE: `HY000` (`ER_RENAMED_NAME`)

  Message: Renamed

  `ER_RENAMED_NAME` was added in 5.1.36.

- Error: `1637` SQLSTATE: `HY000` (`ER_TOO_MANY_CONCURRENT_TRXS`)

  Message: Too many active concurrent transactions

  `ER_TOO_MANY_CONCURRENT_TRXS` was added in 5.1.38.

- Error: `1638` SQLSTATE: `HY000` (`WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED`)

  Message: Non-ASCII separator arguments are not fully supported

  `WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED` was added in 5.1.38.

- Error: `1639` SQLSTATE: `HY000` (`ER_DEBUG_SYNC_TIMEOUT`)

  Message: debug sync point wait timed out

  `ER_DEBUG_SYNC_TIMEOUT` was added in 5.1.40.

- Error: `1640` SQLSTATE: `HY000` (`ER_DEBUG_SYNC_HIT_LIMIT`)

  Message: debug sync point hit limit reached

  `ER_DEBUG_SYNC_HIT_LIMIT` was added in 5.1.40.

B.4 Client Error Codes and Messages

Client error information comes from the following source files:

- The Error values and the symbols in parentheses correspond to definitions in the `include/errmsg.h` MySQL source file.

- The Message values correspond to the error messages that are listed in the `libmysql/errmsg.c` file. `%d` and `%s` represent numbers and strings, respectively, that are substituted into the messages when they are displayed.

Because updates are frequent, it is possible that those files will contain additional error information not listed here.

- Error: `2000` (`CR_UNKNOWN_ERROR`)

  Message: Unknown MySQL error

- Error: `2001` (`CR_SOCKET_CREATE_ERROR`)

  Message: Can't create UNIX socket (%d)

- Error: `2002` (`CR_CONNECTION_ERROR`)

Message: Can't connect to local MySQL server through socket '%s' (%d)

- Error: 2003 (CR_CONN_HOST_ERROR)

Message: Can't connect to MySQL server on '%s' (%d)

- Error: 2004 (CR_IPSOCK_ERROR)

Message: Can't create TCP/IP socket (%d)

- Error: 2005 (CR_UNKNOWN_HOST)

Message: Unknown MySQL server host '%s' (%d)

- Error: 2006 (CR_SERVER_GONE_ERROR)

Message: MySQL server has gone away

- Error: 2007 (CR_VERSION_ERROR)

Message: Protocol mismatch; server version = %d, client version = %d

- Error: 2008 (CR_OUT_OF_MEMORY)

Message: MySQL client ran out of memory

- Error: 2009 (CR_WRONG_HOST_INFO)

Message: Wrong host info

- Error: 2010 (CR_LOCALHOST_CONNECTION)

Message: Localhost via UNIX socket

- Error: 2011 (CR_TCP_CONNECTION)

Message: %s via TCP/IP

- Error: 2012 (CR_SERVER_HANDSHAKE_ERR)

Message: Error in server handshake

- Error: 2013 (CR_SERVER_LOST)

Message: Lost connection to MySQL server during query

- Error: 2014 (CR_COMMANDS_OUT_OF_SYNC)

Message: Commands out of sync; you can't run this command now

- Error: 2015 (CR_NAMEDPIPE_CONNECTION)

Message: Named pipe: %s

- Error: 2016 (CR_NAMEDPIPEWAIT_ERROR)

Message: Can't wait for named pipe to host: %s pipe: %s (%lu)

- Error: 2017 (CR_NAMEDPIPEOPEN_ERROR)

Message: Can't open named pipe to host: %s pipe: %s (%lu)

- Error: `2018` (`CR_NAMEDPIPESETSTATE_ERROR`)

Message: Can't set state of named pipe to host: %s pipe: %s (%lu)

- Error: `2019` (`CR_CANT_READ_CHARSET`)

Message: Can't initialize character set %s (path: %s)

- Error: `2020` (`CR_NET_PACKET_TOO_LARGE`)

Message: Got packet bigger than 'max_allowed_packet' bytes

- Error: `2021` (`CR_EMBEDDED_CONNECTION`)

Message: Embedded server

- Error: `2022` (`CR_PROBE_SLAVE_STATUS`)

Message: Error on SHOW SLAVE STATUS:

- Error: `2023` (`CR_PROBE_SLAVE_HOSTS`)

Message: Error on SHOW SLAVE HOSTS:

- Error: `2024` (`CR_PROBE_SLAVE_CONNECT`)

Message: Error connecting to slave:

- Error: `2025` (`CR_PROBE_MASTER_CONNECT`)

Message: Error connecting to master:

- Error: `2026` (`CR_SSL_CONNECTION_ERROR`)

Message: SSL connection error

- Error: `2027` (`CR_MALFORMED_PACKET`)

Message: Malformed packet

- Error: `2028` (`CR_WRONG_LICENSE`)

Message: This client library is licensed only for use with MySQL servers having '%s' license

- Error: `2029` (`CR_NULL_POINTER`)

Message: Invalid use of null pointer

- Error: `2030` (`CR_NO_PREPARE_STMT`)

Message: Statement not prepared

- Error: `2031` (`CR_PARAMS_NOT_BOUND`)

Message: No data supplied for parameters in prepared statement

- Error: `2032` (`CR_DATA_TRUNCATED`)

Message: Data truncated

- Error: 2033 (CR_NO_PARAMETERS_EXISTS)

  Message: No parameters exist in the statement

- Error: 2034 (CR_INVALID_PARAMETER_NO)

  Message: Invalid parameter number

  The column number for mysql_stmt_fetch_column() was invalid.

  The parameter number for mysql_stmt_send_long_data() was invalid.

- Error: 2035 (CR_INVALID_BUFFER_USE)

  Message: Can't send long data for non-string/non-binary data types (parameter: %d)

- Error: 2036 (CR_UNSUPPORTED_PARAM_TYPE)

  Message: Using unsupported buffer type: %d (parameter: %d)

- Error: 2037 (CR_SHARED_MEMORY_CONNECTION)

  Message: Shared memory: %s

- Error: 2038 (CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR)

  Message: Can't open shared memory; client could not create request event (%lu)

- Error: 2039 (CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR)

  Message: Can't open shared memory; no answer event received from server (%lu)

- Error: 2040 (CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR)

  Message: Can't open shared memory; server could not allocate file mapping (%lu)

- Error: 2041 (CR_SHARED_MEMORY_CONNECT_MAP_ERROR)

  Message: Can't open shared memory; server could not get pointer to file mapping (%lu)

- Error: 2042 (CR_SHARED_MEMORY_FILE_MAP_ERROR)

  Message: Can't open shared memory; client could not allocate file mapping (%lu)

- Error: 2043 (CR_SHARED_MEMORY_MAP_ERROR)

  Message: Can't open shared memory; client could not get pointer to file mapping (%lu)

- Error: 2044 (CR_SHARED_MEMORY_EVENT_ERROR)

  Message: Can't open shared memory; client could not create %s event (%lu)

- Error: 2045 (CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR)

  Message: Can't open shared memory; no answer from server (%lu)

- Error: 2046 (CR_SHARED_MEMORY_CONNECT_SET_ERROR)

Message: Can't open shared memory; cannot send request event to server (%lu)

- Error: `2047` (`CR_CONN_UNKNOW_PROTOCOL`)

  Message: Wrong or unknown protocol

- Error: `2048` (`CR_INVALID_CONN_HANDLE`)

  Message: Invalid connection handle

- Error: `2049` (`CR_SECURE_AUTH`)

  Message: Connection using old (pre-4.1.1) authentication protocol refused (client option 'secure_auth' enabled)

- Error: `2050` (`CR_FETCH_CANCELED`)

  Message: Row retrieval was canceled by mysql_stmt_close() call

- Error: `2051` (`CR_NO_DATA`)

  Message: Attempt to read column without prior row fetch

- Error: `2052` (`CR_NO_STMT_METADATA`)

  Message: Prepared statement contains no metadata

- Error: `2053` (`CR_NO_RESULT_SET`)

  Message: Attempt to read a row while there is no result set associated with the statement

- Error: `2054` (`CR_NOT_IMPLEMENTED`)

  Message: This feature is not implemented yet

- Error: `2055` (`CR_SERVER_LOST_EXTENDED`)

  Message: Lost connection to MySQL server at '%s', system error: %d

  `CR_SERVER_LOST_EXTENDED` was added in 5.1.14.

- Error: `2056` (`CR_STMT_CLOSED`)

  Message: Statement closed indirectly because of a preceeding %s() call

  `CR_STMT_CLOSED` was added in 5.1.18.

- Error: `2057` (`CR_NEW_STMT_METADATA`)

  Message: The number of columns in the result set differs from the number of bound buffers. You must reset the statement, rebind the result set columns, and execute the statement again

  `CR_NEW_STMT_METADATA` was added in 5.1.25.

B.5 Problems and Common Errors

This section lists some common problems and error messages that you may encounter. It describes how to determine the causes of the problems and what to do to solve them.

B.5.1 How to Determine What Is Causing a Problem

When you run into a problem, the first thing you should do is to find out which program or piece of equipment is causing it:

- If you have one of the following symptoms, then it is probably a hardware problems (such as memory, motherboard, CPU, or hard disk) or kernel problem:

  - The keyboard does not work. This can normally be checked by pressing the Caps Lock key. If the Caps Lock light does not change, you have to replace your keyboard. (Before doing this, you should try to restart your computer and check all cables to the keyboard.)

  - The mouse pointer does not move.

  - The machine does not answer to a remote machine's pings.

  - Other programs that are not related to MySQL do not behave correctly.

  - Your system restarted unexpectedly. (A faulty user-level program should never be able to take down your system.)

  In this case, you should start by checking all your cables and run some diagnostic tool to check your hardware! You should also check whether there are any patches, updates, or service packs for your operating system that could likely solve your problem. Check also that all your libraries (such as `glibc`) are up to date.

  It is always good to use a machine with ECC memory to discover memory problems early.

- If your keyboard is locked up, you may be able to recover by logging in to your machine from another machine and executing `kbd_mode -a`.

- Please examine your system log file (`/var/log/messages` or similar) for reasons for your problem. If you think the problem is in MySQL, you should also examine MySQL's log files. See Section 5.4, "MySQL Server Logs".

- If you do not think you have hardware problems, you should try to find out which program is causing problems. Try using `top`, `ps`, Task Manager, or some similar program, to check which program is taking all CPU or is locking the machine.

- Use `top`, `df`, or a similar program to check whether you are out of memory, disk space, file descriptors, or some other critical resource.

- If the problem is some runaway process, you can always try to kill it. If it does not want to die, there is probably a bug in the operating system.

If after you have examined all other possibilities and you have concluded that the MySQL server or a MySQL client is causing the problem, it is time to create a bug report for our mailing list or our support team. In the bug report, try to give a very detailed description of how the system is behaving and what you think is happening. You should also state why you think that MySQL is causing the problem. Take into consideration all the situations in this chapter. State any problems exactly how they appear when you examine your system. Use the "copy and paste" method for any output and error messages from programs and log files.

Try to describe in detail which program is not working and all symptoms you see. We have in the past received many bug reports that state only "the system does not work." This provides us with no information about what could be the problem.

If a program fails, it is always useful to know the following information:

- Has the program in question made a segmentation fault (did it dump core)?

- Is the program taking up all available CPU time? Check with `top`. Let the program run for a while, it may simply be evaluating something computationally intensive.

- If the `mysqld` server is causing problems, can you get any response from it with `mysqladmin -u root ping` or `mysqladmin -u root processlist`?

- What does a client program say when you try to connect to the MySQL server? (Try with `mysql`, for example.) Does the client jam? Do you get any output from the program?

When sending a bug report, you should follow the outline described in Section 1.7, "How to Report Bugs or Problems".

B.5.2 Common Errors When Using MySQL Programs

This section lists some errors that users frequently encounter when running MySQL programs. Although the problems show up when you try to run client programs, the solutions to many of the problems involves changing the configuration of the MySQL server.

B.5.2.1 Access denied

An `Access denied` error can have many causes. Often the problem is related to the MySQL accounts that the server permits client programs to use when connecting. See Section 6.2, "The MySQL Access Privilege System", and Section 6.2.7, "Troubleshooting Problems Connecting to MySQL".

B.5.2.2 Can't connect to [local] MySQL server

A MySQL client on Unix can connect to the `mysqld` server in two different ways: By using a Unix socket file to connect through a file in the file system (default `/tmp/mysql.sock`), or by using TCP/IP, which connects through a port number. A Unix socket file connection is faster than TCP/IP, but can be used only when connecting to a server on the same computer. A Unix socket file is used if you do not specify a host name or if you specify the special host name `localhost`.

If the MySQL server is running on Windows, you can connect using TCP/IP. If the server is started with the `--enable-named-pipe` option, you can also connect with named pipes if you run the client on the host where the server is running. The name of the named pipe is `MySQL` by default. If you do not give a host name when connecting to `mysqld`, a MySQL client first tries to connect to the named pipe. If that does not work, it connects to the TCP/IP port. You can force the use of named pipes on Windows by using `.` as the host name.

The error (2002) `Can't connect to ...` normally means that there is no MySQL server running on the system or that you are using an incorrect Unix socket file name or TCP/IP port number when trying to connect to the server. You should also check that the TCP/IP port you are using has not been blocked by a firewall or port blocking service.

The error (2003) `Can't connect to MySQL server on 'server' (10061)` indicates that the network connection has been refused. You should check that there is a MySQL server running, that it has network connections enabled, and that the network port you specified is the one configured on the server.

Start by checking whether there is a process named `mysqld` running on your server host. (Use `ps xa | grep mysqld` on Unix or the Task Manager on Windows.) If there is no such process, you should start the server. See Section 2.12.2, "Starting the Server".

If a `mysqld` process is running, you can check it by trying the following commands. The port number or Unix socket file name might be different in your setup. `host_ip` represents the IP address of the machine where the server is running.

```
shell> mysqladmin version
shell> mysqladmin variables
shell> mysqladmin -h `hostname` version variables
shell> mysqladmin -h `hostname` --port=3306 version
shell> mysqladmin -h host_ip version
shell> mysqladmin --protocol=SOCKET --socket=/tmp/mysql.sock version
```

Note the use of backticks rather than forward quotation marks with the `hostname` command; these cause the output of `hostname` (that is, the current host name) to be substituted into the `mysqladmin` command. If you have no `hostname` command or are running on Windows, you can manually type the host name of your machine (without backticks) following the `-h` option. You can also try `-h 127.0.0.1` to connect with TCP/IP to the local host.

Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with `--skip-networking`, it will not accept TCP/IP connections at all. If the server was started with `--bind-address=127.0.0.1`, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.

Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or the Windows XP personal firewall may need to be configured not to block the MySQL port.

Here are some reasons the `Can't connect to local MySQL server` error might occur:

- `mysqld` is not running on the local host. Check your operating system's process list to ensure the `mysqld` process is present.

- You're running a MySQL server on Windows with many TCP/IP connections to it. If you're experiencing that quite often your clients get that error, you can find a workaround here: Connection to MySQL Server Failing on Windows.

- Someone has removed the Unix socket file that `mysqld` uses (`/tmp/mysql.sock` by default). For example, you might have a `cron` job that removes old files from the `/tmp` directory. You can always run `mysqladmin version` to check whether the Unix socket file that `mysqladmin` is trying to use really exists. The fix in this case is to change the `cron` job to not remove `mysql.sock` or to place the socket file somewhere else. See Section B.5.3.6, "How to Protect or Change the MySQL Unix Socket File".

- You have started the `mysqld` server with the `--socket=/path/to/socket` option, but forgotten to tell client programs the new name of the socket file. If you change the socket path name for the server, you must also notify the MySQL clients. You can do this by providing the same `--socket` option when you run client programs. You also need to ensure that clients have permission to access the `mysql.sock` file. To find out where the socket file is, you can do:

```
shell> netstat -ln | grep mysql
```

See Section B.5.3.6, "How to Protect or Change the MySQL Unix Socket File".

- You are using Linux and one server thread has died (dumped core). In this case, you must kill the other `mysqld` threads (for example, with `kill` or with the `mysql_zap` script) before you can restart the MySQL server. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

- The server or client program might not have the proper access privileges for the directory that holds the Unix socket file or the socket file itself. In this case, you must either change the access privileges for the directory or socket file so that the server and clients can access them, or restart `mysqld` with a `--socket` option that specifies a socket file name in a directory where the server can create it and where client programs can access it.

If you get the error message `Can't connect to MySQL server on some_host`, you can try the following things to find out what the problem is:

- Check whether the server is running on that host by executing `telnet some_host 3306` and pressing the Enter key a couple of times. (3306 is the default MySQL port number. Change the value if your server is listening to a different port.) If there is a MySQL server running and listening to the port, you should get a response that includes the server's version number. If you get an error such as `telnet: Unable to connect to remote host: Connection refused`, then there is no server running on the given port.

- If the server is running on the local host, try using `mysqladmin -h localhost variables` to connect using the Unix socket file. Verify the TCP/IP port number that the server is configured to listen to (it is the value of the `port` variable.)

- If you are running under Linux and Security-Enhanced Linux (SELinux) is enabled, make sure you have disabled SELinux protection for the `mysqld` process.

Connection to MySQL Server Failing on Windows

When you're running a MySQL server on Windows with many TCP/IP connections to it, and you're experiencing that quite often your clients get a `Can't connect to MySQL server` error, the reason might be that Windows does not allow for enough ephemeral (short-lived) ports to serve those connections.

The purpose of `TIME_WAIT` is to keep a connection accepting packets even after the connection has been closed. This is because Internet routing can cause a packet to take a slow route to its destination and it may arrive after both sides have agreed to close. If the port is in use for a new connection, that packet from the old connection could break the protocol or compromise personal information from the original connection. The `TIME_WAIT` delay prevents this by ensuring that the port cannot be reused until after some time has been permitted for those delayed packets to arrive.

It is safe to reduce `TIME_WAIT` greatly on LAN connections because there is little chance of packets arriving at very long delays, as they could through the Internet with its comparatively large distances and latencies.

Windows permits ephemeral (short-lived) TCP ports to the user. After any port is closed it will remain in a `TIME_WAIT` status for 120 seconds. The port will not be available again until this time expires. The default range of port numbers depends on the version of Windows, with a more limited number of ports in older versions:

- Windows through Server 2003: Ports in range 1025–5000

- Windows Vista, Server 2008, and newer: Ports in range 49152–65535

With a small stack of available TCP ports (5000) and a high number of TCP ports being open and closed over a short period of time along with the `TIME_WAIT` status you have a good chance for running out of ports. There are two ways to address this problem:

- Reduce the number of TCP ports consumed quickly by investigating connection pooling or persistent connections where possible

- Tune some settings in the Windows registry (see below)

> **Important**
>
> The following procedure involves modifying the Windows registry. Before you modify the registry, make sure to back it up and make sure that you understand how to restore it if a problem occurs. For information about how to back up, restore, and edit the registry, view the following article in the Microsoft Knowledge Base: http://support.microsoft.com/kb/256986/EN-US/.

1. Start Registry Editor (`Regedt32.exe`).

2. Locate the following key in the registry:

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Tcpip\Parameters
```

3. On the `Edit` menu, click `Add Value`, and then add the following registry value:

```
Value Name: MaxUserPort
Data Type: REG_DWORD
Value: 65534
```

   This sets the number of ephemeral ports available to any user. The valid range is between 5000 and 65534 (decimal). The default value is 0x1388 (5000 decimal).

4. On the `Edit` menu, click `Add Value`, and then add the following registry value:

```
Value Name: TcpTimedWaitDelay
Data Type: REG_DWORD
Value: 30
```

   This sets the number of seconds to hold a TCP port connection in `TIME_WAIT` state before closing. The valid range is between 30 and 300 decimal, although you may wish to check with Microsoft for the latest permitted values. The default value is 0x78 (120 decimal).

5. Quit Registry Editor.

6. Reboot the machine.

Note: Undoing the above should be as simple as deleting the registry entries you've created.

B.5.2.3 Lost connection to MySQL server

There are three likely causes for this error message.

Usually it indicates network connectivity trouble and you should check the condition of your network if this error occurs frequently. If the error message includes "during query," this is probably the case you are experiencing.

Sometimes the "during query" form happens when millions of rows are being sent as part of one or more queries. If you know that this is happening, you should try increasing `net_read_timeout` from its default of 30 seconds to 60 seconds or longer, sufficient for the data transfer to complete.

More rarely, it can happen when the client is attempting the initial connection to the server. In this case, if your `connect_timeout` value is set to only a few seconds, you may be able to resolve the problem by increasing it to ten seconds, perhaps more if you have a very long distance or slow connection. You can determine whether you are experiencing this more uncommon cause by using `SHOW GLOBAL STATUS LIKE 'Aborted_connects'`. It will increase by one for each initial connection attempt that the server

aborts. You may see "reading authorization packet" as part of the error message; if so, that also suggests that this is the solution that you need.

If the cause is none of those just described, you may be experiencing a problem with `BLOB` values that are larger than `max_allowed_packet`, which can cause this error with some clients. Sometime you may see an `ER_NET_PACKET_TOO_LARGE` error, and that confirms that you need to increase `max_allowed_packet`.

B.5.2.4 Client does not support authentication protocol

The current implementation of the authentication protocol uses a password hashing algorithm that is incompatible with that used by older (pre-4.1) clients. Attempts to connect to a 4.1 or newer server with an older client may fail with the following message:

```
shell> mysql
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

To deal with this problem, the preferred solution is to upgrade all client programs to use a 4.1.1 or newer client library. If that is not possible, use one of the following approaches:

- To connect to the server with a pre-4.1 client program, use an account that still has a pre-4.1-style password.

- Reset the password to pre-4.1 style for each user that needs to use a pre-4.1 client program. This can be done using the `SET PASSWORD` statement and the `OLD_PASSWORD()` function:

```
mysql> SET PASSWORD FOR
    -> 'some_user'@'some_host' = OLD_PASSWORD('new_password');
```

Substitute the password you want to use for "`new_password`" in the preceding example. MySQL cannot tell you what the original password was, so you'll need to pick a new one.

- Tell the server to use the older password hashing algorithm by default:

1. Start `mysqld` with the `old_passwords` system variable set to 1.

2. Assign an old-format password to each account that has had its password updated to the longer 4.1 format. You can identify these accounts with the following query:

```
mysql> SELECT Host, User, Password FROM mysql.user
    -> WHERE LENGTH(Password) > 16;
```

For each account record displayed by the query, use the `Host` and `User` values and assign a password using one of the methods described previously.

The `Client does not support authentication protocol` error also can occur if multiple versions of MySQL are installed but client programs are dynamically linked and link to an older library. Make sure that clients use the most recent library version with which they are compatible. The procedure to do this will depend on your system.

> **Note**
>
> The PHP `mysql` extension does not support the authentication protocol in MySQL 4.1.1 and higher. This is true regardless of the PHP version being used. If you wish to use the `mysql` extension with MySQL 4.1 or newer, you may need to follow one

> of the options discussed above for configuring MySQL to work with old clients. The `mysqli` extension (stands for "MySQL, Improved"; added in PHP 5) is compatible with the improved password hashing employed in MySQL 4.1 and higher, and no special configuration of MySQL need be done to use this MySQL client library. For more information about the `mysqli` extension, see http://php.net/mysqli.

For additional background on password hashing and authentication, see Section 6.1.2.4, "Password Hashing in MySQL".

B.5.2.5 Password Fails When Entered Interactively

MySQL client programs prompt for a password when invoked with a `--password` or `-p` option that has no following password value:

```
shell> mysql -u user_name -p
Enter password:
```

On some systems, you may find that your password works when specified in an option file or on the command line, but not when you enter it interactively at the `Enter password:` prompt. This occurs when the library provided by the system to read passwords limits password values to a small number of characters (typically eight). That is a problem with the system library, not with MySQL. To work around it, change your MySQL password to a value that is eight or fewer characters long, or put your password in an option file.

B.5.2.6 Host 'host_name' is blocked

If the following error occurs, it means that `mysqld` has received many connection requests from the given host that were interrupted in the middle:

```
Host 'host_name' is blocked because of many connection errors.
Unblock with 'mysqladmin flush-hosts'
```

The value of the `max_connect_errors` system variable determines how many successive interrupted connection requests are permitted. (See Section 5.1.4, "Server System Variables".) After `max_connect_errors` failed requests without a successful connection, `mysqld` assumes that something is wrong (for example, that someone is trying to break in), and blocks the host from further connections until you issue a `FLUSH HOSTS` statement or execute a `mysqladmin flush-hosts` command.

By default, `mysqld` blocks a host after 10 connection errors. You can adjust the value by setting `max_connect_errors` at server startup:

```
shell> mysqld_safe --max_connect_errors=10000 &
```

The value can also be set at runtime:

```
mysql> SET GLOBAL max_connect_errors=10000;
```

If you get the `Host 'host_name' is blocked` error message for a given host, you should first verify that there is nothing wrong with TCP/IP connections from that host. If you are having network problems, it does you no good to increase the value of the `max_connect_errors` variable.

B.5.2.7 Too many connections

If you get a `Too many connections` error when you try to connect to the `mysqld` server, this means that all available connections are in use by other clients.

The number of connections permitted is controlled by the `max_connections` system variable. Beginning with MySQL 5.1.15, its default value is 151 to improve performance when MySQL is used with the Apache Web server. (Previously, the default was 100.) If you need to support more connections, you should set a larger value for this variable.

`mysqld` actually permits `max_connections+1` clients to connect. The extra connection is reserved for use by accounts that have the `SUPER` privilege. By granting the `SUPER` privilege to administrators and not to normal users (who should not need it), an administrator can connect to the server and use `SHOW PROCESSLIST` to diagnose problems even if the maximum number of unprivileged clients are connected. See Section 13.7.5.31, "SHOW PROCESSLIST Syntax".

The maximum number of connections MySQL supports depends on the quality of the thread library on a given platform, the amount of RAM available, how much RAM is used for each connection, the workload from each connection, and the desired response time. Linux or Solaris should be able to support at 500 to 1000 simultaneous connections routinely and as many as 10,000 connections if you have many gigabytes of RAM available and the workload from each is low or the response time target undemanding. Windows is limited to (open tables × 2 + open connections) < 2048 due to the Posix compatibility layer used on that platform.

Increasing `open-files-limit` may be necessary. Also see Section 2.5, "Installing MySQL on Linux", for how to raise the operating system limit on how many handles can be used by MySQL.

B.5.2.8 Out of memory

If you issue a query using the `mysql` client program and receive an error like the following one, it means that `mysql` does not have enough memory to store the entire query result:

```
mysql: Out of memory at line 42, 'malloc.c'
mysql: needed 8136 byte (8k), memory in use: 12481367 bytes (12189k)
ERROR 2008: MySQL client ran out of memory
```

To remedy the problem, first check whether your query is correct. Is it reasonable that it should return so many rows? If not, correct the query and try again. Otherwise, you can invoke `mysql` with the `--quick` option. This causes it to use the `mysql_use_result()` C API function to retrieve the result set, which places less of a load on the client (but more on the server).

B.5.2.9 MySQL server has gone away

This section also covers the related `Lost connection to server during query` error.

The most common reason for the `MySQL server has gone away` error is that the server timed out and closed the connection. In this case, you normally get one of the following error codes (which one you get is operating system-dependent).

Error Code	Description
`CR_SERVER_GONE_ERROR`	The client couldn't send a question to the server.
`CR_SERVER_LOST`	The client didn't get an error when writing to the server, but it didn't get a full answer (or any answer) to the question.

By default, the server closes the connection after eight hours if nothing has happened. You can change the time limit by setting the `wait_timeout` variable when you start `mysqld`. See Section 5.1.4, "Server System Variables".

If you have a script, you just have to issue the query again for the client to do an automatic reconnection. This assumes that you have automatic reconnection in the client enabled (which is the default for the `mysql` command-line client).

Some other common reasons for the `MySQL server has gone away` error are:

- You (or the db administrator) has killed the running thread with a `KILL` statement or a `mysqladmin kill` command.

- You tried to run a query after closing the connection to the server. This indicates a logic error in the application that should be corrected.

- A client application running on a different host does not have the necessary privileges to connect to the MySQL server from that host.

- You got a timeout from the TCP/IP connection on the client side. This may happen if you have been using the commands: `mysql_options(..., MYSQL_OPT_READ_TIMEOUT,...)` or `mysql_options(..., MYSQL_OPT_WRITE_TIMEOUT,...)`. In this case increasing the timeout may help solve the problem.

- You have encountered a timeout on the server side and the automatic reconnection in the client is disabled (the `reconnect` flag in the `MYSQL` structure is equal to 0).

- You are using a Windows client and the server had dropped the connection (probably because `wait_timeout` expired) before the command was issued.

  The problem on Windows is that in some cases MySQL does not get an error from the OS when writing to the TCP/IP connection to the server, but instead gets the error when trying to read the answer from the connection.

  Prior to MySQL 5.1.8, even if the `reconnect` flag in the `MYSQL` structure is equal to 1, MySQL does not automatically reconnect and re-issue the query as it doesn't know if the server did get the original query or not.

  The solution to this is to either do a `mysql_ping()` on the connection if there has been a long time since the last query (this is what Connector/ODBC does) or set `wait_timeout` on the `mysqld` server so high that it in practice never times out.

- You can also get these errors if you send a query to the server that is incorrect or too large. If `mysqld` receives a packet that is too large or out of order, it assumes that something has gone wrong with the client and closes the connection. If you need big queries (for example, if you are working with big `BLOB` columns), you can increase the query limit by setting the server's `max_allowed_packet` variable, which has a default value of 1MB. You may also need to increase the maximum packet size on the client end. More information on setting the packet size is given in Section B.5.2.10, "Packet Too Large".

  An `INSERT` or `REPLACE` statement that inserts a great many rows can also cause these sorts of errors. Either one of these statements sends a single request to the server irrespective of the number of rows to be inserted; thus, you can often avoid the error by reducing the number of rows sent per `INSERT` or `REPLACE`.

- You also get a lost connection if you are sending a packet 16MB or larger if your client is older than 4.0.8 and your server is 4.0.8 and above, or the other way around.

- It is also possible to see this error if host name lookups fail (for example, if the DNS server on which your server or network relies goes down). This is because MySQL is dependent on the host system for name resolution, but has no way of knowing whether it is working—from MySQL's point of view the problem is indistinguishable from any other network timeout.

You may also see the `MySQL server has gone away` error if MySQL is started with the `--skip-networking` option.

Another networking issue that can cause this error occurs if the MySQL port (default 3306) is blocked by your firewall, thus preventing any connections at all to the MySQL server.

- You can also encounter this error with applications that fork child processes, all of which try to use the same connection to the MySQL server. This can be avoided by using a separate connection for each child process.

- You have encountered a bug where the server died while executing the query.

You can check whether the MySQL server died and restarted by executing `mysqladmin version` and examining the server's uptime. If the client connection was broken because `mysqld` crashed and restarted, you should concentrate on finding the reason for the crash. Start by checking whether issuing the query again kills the server again. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

You can get more information about the lost connections by starting `mysqld` with the `--log-warnings=2` option. This logs some of the disconnected errors in the `hostname.err` file. See Section 5.4.2, "The Error Log".

If you want to create a bug report regarding this problem, be sure that you include the following information:

- Indicate whether the MySQL server died. You can find information about this in the server error log. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing".

- If a specific query kills `mysqld` and the tables involved were checked with `CHECK TABLE` before you ran the query, can you provide a reproducible test case? See Section 22.4, "Debugging and Porting MySQL".

- What is the value of the `wait_timeout` system variable in the MySQL server? (`mysqladmin variables` gives you the value of this variable.)

- Have you tried to run `mysqld` with the general query log enabled to determine whether the problem query appears in the log? (See Section 5.4.3, "The General Query Log".)

See also Section B.5.2.11, "Communication Errors and Aborted Connections", and Section 1.7, "How to Report Bugs or Problems".

B.5.2.10 Packet Too Large

A communication packet is a single SQL statement sent to the MySQL server, a single row that is sent to the client, or a binary log event sent from a master replication server to a slave.

The largest possible packet that can be transmitted to or from a MySQL 5.1 server or client is 1GB.

When a MySQL client or the `mysqld` server receives a packet bigger than `max_allowed_packet` bytes, it issues an `ER_NET_PACKET_TOO_LARGE` error and closes the connection. With some clients, you may also get a `Lost connection to MySQL server during query` error if the communication packet is too large.

Both the client and the server have their own `max_allowed_packet` variable, so if you want to handle big packets, you must increase this variable both in the client and in the server.

If you are using the `mysql` client program, its default `max_allowed_packet` variable is 16MB. To set a larger value, start `mysql` like this:

```
shell> mysql --max_allowed_packet=32M
```

That sets the packet size to 32MB.

The server's default `max_allowed_packet` value is 1MB. You can increase this if the server needs to handle big queries (for example, if you are working with big `BLOB` columns). For example, to set the variable to 16MB, start the server like this:

```
shell> mysqld --max_allowed_packet=16M
```

You can also use an option file to set `max_allowed_packet`. For example, to set the size for the server to 16MB, add the following lines in an option file:

```
[mysqld]
max_allowed_packet=16M
```

It is safe to increase the value of this variable because the extra memory is allocated only when needed. For example, `mysqld` allocates more memory only when you issue a long query or when `mysqld` must return a large result row. The small default value of the variable is a precaution to catch incorrect packets between the client and server and also to ensure that you do not run out of memory by using large packets accidentally.

You can also get strange problems with large packets if you are using large `BLOB` values but have not given `mysqld` access to enough memory to handle the query. If you suspect this is the case, try adding `ulimit -d 256000` to the beginning of the `mysqld_safe` script and restarting `mysqld`.

B.5.2.11 Communication Errors and Aborted Connections

If connection problems occur such as communication errors or aborted connections, use these sources of information to diagnose problems:

- The error log. See Section 5.4.2, "The Error Log".

- The general query log. See Section 5.4.3, "The General Query Log".

- The `Aborted_xxx` status variables. See Section 5.1.6, "Server Status Variables".

If you start the server with the `--log-warnings` option, you might find messages like this in your error log:

```
Aborted connection 854 to db: 'employees' user: 'josh'
```

If a client is unable even to connect, the server increments the `Aborted_connects` status variable. Unsuccessful connection attempts can occur for the following reasons:

- A client attempts to access a database but has no privileges for it.

- A client uses an incorrect password.

- A connection packet does not contain the right information.

- It takes more than `connect_timeout` seconds to obtain a connect packet. See Section 5.1.4, "Server System Variables".

If these kinds of things happen, it might indicate that someone is trying to break into your server! If the general query log is enabled, messages for these types of problems are logged to it.

If a client successfully connects but later disconnects improperly or is terminated, the server increments the `Aborted_clients` status variable, and logs an `Aborted connection` message to the error log. The cause can be any of the following:

- The client program did not call `mysql_close()` before exiting.

- The client had been sleeping more than `wait_timeout` or `interactive_timeout` seconds without issuing any requests to the server. See Section 5.1.4, "Server System Variables".

- The client program ended abruptly in the middle of a data transfer.

Other reasons for problems with aborted connections or aborted clients:

- The `max_allowed_packet` variable value is too small or queries require more memory than you have allocated for `mysqld`. See Section B.5.2.10, "Packet Too Large".

- Use of Ethernet protocol with Linux, both half and full duplex. Some Linux Ethernet drivers have this bug. You should test for this bug by transferring a huge file using FTP between the client and server machines. If a transfer goes in burst-pause-burst-pause mode, you are experiencing a Linux duplex syndrome. Switch the duplex mode for both your network card and hub/switch to either full duplex or to half duplex and test the results to determine the best setting.

- A problem with the thread library that causes interrupts on reads.

- Badly configured TCP/IP.

- Faulty Ethernets, hubs, switches, cables, and so forth. This can be diagnosed properly only by replacing hardware.

See also Section B.5.2.9, "MySQL server has gone away".

B.5.2.12 The table is full

If a table-full error occurs, it may be that the disk is full or that the table has reached its maximum size. The effective maximum table size for MySQL databases is usually determined by operating system constraints on file sizes, not by MySQL internal limits. See Section C.7.3, "Limits on Table Size".

This error can occur sometimes for MySQL Cluster tables even when there appears to be more than sufficient data memory available. See the documentation for the `DataMemory` MySQL Cluster data node configuration parameter, as well as Section 17.1.2, "MySQL Cluster Nodes, Node Groups, Replicas, and Partitions", for more information.

B.5.2.13 Can't create/write to file

If you get an error of the following type for some queries, it means that MySQL cannot create a temporary file for the result set in the temporary directory:

```
Can't create/write to file '\\sqla3fe_0.ism'.
```

The preceding error is a typical message for Windows; the Unix message is similar.

One fix is to start `mysqld` with the `--tmpdir` option or to add the option to the `[mysqld]` section of your option file. For example, to specify a directory of `C:\temp`, use these lines:

```
[mysqld]
tmpdir=C:/temp
```

The `C:\temp` directory must exist and have sufficient space for the MySQL server to write to. See Section 4.2.6, "Using Option Files".

Another cause of this error can be permissions issues. Make sure that the MySQL server can write to the `tmpdir` directory.

Check also the error code that you get with `perror`. One reason the server cannot write to a table is that the file system is full:

```
shell> perror 28
OS error code  28:  No space left on device
```

If you get an error of the following type during startup, it indicates that the file system or directory used for storing data files is write protected. Provided that the write error is to a test file, the error is not serious and can be safely ignored.

```
Can't create test file /usr/local/mysql/data/master.lower-test
```

B.5.2.14 Commands out of sync

If you get `Commands out of sync; you can't run this command now` in your client code, you are calling client functions in the wrong order.

This can happen, for example, if you are using `mysql_use_result()` and try to execute a new query before you have called `mysql_free_result()`. It can also happen if you try to execute two queries that return data without calling `mysql_use_result()` or `mysql_store_result()` in between.

B.5.2.15 Ignoring user

If you get the following error, it means that when `mysqld` was started or when it reloaded the grant tables, it found an account in the `user` table that had an invalid password.

```
Found wrong password for user 'some_user'@'some_host'; ignoring user
```

As a result, the account is simply ignored by the permission system.

The following list indicates possible causes of and fixes for this problem:

- You may be running a new version of `mysqld` with an old `user` table. Check whether the `Password` column of that table is shorter than 16 characters. If so, correct this condition by running `mysql_upgrade`.

- The account has an old password (eight characters long). Update the account in the `user` table to have a new password.

- You have specified a password in the `user` table without using the `PASSWORD()` function. Use `mysql` to update the account in the `user` table with a new password, making sure to use the `PASSWORD()` function:

```
mysql> UPDATE user SET Password=PASSWORD('new_password')
    -> WHERE User='some_user' AND Host='some_host';
```

B.5.2.16 Table 'tbl_name' doesn't exist

If you get either of the following errors, it usually means that no table exists in the default database with the given name:

```
Table 'tbl_name' doesn't exist
Can't find file: 'tbl_name' (errno: 2)
```

In some cases, it may be that the table does exist but that you are referring to it incorrectly:

- Because MySQL uses directories and files to store databases and tables, database and table names are case sensitive if they are located on a file system that has case-sensitive file names.

- Even for file systems that are not case sensitive, such as on Windows, all references to a given table within a query must use the same lettercase.

You can check which tables are in the default database with SHOW TABLES. See Section 13.7.5, "SHOW Syntax".

B.5.2.17 Can't initialize character set

You might see an error like this if you have character set problems:

```
MySQL Connection Failed: Can't initialize character set charset_name
```

This error can have any of the following causes:

- The character set is a multibyte character set and you have no support for the character set in the client. In this case, you need to recompile the client by running configure with the --with-charset=charset_name or --with-extra-charsets=charset_name option. See Section 2.11.4, "MySQL Source-Configuration Options".

  All standard MySQL binaries are compiled with --with-extra-charsets=complex or (for Windows) --with-extra-charsets=complex, which enables support for all multibyte character sets. See Section 2.11.4, "MySQL Source-Configuration Options".

- The character set is a simple character set that is not compiled into mysqld, and the character set definition files are not in the place where the client expects to find them.

  In this case, you need to use one of the following methods to solve the problem:

  - Recompile the client with support for the character set. See Section 2.11.4, "MySQL Source-Configuration Options".

  - Specify to the client the directory where the character set definition files are located. For many clients, you can do this with the --character-sets-dir option.

  - Copy the character definition files to the path where the client expects them to be.

B.5.2.18 File Not Found and Similar Errors

If you get ERROR 'file_name' not found (errno: 23), Can't open file: file_name (errno: 24), or any other error with errno 23 or errno 24 from MySQL, it means that you have not allocated enough file descriptors for the MySQL server. You can use the perror utility to get a description of what the error number means:

```
shell> perror 23
OS error code  23:  File table overflow
shell> perror 24
OS error code  24:  Too many open files
shell> perror 11
```

```
OS error code  11:  Resource temporarily unavailable
```

The problem here is that `mysqld` is trying to keep open too many files simultaneously. You can either tell `mysqld` not to open so many files at once or increase the number of file descriptors available to `mysqld`.

To tell `mysqld` to keep open fewer files at a time, you can make the table cache smaller by reducing the value of the `table_open_cache` system variable (the default value is 64). This may not entirely prevent running out of file descriptors because in some circumstances the server may attempt to extend the cache size temporarily, as described in Section 8.4.3.1, "How MySQL Opens and Closes Tables". Reducing the value of `max_connections` also reduces the number of open files (the default value is 100).

To change the number of file descriptors available to `mysqld`, you can use the `--open-files-limit` option to `mysqld_safe` or set the `open_files_limit` system variable. See Section 5.1.4, "Server System Variables". The easiest way to set these values is to add an option to your option file. See Section 4.2.6, "Using Option Files". If you have an old version of `mysqld` that does not support setting the open files limit, you can edit the `mysqld_safe` script. There is a commented-out line `ulimit -n 256` in the script. You can remove the "#" character to uncomment this line, and change the number `256` to set the number of file descriptors to be made available to `mysqld`.

`--open-files-limit` and `ulimit` can increase the number of file descriptors, but only up to the limit imposed by the operating system. There is also a "hard" limit that can be overridden only if you start `mysqld_safe` or `mysqld` as `root` (just remember that you also need to start the server with the `--user` option in this case so that it does not continue to run as `root` after it starts up). If you need to increase the operating system limit on the number of file descriptors available to each process, consult the documentation for your system.

Note

If you run the `tcsh` shell, `ulimit` does not work! `tcsh` also reports incorrect values when you ask for the current limits. In this case, you should start `mysqld_safe` using `sh`.

B.5.2.19 Table-Corruption Issues

If you have started `mysqld` with `--myisam-recover`, MySQL automatically checks and tries to repair `MyISAM` tables if they are marked as 'not closed properly' or 'crashed'. If this happens, MySQL writes an entry in the `hostname.err` file `'Warning: Checking table ...'` which is followed by `Warning: Repairing table` if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further.

See also Section 5.1.3, "Server Command Options", and Section 22.4.1.7, "Making a Test Case If You Experience Table Corruption".

B.5.3 Administration-Related Issues

B.5.3.1 Problems with File Permissions

If you have problems with file permissions, the `UMASK` or `UMASK_DIR` environment variable might be set incorrectly when `mysqld` starts. For example, MySQL might issue the following error message when you create a table:

```
ERROR: Can't find file: 'path/with/filename.frm' (Errcode: 13)
```

The default `UMASK` and `UMASK_DIR` values are `0660` and `0700`, respectively. MySQL assumes that the value for `UMASK` or `UMASK_DIR` is in octal if it starts with a zero. For example, setting `UMASK=0600` is equivalent to `UMASK=384` because 0600 octal is 384 decimal.

To change the default `UMASK` value, start `mysqld_safe` as follows:

```
shell> UMASK=384  # = 600 in octal
shell> export UMASK
shell> mysqld_safe &
```

By default, MySQL creates database directories with an access permission value of `0700`. To modify this behavior, set the `UMASK_DIR` variable. If you set its value, new directories are created with the combined `UMASK` and `UMASK_DIR` values. For example, to give group access to all new directories, start `mysqld_safe` as follows:

```
shell> UMASK_DIR=504  # = 770 in octal
shell> export UMASK_DIR
shell> mysqld_safe &
```

For additional details, see Section 2.14, "Environment Variables".

B.5.3.2 How to Reset the Root Password

If you have never assigned a `root` password for MySQL, the server does not require a password at all for connecting as `root`. However, this is insecure. For instructions on assigning passwords, see Section 2.12.4, "Securing the Initial MySQL Accounts".

If you know the `root` password and want to change it, see Section 13.7.1.6, "SET PASSWORD Syntax".

If you assigned a `root` password previously but have forgotten it, you can assign a new password. The following sections provide instructions for Windows and Unix and Unix-like systems, as well as generic instructions that apply to any system.

Resetting the Root Password: Windows Systems

On Windows, use the following procedure to reset the password for the MySQL `'root'@'localhost'` account. To change the password for a `root` account with a different host name part, modify the instructions to use that host name.

1. Log on to your system as Administrator.

2. Stop the MySQL server if it is running. For a server that is running as a Windows service, go to the Services manager: From the **Start** menu, select **Control Panel**, then **Administrative Tools**, then **Services**. Find the MySQL service in the list and stop it.

   If your server is not running as a service, you may need to use the Task Manager to force it to stop.

3. Create a text file containing the following statement on a single line. Replace the password with the password that you want to use.

```
SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
```

4. Save the file. This example assumes that you name the file `C:\mysql-init.txt`.

5. Open a console window to get to the command prompt: From the **Start** menu, select **Run**, then enter `cmd` as the command to be run.

6. Start the MySQL server with the special `--init-file` option (notice that the backslash in the option value is doubled):

```
C:\> cd "C:\Program Files\MySQL\MySQL Server 5.1\bin"
C:\> mysqld --init-file=C:\\mysql-init.txt
```

If you installed MySQL to a different location, adjust the `cd` command accordingly.

The server executes the contents of the file named by the `--init-file` option at startup, changing the `'root'@'localhost'` account password.

To have server output to appear in the console window rather than in a log file, add the `--console` option to the `mysqld` command.

If you installed MySQL using the MySQL Installation Wizard, you may need to specify a `--defaults-file` option. For example:

```
C:\> mysqld
         --defaults-file="C:\\Program Files\\MySQL\\MySQL Server 5.1\\my.ini"
         --init-file=C:\\mysql-init.txt
```

The appropriate `--defaults-file` setting can be found using the Services Manager: From the **Start** menu, select **Control Panel**, then **Administrative Tools**, then **Services**. Find the MySQL service in the list, right-click it, and choose the `Properties` option. The `Path to executable` field contains the `--defaults-file` setting.

7. After the server has started successfully, delete `C:\mysql-init.txt`.

You should now be able to connect to the MySQL server as `root` using the new password. Stop the MySQL server and restart it normally. If you run the server as a service, start it from the Windows Services window. If you start the server manually, use whatever command you normally use.

Resetting the Root Password: Unix and Unix-Like Systems

On Unix, use the following procedure to reset the password for the MySQL `'root'@'localhost'` account. To change the password for a `root` account with a different host name part, modify the instructions to use that host name.

The instructions assume that you will start the MySQL server from the Unix login account that you normally use for running it. For example, if you run the server using the `mysql` login account, you should log in as `mysql` before using the instructions. Alternatively, you can log in as `root`, but in this case you *must* start `mysqld` with the `--user=mysql` option. If you start the server as `root` without using `--user=mysql`, the server may create `root`-owned files in the data directory, such as log files, and these may cause permission-related problems for future server startups. If that happens, you will need to either change the ownership of the files to `mysql` or remove them.

1. Log on to your system as the Unix user that the MySQL server runs as (for example, `mysql`).

2. Stop the MySQL server if it is running. Locate the `.pid` file that contains the server's process ID. The exact location and name of this file depend on your distribution, host name, and configuration. Common locations are `/var/lib/mysql/`, `/var/run/mysqld/`, and `/usr/local/mysql/data/`. Generally, the file name has an extension of `.pid` and begins with either `mysqld` or your system's host name.

   Stop the MySQL server by sending a normal `kill` (not `kill -9`) to the `mysqld` process. Use the actual path name of the `.pid` file in the following command:

```
shell> kill `cat /mysql-data-directory/host_name.pid`
```

Use backticks (not forward quotation marks) with the `cat` command. These cause the output of `cat` to be substituted into the `kill` command.

3. Create a text file containing the following statement on a single line. Replace the password with the password that you want to use.

```
SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
```

4. Save the file. This example assumes that you name the file `/home/me/mysql-init`. The file contains the password, so do not save it where it can be read by other users. If you are not logged in as `mysql` (the user the server runs as), make sure that the file has permissions that permit `mysql` to read it.

5. Start the MySQL server with the special `--init-file` option:

```
shell> mysqld_safe --init-file=/home/me/mysql-init &
```

The server executes the contents of the file named by the `--init-file` option at startup, changing the `'root'@'localhost'` account password.

6. After the server has started successfully, delete `/home/me/mysql-init`.

You should now be able to connect to the MySQL server as `root` using the new password. Stop the server and restart it normally.

Resetting the Root Password: Generic Instructions

The preceding sections provide password-resetting instructions specifically for Windows and Unix and Unix-like systems. Alternatively, on any platform, you can reset the password using the `mysql` client (but this approach is less secure):

1. Stop the MySQL server if necessary, then restart it with the `--skip-grant-tables` option. This enables anyone to connect without a password and with all privileges, and disables account-management statements such as `SET PASSWORD`. Because this is insecure, you might want to use `--skip-grant-tables` in conjunction with `--skip-networking` to prevent remote clients from connecting.

2. Connect to the MySQL server using the `mysql` client; no password is necessary because the server was started with `--skip-grant-tables`:

```
shell> mysql
```

3. In the `mysql` client, tell the server to reload the grant tables so that account-management statements work:

```
mysql> FLUSH PRIVILEGES;
```

Then change the `'root'@'localhost'` account password. Replace the password with the password that you want to use. To change the password for a `root` account with a different host name part, modify the instructions to use that host name.

```
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
```

You should now be able to connect to the MySQL server as `root` using the new password. Stop the server and restart it normally (without the `--skip-grant-tables` and `--skip-networking` options).

B.5.3.3 What to Do If MySQL Keeps Crashing

Each MySQL version is tested on many platforms before it is released. This does not mean that there are no bugs in MySQL, but if there are bugs, they should be very few and can be hard to find. If you have a problem, it always helps if you try to find out exactly what crashes your system, because you have a much better chance of getting the problem fixed quickly.

First, you should try to find out whether the problem is that the `mysqld` server dies or whether your problem has to do with your client. You can check how long your `mysqld` server has been up by executing `mysqladmin version`. If `mysqld` has died and restarted, you may find the reason by looking in the server's error log. See Section 5.4.2, "The Error Log".

On some systems, you can find in the error log a stack trace of where `mysqld` died that you can resolve with the `resolve_stack_dump` program. See Section 22.4, "Debugging and Porting MySQL". Note that the variable values written in the error log may not always be 100% correct.

Many server crashes are caused by corrupted data files or index files. MySQL updates the files on disk with the `write()` system call after every SQL statement and before the client is notified about the result. (This is not true if you are running with `--delay-key-write`, in which case data files are written but not index files.) This means that data file contents are safe even if `mysqld` crashes, because the operating system ensures that the unflushed data is written to disk. You can force MySQL to flush everything to disk after every SQL statement by starting `mysqld` with the `--flush` option.

The preceding means that normally you should not get corrupted tables unless one of the following happens:

* The MySQL server or the server host was killed in the middle of an update.

* You have found a bug in `mysqld` that caused it to die in the middle of an update.

* Some external program is manipulating data files or index files at the same time as `mysqld` without locking the table properly.

* You are running many `mysqld` servers using the same data directory on a system that does not support good file system locks (normally handled by the `lockd` lock manager), or you are running multiple servers with external locking disabled.

* You have a crashed data file or index file that contains very corrupt data that confused `mysqld`.

* You have found a bug in the data storage code. This isn't likely, but it is at least possible. In this case, you can try to change the storage engine to another engine by using `ALTER TABLE` on a repaired copy of the table.

Because it is very difficult to know why something is crashing, first try to check whether things that work for others crash for you. Please try the following things:

* Stop the `mysqld` server with `mysqladmin shutdown`, run `myisamchk --silent --force */ *.MYI` from the data directory to check all `MyISAM` tables, and restart `mysqld`. This ensures that you are running from a clean state. See Chapter 5, *MySQL Server Administration*.

* Start `mysqld` with the general query log enabled (see Section 5.4.3, "The General Query Log"). Then try to determine from the information written to the log whether some specific query kills the server. About 95% of all bugs are related to a particular query. Normally, this is one of the last queries in the log file just before the server restarts. See Section 5.4.3, "The General Query Log". If you can repeatedly kill MySQL with a specific query, even when you have checked all tables just before issuing it, then you have been able to locate the bug and should submit a bug report for it. See Section 1.7, "How to Report Bugs or Problems".

- Try to make a test case that we can use to repeat the problem. See Section 22.4, "Debugging and Porting MySQL".

- Try running the tests in the `mysql-test` directory and the MySQL benchmarks. See Section 22.1.2, "The MySQL Test Suite". They should test MySQL rather well. You can also add code to the benchmarks that simulates your application. The benchmarks can be found in the `sql-bench` directory in a source distribution or, for a binary distribution, in the `sql-bench` directory under your MySQL installation directory.

- Try the `fork_big.pl` script. (It is located in the `tests` directory of source distributions.)

- If you configure MySQL for debugging, it is much easier to gather information about possible errors if something goes wrong. Configuring MySQL for debugging causes a safe memory allocator to be included that can find some errors. It also provides a lot of output about what is happening. Reconfigure MySQL with the `--with-debug` or `--with-debug=full` option to `configure` and then recompile. See Section 22.4, "Debugging and Porting MySQL".

- Make sure that you have applied the latest patches for your operating system.

- Use the `--skip-external-locking` option to `mysqld`. On some systems, the `lockd` lock manager does not work properly; the `--skip-external-locking` option tells `mysqld` not to use external locking. (This means that you cannot run two `mysqld` servers on the same data directory and that you must be careful if you use `myisamchk`. Nevertheless, it may be instructive to try the option as a test.)

- Have you tried `mysqladmin -u root processlist` when `mysqld` appears to be running but not responding? Sometimes `mysqld` is not comatose even though you might think so. The problem may be that all connections are in use, or there may be some internal lock problem. `mysqladmin -u root processlist` usually is able to make a connection even in these cases, and can provide useful information about the current number of connections and their status.

- Run the command `mysqladmin -i 5 status` or `mysqladmin -i 5 -r status` in a separate window to produce statistics while you run your other queries.

- Try the following:

  1. Start `mysqld` from `gdb` (or another debugger). See Section 22.4, "Debugging and Porting MySQL".

  2. Run your test scripts.

  3. Print the backtrace and the local variables at the three lowest levels. In `gdb`, you can do this with the following commands when `mysqld` has crashed inside `gdb`:

     ```
     backtrace
     info local
     up
     info local
     up
     info local
     ```

     With `gdb`, you can also examine which threads exist with `info threads` and switch to a specific thread with `thread N`, where `N` is the thread ID.

- Try to simulate your application with a Perl script to force MySQL to crash or misbehave.

- Send a normal bug report. See Section 1.7, "How to Report Bugs or Problems". Be even more detailed than usual. Because MySQL works for many people, it may be that the crash results from something that exists only on your computer (for example, an error that is related to your particular system libraries).

- If you have a problem with tables containing dynamic-length rows and you are using only `VARCHAR` columns (not `BLOB` or `TEXT` columns), you can try to change all `VARCHAR` to `CHAR` with `ALTER TABLE`. This forces MySQL to use fixed-size rows. Fixed-size rows take a little extra space, but are much more tolerant to corruption.

  The current dynamic row code has been in use for several years with very few problems, but dynamic-length rows are by nature more prone to errors, so it may be a good idea to try this strategy to see whether it helps.

- Do not rule out your server hardware when diagnosing problems. Defective hardware can be the cause of data corruption. Particular attention should be paid to your memory and disk subsystems when troubleshooting hardware.

B.5.3.4 How MySQL Handles a Full Disk

This section describes how MySQL responds to disk-full errors (such as "no space left on device"), and to quota-exceeded errors (such as "write failed" or "user block limit reached").

This section is relevant for writes to `MyISAM` tables. It also applies for writes to binary log files and binary log index file, except that references to "row" and "record" should be understood to mean "event."

When a disk-full condition occurs, MySQL does the following:

- It checks once every minute to see whether there is enough space to write the current row. If there is enough space, it continues as if nothing had happened.

- Every 10 minutes it writes an entry to the log file, warning about the disk-full condition.

To alleviate the problem, you can take the following actions:

- To continue, you only have to free enough disk space to insert all records.

- To abort the thread, you must use `mysqladmin kill`. The thread is aborted the next time it checks the disk (in one minute).

- Other threads might be waiting for the table that caused the disk-full condition. If you have several "locked" threads, killing the one thread that is waiting on the disk-full condition enables the other threads to continue.

Exceptions to the preceding behavior are when you use `REPAIR TABLE` or `OPTIMIZE TABLE` or when the indexes are created in a batch after `LOAD DATA INFILE` or after an `ALTER TABLE` statement. All of these statements may create large temporary files that, if left to themselves, would cause big problems for the rest of the system. If the disk becomes full while MySQL is doing any of these operations, it removes the big temporary files and mark the table as crashed. The exception is that for `ALTER TABLE`, the old table is left unchanged.

B.5.3.5 Where MySQL Stores Temporary Files

On Unix, MySQL uses the value of the `TMPDIR` environment variable as the path name of the directory in which to store temporary files. If `TMPDIR` is not set, MySQL uses the system default, which is usually `/tmp`, `/var/tmp`, or `/usr/tmp`.

On Windows, Netware and OS2, MySQL checks in order the values of the `TMPDIR`, `TEMP`, and `TMP` environment variables. For the first one found to be set, MySQL uses it and does not check those remaining. If none of `TMPDIR`, `TEMP`, or `TMP` are set, MySQL uses the Windows system default, which is usually `C:\windows\temp\`.

If the file system containing your temporary file directory is too small, you can use the `mysqld --tmpdir` option to specify a directory in a file system where you have enough space. On replication slaves, you can use `--slave-load-tmpdir` to specify a separate directory for holding temporary files when replicating `LOAD DATA INFILE` statements.

The `--tmpdir` option can be set to a list of several paths that are used in round-robin fashion. Paths should be separated by colon characters ("`:`") on Unix and semicolon characters ("`;`") on Windows, NetWare, and OS/2.

> **Note**
>
> To spread the load effectively, these paths should be located on different *physical* disks, not different partitions of the same disk.

If the MySQL server is acting as a replication slave, you should be sure to set `--slave-load-tmpdir` not to point to a directory that is on a memory-based file system or to a directory that is cleared when the server host restarts. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA INFILE` operations. If files in the slave temporary file directory are lost when the server restarts, replication fails.

MySQL arranges that temporary files are removed if `mysqld` is terminated. On platforms that support it (such as Unix), this is done by unlinking the file after opening it. The disadvantage of this is that the name does not appear in directory listings and you do not see a big temporary file that fills up the file system in which the temporary file directory is located. (In such cases, `lsof +L1` may be helpful in identifying large files associated with `mysqld`.)

When sorting (`ORDER BY` or `GROUP BY`), MySQL normally uses one or two temporary files. The maximum disk space required is determined by the following expression:

```
(length of what is sorted + sizeof(row pointer))
* number of matched rows
* 2
```

The row pointer size is usually four bytes, but may grow in the future for really big tables.

For some `SELECT` queries, MySQL also creates temporary SQL tables. These are not hidden and have names of the form `SQL_*`.

`ALTER TABLE` creates a temporary copy of the original table in the same directory as the original table.

B.5.3.6 How to Protect or Change the MySQL Unix Socket File

The default location for the Unix socket file that the server uses for communication with local clients is `/tmp/mysql.sock`. (For some distribution formats, the directory might be different, such as `/var/lib/mysql` for RPMs.)

On some versions of Unix, anyone can delete files in the `/tmp` directory or other similar directories used for temporary files. If the socket file is located in such a directory on your system, this might cause problems.

On most versions of Unix, you can protect your `/tmp` directory so that files can be deleted only by their owners or the superuser (`root`). To do this, set the `sticky` bit on the `/tmp` directory by logging in as `root` and using the following command:

```
shell> chmod +t /tmp
```

You can check whether the `sticky` bit is set by executing `ls -ld /tmp`. If the last permission character is `t`, the bit is set.

Another approach is to change the place where the server creates the Unix socket file. If you do this, you should also let client programs know the new location of the file. You can specify the file location in several ways:

- Specify the path in a global or local option file. For example, put the following lines in `/etc/my.cnf`:

```
[mysqld]
socket=/path/to/socket

[client]
socket=/path/to/socket
```

  See Section 4.2.6, "Using Option Files".

- Specify a `--socket` option on the command line to `mysqld_safe` and when you run client programs.

- Set the `MYSQL_UNIX_PORT` environment variable to the path of the Unix socket file.

- Recompile MySQL from source to use a different default Unix socket file location. Define the path to the file with the `--with-unix-socket-path` option when you run `configure`. See Section 2.11.4, "MySQL Source-Configuration Options".

You can test whether the new socket location works by attempting to connect to the server with this command:

```
shell> mysqladmin --socket=/path/to/socket version
```

B.5.3.7 Time Zone Problems

If you have a problem with `SELECT NOW()` returning values in UTC and not your local time, you have to tell the server your current time zone. The same applies if `UNIX_TIMESTAMP()` returns the wrong value. This should be done for the environment in which the server runs; for example, in `mysqld_safe` or `mysql.server`. See Section 2.14, "Environment Variables".

You can set the time zone for the server with the `--timezone=timezone_name` option to `mysqld_safe`. You can also set it by setting the `TZ` environment variable before you start `mysqld`.

The permissible values for `--timezone` or `TZ` are system dependent. Consult your operating system documentation to see what values are acceptable.

B.5.4 Query-Related Issues

B.5.4.1 Case Sensitivity in String Searches

For nonbinary strings (`CHAR`, `VARCHAR`, `TEXT`), string searches use the collation of the comparison operands. For binary strings (`BINARY`, `VARBINARY`, `BLOB`), comparisons use the numeric values of the bytes in the operands; this means that for alphabetic characters, comparisons will be case sensitive.

A comparison between a nonbinary string and binary string is treated as a comparison of binary strings.

Simple comparison operations (`>=, >, =, <, <=`, sorting, and grouping) are based on each character's "sort value." Characters with the same sort value are treated as the same character. For example, if "e" and "é" have the same sort value in a given collation, they compare as equal.

The default character set and collation are `latin1` and `latin1_swedish_ci`, so nonbinary string comparisons are case insensitive by default. This means that if you search with `col_name LIKE 'a%'`, you get all column values that start with `A` or `a`. To make this search case sensitive, make sure that one of the operands has a case sensitive or binary collation. For example, if you are comparing a column and a string that both have the `latin1` character set, you can use the `COLLATE` operator to cause either operand to have the `latin1_general_cs` or `latin1_bin` collation:

```
col_name COLLATE latin1_general_cs LIKE 'a%'
col_name LIKE 'a%' COLLATE latin1_general_cs
col_name COLLATE latin1_bin LIKE 'a%'
col_name LIKE 'a%' COLLATE latin1_bin
```

If you want a column always to be treated in case-sensitive fashion, declare it with a case sensitive or binary collation. See Section 13.1.17, "CREATE TABLE Syntax".

To cause a case-sensitive comparison of nonbinary strings to be case insensitive, use `COLLATE` to name a case-insensitive collation. The strings in the following example normally are case sensitive, but `COLLATE` changes the comparison to be case insensitive:

```
mysql> SET @s1 = 'MySQL' COLLATE latin1_bin,
    ->     @s2 = 'mysql' COLLATE latin1_bin;
mysql> SELECT @s1 = @s2;
+-----------+
| @s1 = @s2 |
+-----------+
|         0 |
+-----------+
mysql> SELECT @s1 COLLATE latin1_swedish_ci = @s2;
+-------------------------------------+
| @s1 COLLATE latin1_swedish_ci = @s2 |
+-------------------------------------+
|                                   1 |
+-------------------------------------+
```

A binary string is case sensitive in comparisons. To compare the string as case insensitive, convert it to a nonbinary string and use `COLLATE` to name a case-insensitive collation:

```
mysql> SET @s = BINARY 'MySQL';
mysql> SELECT @s = 'mysql';
+--------------+
| @s = 'mysql' |
+--------------+
|            0 |
+--------------+
mysql> SELECT CONVERT(@s USING latin1) COLLATE latin1_swedish_ci = 'mysql';
+-------------------------------------------------------------+
| CONVERT(@s USING latin1) COLLATE latin1_swedish_ci = 'mysql' |
+-------------------------------------------------------------+
|                                                           1 |
+-------------------------------------------------------------+
```

To determine whether a value will compare as a nonbinary or binary string, use the `COLLATION()` function. This example shows that `VERSION()` returns a string that has a case-insensitive collation, so comparisons are case insensitive:

```
mysql> SELECT COLLATION(VERSION());
+----------------------+
| COLLATION(VERSION()) |
+----------------------+
```

```
| utf8_general_ci      |
+----------------------+
```

For binary strings, the collation value is `binary`, so comparisons will be case sensitive. One context in which you will see `binary` is for compression and encryption functions, which return binary strings as a general rule: string:

```
mysql> SELECT COLLATION(ENCRYPT('x')), COLLATION(SHA1('x'));
+-------------------------+----------------------+
| COLLATION(ENCRYPT('x')) | COLLATION(SHA1('x')) |
+-------------------------+----------------------+
| binary                  | binary               |
+-------------------------+----------------------+
```

B.5.4.2 Problems Using DATE Columns

The format of a `DATE` value is `'YYYY-MM-DD'`. According to standard SQL, no other format is permitted. You should use this format in `UPDATE` expressions and in the `WHERE` clause of `SELECT` statements. For example:

```
SELECT * FROM t1 WHERE date >= '2003-05-05';
```

As a convenience, MySQL automatically converts a date to a number if the date is used in a numeric context and vice versa. MySQL also permits a "relaxed" string format when updating and in a `WHERE` clause that compares a date to a `DATE`, `DATETIME`, or `TIMESTAMP` column. "Relaxed" format means that any punctuation character may be used as the separator between parts. For example, `'2004-08-15'` and `'2004#08#15'` are equivalent. MySQL can also convert a string containing no separators (such as `'20040815'`), provided it makes sense as a date.

When you compare a `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` to a constant string with the `<`, `<=`, `=`, `>=`, `>`, or `BETWEEN` operators, MySQL normally converts the string to an internal long integer for faster comparison (and also for a bit more "relaxed" string checking). However, this conversion is subject to the following exceptions:

- When you compare two columns

- When you compare a `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` column to an expression

- When you use any comparison method other than those just listed, such as `IN` or `STRCMP()`.

For those exceptions, the comparison is done by converting the objects to strings and performing a string comparison.

To be on the safe side, assume that strings are compared as strings and use the appropriate string functions if you want to compare a temporal value to a string.

The special "zero" date `'0000-00-00'` can be stored and retrieved as `'0000-00-00'`. When a `'0000-00-00'` date is used through Connector/ODBC, it is automatically converted to `NULL` because ODBC cannot handle that kind of date.

Because MySQL performs the conversions just described, the following statements work (assume that `idate` is a `DATE` column):

```
INSERT INTO t1 (idate) VALUES (19970505);
INSERT INTO t1 (idate) VALUES ('19970505');
INSERT INTO t1 (idate) VALUES ('97-05-05');
INSERT INTO t1 (idate) VALUES ('1997.05.05');
```

```
INSERT INTO t1 (idate) VALUES ('1997 05 05');
INSERT INTO t1 (idate) VALUES ('0000-00-00');

SELECT idate FROM t1 WHERE idate >= '1997-05-05';
SELECT idate FROM t1 WHERE idate >= 19970505;
SELECT MOD(idate,100) FROM t1 WHERE idate >= 19970505;
SELECT idate FROM t1 WHERE idate >= '19970505';
```

However, the following statement does not work:

```
SELECT idate FROM t1 WHERE STRCMP(idate,'20030505')=0;
```

`STRCMP()` is a string function, so it converts `idate` to a string in `'YYYY-MM-DD'` format and performs a string comparison. It does not convert `'20030505'` to the date `'2003-05-05'` and perform a date comparison.

If you enable the `ALLOW_INVALID_DATES` SQL mode, MySQL permits you to store dates that are given only limited checking: MySQL requires only that the day is in the range from 1 to 31 and the month is in the range from 1 to 12. This makes MySQL very convenient for Web applications where you obtain year, month, and day in three different fields and you want to store exactly what the user inserted (without date validation).

MySQL permits you to store dates where the day or month and day are zero. This is convenient if you want to store a birthdate in a `DATE` column and you know only part of the date. To disallow zero month or day parts in dates, enable the `NO_ZERO_IN_DATE` SQL mode.

MySQL permits you to store a "zero" value of `'0000-00-00'` as a "dummy date." This is in some cases more convenient than using `NULL` values. If a date to be stored in a `DATE` column cannot be converted to any reasonable value, MySQL stores `'0000-00-00'`. To disallow `'0000-00-00'`, enable the `NO_ZERO_DATE` SQL mode.

To have MySQL check all dates and accept only legal dates (unless overridden by `IGNORE`), set the `sql_mode` system variable to `"NO_ZERO_IN_DATE,NO_ZERO_DATE"`.

B.5.4.3 Problems with NULL Values

The concept of the `NULL` value is a common source of confusion for newcomers to SQL, who often think that `NULL` is the same thing as an empty string `''`. This is not the case. For example, the following statements are completely different:

```
mysql> INSERT INTO my_table (phone) VALUES (NULL);
mysql> INSERT INTO my_table (phone) VALUES ('');
```

Both statements insert a value into the `phone` column, but the first inserts a `NULL` value and the second inserts an empty string. The meaning of the first can be regarded as "phone number is not known" and the meaning of the second can be regarded as "the person is known to have no phone, and thus no phone number."

To help with `NULL` handling, you can use the `IS NULL` and `IS NOT NULL` operators and the `IFNULL()` function.

In SQL, the `NULL` value is never true in comparison to any other value, even `NULL`. An expression that contains `NULL` always produces a `NULL` value unless otherwise indicated in the documentation for the operators and functions involved in the expression. All columns in the following example return `NULL`:

```
mysql> SELECT NULL, 1+NULL, CONCAT('Invisible',NULL);
```

To search for column values that are `NULL`, you cannot use an `expr = NULL` test. The following statement returns no rows, because `expr = NULL` is never true for any expression:

```
mysql> SELECT * FROM my_table WHERE phone = NULL;
```

To look for `NULL` values, you must use the `IS NULL` test. The following statements show how to find the `NULL` phone number and the empty phone number:

```
mysql> SELECT * FROM my_table WHERE phone IS NULL;
mysql> SELECT * FROM my_table WHERE phone = '';
```

See Section 3.3.4.6, "Working with NULL Values", for additional information and examples.

You can add an index on a column that can have `NULL` values if you are using the `MyISAM`, `InnoDB`, or `MEMORY` storage engine. Otherwise, you must declare an indexed column `NOT NULL`, and you cannot insert `NULL` into the column.

When reading data with `LOAD DATA INFILE`, empty or missing columns are updated with `''`. To load a `NULL` value into a column, use `\N` in the data file. The literal word "`NULL`" may also be used under some circumstances. See Section 13.2.6, "LOAD DATA INFILE Syntax".

When using `DISTINCT`, `GROUP BY`, or `ORDER BY`, all `NULL` values are regarded as equal.

When using `ORDER BY`, `NULL` values are presented first, or last if you specify `DESC` to sort in descending order.

Aggregate (summary) functions such as `COUNT()`, `MIN()`, and `SUM()` ignore `NULL` values. The exception to this is `COUNT(*)`, which counts rows and not individual column values. For example, the following statement produces two counts. The first is a count of the number of rows in the table, and the second is a count of the number of non-`NULL` values in the `age` column:

```
mysql> SELECT COUNT(*), COUNT(age) FROM person;
```

For some data types, MySQL handles `NULL` values specially. If you insert `NULL` into a `TIMESTAMP` column, the current date and time is inserted. If you insert `NULL` into an integer or floating-point column that has the `AUTO_INCREMENT` attribute, the next number in the sequence is inserted.

B.5.4.4 Problems with Column Aliases

An alias can be used in a query select list to give a column a different name. You can use the alias in `GROUP BY`, `ORDER BY`, or `HAVING` clauses to refer to the column:

```
SELECT SQRT(a*b) AS root FROM tbl_name
  GROUP BY root HAVING root > 0;
SELECT id, COUNT(*) AS cnt FROM tbl_name
  GROUP BY id HAVING cnt > 0;
SELECT id AS 'Customer identity' FROM tbl_name;
```

Standard SQL disallows references to column aliases in a `WHERE` clause. This restriction is imposed because when the `WHERE` clause is evaluated, the column value may not yet have been determined. For example, the following query is illegal:

```
SELECT id, COUNT(*) AS cnt FROM tbl_name
  WHERE cnt > 0 GROUP BY id;
```

The `WHERE` clause determines which rows should be included in the `GROUP BY` clause, but it refers to the alias of a column value that is not known until after the rows have been selected, and grouped by the `GROUP BY`.

In the select list of a query, a quoted column alias can be specified using identifier or string quoting characters:

```
SELECT 1 AS `one`, 2 AS 'two';
```

Elsewhere in the statement, quoted references to the alias must use identifier quoting or the reference is treated as a string literal. For example, this statement groups by the values in column `id`, referenced using the alias `` `a` ``:

```
SELECT id AS 'a', COUNT(*) AS cnt FROM tbl_name
  GROUP BY `a`;
```

But this statement groups by the literal string `'a'` and will not work as expected:

```
SELECT id AS 'a', COUNT(*) AS cnt FROM tbl_name
  GROUP BY 'a';
```

B.5.4.5 Rollback Failure for Nontransactional Tables

If you receive the following message when trying to perform a `ROLLBACK`, it means that one or more of the tables you used in the transaction do not support transactions:

```
Warning: Some non-transactional changed tables couldn't be rolled back
```

These nontransactional tables are not affected by the `ROLLBACK` statement.

If you were not deliberately mixing transactional and nontransactional tables within the transaction, the most likely cause for this message is that a table you thought was transactional actually is not. This can happen if you try to create a table using a transactional storage engine that is not supported by your `mysqld` server (or that was disabled with a startup option). If `mysqld` does not support a storage engine, it instead creates the table as a `MyISAM` table, which is nontransactional.

You can check the storage engine for a table by using either of these statements:

```
SHOW TABLE STATUS LIKE 'tbl_name';
SHOW CREATE TABLE tbl_name;
```

See Section 13.7.5.38, "SHOW TABLE STATUS Syntax", and Section 13.7.5.12, "SHOW CREATE TABLE Syntax".

You can check which storage engines your `mysqld` server supports by using this statement:

```
SHOW ENGINES;
```

You can also use the following statement, and check the value of the variable that is associated with the storage engine in which you are interested:

```
SHOW VARIABLES LIKE 'have_%';
```

For example, to determine whether the `InnoDB` storage engine is available, check the value of the `have_innodb` variable.

See Section 13.7.5.17, "SHOW ENGINES Syntax", and Section 13.7.5.41, "SHOW VARIABLES Syntax".

B.5.4.6 Deleting Rows from Related Tables

If the total length of the `DELETE` statement for `related_table` is more than 1MB (the default value of the `max_allowed_packet` system variable), you should split it into smaller parts and execute multiple `DELETE` statements. You probably get the fastest `DELETE` by specifying only 100 to 1,000 `related_column` values per statement if the `related_column` is indexed. If the `related_column` isn't indexed, the speed is independent of the number of arguments in the `IN` clause.

B.5.4.7 Solving Problems with No Matching Rows

If you have a complicated query that uses many tables but that returns no rows, you should use the following procedure to find out what is wrong:

1. Test the query with `EXPLAIN` to check whether you can find something that is obviously wrong. See Section 13.8.2, "EXPLAIN Syntax".

2. Select only those columns that are used in the `WHERE` clause.

3. Remove one table at a time from the query until it returns some rows. If the tables are large, it is a good idea to use `LIMIT 10` with the query.

4. Issue a `SELECT` for the column that should have matched a row against the table that was last removed from the query.

5. If you are comparing `FLOAT` or `DOUBLE` columns with numbers that have decimals, you cannot use equality (`=`) comparisons. This problem is common in most computer languages because not all floating-point values can be stored with exact precision. In some cases, changing the `FLOAT` to a `DOUBLE` fixes this. See Section B.5.4.8, "Problems with Floating-Point Values".

6. If you still cannot figure out what is wrong, create a minimal test that can be run with `mysql test < query.sql` that shows your problems. You can create a test file by dumping the tables with `mysqldump --quick db_name tbl_name_1 ... tbl_name_n > query.sql`. Open the file in an editor, remove some insert lines (if there are more than needed to demonstrate the problem), and add your `SELECT` statement at the end of the file.

   Verify that the test file demonstrates the problem by executing these commands:

   ```
   shell> mysqladmin create test2
   shell> mysql test2 < query.sql
   ```

   Attach the test file to a bug report, which you can file using the instructions in Section 1.7, "How to Report Bugs or Problems".

B.5.4.8 Problems with Floating-Point Values

Floating-point numbers sometimes cause confusion because they are approximate and not stored as exact values. A floating-point value as written in an SQL statement may not be the same as the value represented internally. Attempts to treat floating-point values as exact in comparisons may lead to problems. They are also subject to platform or implementation dependencies. The `FLOAT` and `DOUBLE` data types are subject to these issues. For `DECIMAL` columns, MySQL performs operations with a precision of 65 decimal digits, which should solve most common inaccuracy problems.

The following example uses `DOUBLE` to demonstrate how calculations that are done using floating-point operations are subject to floating-point error.

```
mysql> CREATE TABLE t1 (i INT, d1 DOUBLE, d2 DOUBLE);
mysql> INSERT INTO t1 VALUES (1, 101.40, 21.40), (1, -80.00, 0.00),
    -> (2, 0.00, 0.00), (2, -13.20, 0.00), (2, 59.60, 46.40),
    -> (2, 30.40, 30.40), (3, 37.00, 7.40), (3, -29.60, 0.00),
    -> (4, 60.00, 15.40), (4, -10.60, 0.00), (4, -34.00, 0.00),
    -> (5, 33.00, 0.00), (5, -25.80, 0.00), (5, 0.00, 7.20),
    -> (6, 0.00, 0.00), (6, -51.40, 0.00);

mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b
    -> FROM t1 GROUP BY i HAVING a <> b;

+------+-------+------+
| i    | a     | b    |
+------+-------+------+
|    1 |  21.4 | 21.4 |
|    2 |  76.8 | 76.8 |
|    3 |   7.4 |  7.4 |
|    4 |  15.4 | 15.4 |
|    5 |   7.2 |  7.2 |
|    6 | -51.4 |    0 |
+------+-------+------+
```

The result is correct. Although the first five records look like they should not satisfy the comparison (the values of `a` and `b` do not appear to be different), they may do so because the difference between the numbers shows up around the tenth decimal or so, depending on factors such as computer architecture or the compiler version or optimization level. For example, different CPUs may evaluate floating-point numbers differently.

If columns `d1` and `d2` had been defined as `DECIMAL` rather than `DOUBLE`, the result of the `SELECT` query would have contained only one row—the last one shown above.

The correct way to do floating-point number comparison is to first decide on an acceptable tolerance for differences between the numbers and then do the comparison against the tolerance value. For example, if we agree that floating-point numbers should be regarded the same if they are same within a precision of one in ten thousand (0.0001), the comparison should be written to find differences larger than the tolerance value:

```
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) > 0.0001;
+------+-------+------+
| i    | a     | b    |
+------+-------+------+
|    6 | -51.4 |    0 |
+------+-------+------+
1 row in set (0.00 sec)
```

Conversely, to get rows where the numbers are the same, the test should find differences within the tolerance value:

```
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) <= 0.0001;
+------+------+------+
| i    | a    | b    |
+------+------+------+
|    1 | 21.4 | 21.4 |
|    2 | 76.8 | 76.8 |
|    3 |  7.4 |  7.4 |
|    4 | 15.4 | 15.4 |
|    5 |  7.2 |  7.2 |
+------+------+------+
5 rows in set (0.03 sec)
```

Floating-point values are subject to platform or implementation dependencies. Suppose that you execute the following statements:

```
CREATE TABLE t1(c1 FLOAT(53,0), c2 FLOAT(53,0));
INSERT INTO t1 VALUES('1e+52','-1e+52');
SELECT * FROM t1;
```

On some platforms, the `SELECT` statement returns `inf` and `-inf`. On others, it returns `0` and `-0`.

An implication of the preceding issues is that if you attempt to create a replication slave by dumping table contents with `mysqldump` on the master and reloading the dump file into the slave, tables containing floating-point columns might differ between the two hosts.

B.5.5 Optimizer-Related Issues

MySQL uses a cost-based optimizer to determine the best way to resolve a query. In many cases, MySQL can calculate the best possible query plan, but sometimes MySQL does not have enough information about the data at hand and has to make "educated" guesses about the data.

For the cases when MySQL does not do the "right" thing, tools that you have available to help MySQL are:

- Use the `EXPLAIN` statement to get information about how MySQL processes a query. To use it, just add the keyword `EXPLAIN` to the front of your `SELECT` statement:

```
mysql> EXPLAIN SELECT * FROM t1, t2 WHERE t1.i = t2.i;
```

  `EXPLAIN` is discussed in more detail in Section 13.8.2, "EXPLAIN Syntax".

- Use `ANALYZE TABLE tbl_name` to update the key distributions for the scanned table. See Section 13.7.2.1, "ANALYZE TABLE Syntax".

- Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to using the given index:

```
SELECT * FROM t1, t2 FORCE INDEX (index_for_column)
WHERE t1.col_name=t2.col_name;
```

  `USE INDEX` and `IGNORE INDEX` may also be useful. See Section 8.9.3, "Index Hints".

- Global and table-level `STRAIGHT_JOIN`. See Section 13.2.8, "SELECT Syntax".

- You can tune global or thread-specific system variables. For example, start `mysqld` with the `--max-seeks-for-key=1000` option or use `SET max_seeks_for_key=1000` to tell the optimizer to assume that no key scan causes more than 1,000 key seeks. See Section 5.1.4, "Server System Variables".

B.5.6 Table Definition-Related Issues

B.5.6.1 Problems with ALTER TABLE

If you get a duplicate-key error when using `ALTER TABLE` to change the character set or collation of a character column, the cause is either that the new column collation maps two keys to the same value or that the table is corrupted. In the latter case, you should run `REPAIR TABLE` on the table.

If `ALTER TABLE` dies with the following error, the problem may be that MySQL crashed during an earlier `ALTER TABLE` operation and there is an old table named `A-xxx` or `B-xxx` lying around:

```
Error on rename of './database/name.frm'
to './database/B-xxx.frm' (Errcode: 17)
```

In this case, go to the MySQL data directory and delete all files that have names starting with `A-` or `B-`. (You may want to move them elsewhere instead of deleting them.)

`ALTER TABLE` works in the following way:

- Create a new table named `A-xxx` with the requested structural changes.

- Copy all rows from the original table to `A-xxx`.

- Rename the original table to `B-xxx`.

- Rename `A-xxx` to your original table name.

- Delete `B-xxx`.

If something goes wrong with the renaming operation, MySQL tries to undo the changes. If something goes seriously wrong (although this shouldn't happen), MySQL may leave the old table as `B-xxx`. A simple rename of the table files at the system level should get your data back.

If you use `ALTER TABLE` on a transactional table or if you are using Windows or OS/2, `ALTER TABLE` unlocks the table if you had done a `LOCK TABLE` on it. This is done because `InnoDB` and these operating systems cannot drop a table that is in use.

B.5.6.2 TEMPORARY Table Problems

The following list indicates limitations on the use of `TEMPORARY` tables:

- A `TEMPORARY` table can only be of type `MEMORY`, `MyISAM`, `MERGE`, or `InnoDB`.

  Temporary tables are not supported for MySQL Cluster.

- You cannot refer to a `TEMPORARY` table more than once in the same query. For example, the following does not work:

```
mysql> SELECT * FROM temp_table, temp_table AS t2;
ERROR 1137: Can't reopen table: 'temp_table'
```

  This error also occurs if you refer to a temporary table multiple times in a stored function under different aliases, even if the references occur in different statements within the function.

- The `SHOW TABLES` statement does not list `TEMPORARY` tables.

- You cannot use `RENAME` to rename a `TEMPORARY` table. However, you can use `ALTER TABLE` instead:

```
mysql> ALTER TABLE orig_name RENAME new_name;
```

- There are known issues in using temporary tables with replication. See Section 16.4.1, "Replication Features and Issues", for more information.

B.5.7 Known Issues in MySQL

This section lists known issues in recent versions of MySQL.

For information about platform-specific issues, see the installation and porting instructions in Section 2.1, "General Installation Guidance", and Section 22.4, "Debugging and Porting MySQL".

The following problems are known:

- Subquery optimization for `IN` is not as effective as for `=`.

- Even if you use `lower_case_table_names=2` (which enables MySQL to remember the case used for databases and table names), MySQL does not remember the case used for database names for the function `DATABASE()` or within the various logs (on case-insensitive systems).

- Dropping a `FOREIGN KEY` constraint does not work in replication because the constraint may have another name on the slave.

- `REPLACE` (and `LOAD DATA` with the `REPLACE` option) does not trigger `ON DELETE CASCADE`.

- `DISTINCT` with `ORDER BY` does not work inside `GROUP_CONCAT()` if you do not use all and only those columns that are in the `DISTINCT` list.

- If one user has a long-running transaction and another user drops a table that is updated in the transaction, there is small chance that the binary log may contain the `DROP TABLE` statement before the table is used in the transaction itself.

- When inserting a big integer value (between 2^{63} and $2^{64}-1$) into a decimal or string column, it is inserted as a negative value because the number is evaluated in a signed integer context.

- `FLUSH TABLES WITH READ LOCK` does not block `COMMIT` if the server is running without binary logging, which may cause a problem (of consistency between tables) when doing a full backup.

- `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` may cause problems on tables for which you are using `INSERT DELAYED`.

- Performing `LOCK TABLE ...` and `FLUSH TABLES ...` does not guarantee that there isn't a half-finished transaction in progress on the table.

- With statement-based binary logging, the master writes the executed queries to the binary log. This is a very fast, compact, and efficient logging method that works perfectly in most cases. However, it is possible for the data on the master and slave to become different if a query is designed in such a way that the data modification is nondeterministic (generally not a recommended practice, even outside of replication).

  For example:

  - `CREATE TABLE ... SELECT` or `INSERT ... SELECT` statements that insert zero or `NULL` values into an `AUTO_INCREMENT` column.

  - `DELETE` if you are deleting rows from a table that has foreign keys with `ON DELETE CASCADE` properties.

  - `REPLACE ... SELECT`, `INSERT IGNORE ... SELECT` if you have duplicate key values in the inserted data.

  If and only if the preceding queries have no `ORDER BY` clause guaranteeing a deterministic order.

  For example, for `INSERT ... SELECT` with no `ORDER BY`, the `SELECT` may return rows in a different order (which results in a row having different ranks, hence getting a different number in the `AUTO_INCREMENT` column), depending on the choices made by the optimizers on the master and slave.

A query is optimized differently on the master and slave only if:

- The table is stored using a different storage engine on the master than on the slave. (It is possible to use different storage engines on the master and slave. For example, you can use `InnoDB` on the master, but `MyISAM` on the slave if the slave has less available disk space.)

- MySQL buffer sizes (`key_buffer_size`, and so on) are different on the master and slave.

- The master and slave run different MySQL versions, and the optimizer code differs between these versions.

  This problem may also affect database restoration using `mysqlbinlog|mysql`.

  The easiest way to avoid this problem is to add an `ORDER BY` clause to the aforementioned nondeterministic queries to ensure that the rows are always stored or modified in the same order. Using row-based or mixed logging format also avoids the problem.

- Log file names are based on the server host name if you do not specify a file name with the startup option. To retain the same log file names if you change your host name to something else, you must explicitly use options such as `--log-bin=old_host_name-bin`. See Section 5.1.3, "Server Command Options". Alternatively, rename the old files to reflect your host name change. If these are binary logs, you must edit the binary log index file and fix the binary log file names there as well. (The same is true for the relay logs on a slave server.)

- `mysqlbinlog` does not delete temporary files left after a `LOAD DATA INFILE` statement. See Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files".

- `RENAME` does not work with `TEMPORARY` tables or tables used in a `MERGE` table.

- Due to the way table format (`.frm`) files are stored, you cannot use character 255 (`CHAR(255)`) in table names, column names, or enumerations.

- When using `SET CHARACTER SET`, you cannot use translated characters in database, table, and column names.

- You cannot use "_" or "%" with `ESCAPE` in `LIKE ... ESCAPE`.

- The server uses only the first `max_sort_length` bytes when comparing data values. This means that values cannot reliably be used in `GROUP BY`, `ORDER BY`, or `DISTINCT` if they differ only after the first `max_sort_length` bytes. To work around this, increase the variable value. The default value of `max_sort_length` is 1024 and can be changed at server startup time or at runtime.

- Numeric calculations are done with `BIGINT` or `DOUBLE` (both are normally 64 bits long). Which precision you get depends on the function. The general rule is that bit functions are performed with `BIGINT` precision, `IF()` and `ELT()` with `BIGINT` or `DOUBLE` precision, and the rest with `DOUBLE` precision. You should try to avoid using unsigned long long values if they resolve to be larger than 63 bits (9223372036854775807) for anything other than bit fields.

- You can have up to 255 `ENUM` and `SET` columns in one table.

- In `MIN()`, `MAX()`, and other aggregate functions, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set.

- In an `UPDATE` statement, columns are updated from left to right. If you refer to an updated column, you get the updated value instead of the original value. For example, the following statement increments `KEY` by 2, **not** 1:

```
mysql> UPDATE tbl_name SET KEY=KEY+1,KEY=KEY+1;
```

- You can refer to multiple temporary tables in the same query, but you cannot refer to any given temporary table more than once. For example, the following does not work:

```
mysql> SELECT * FROM temp_table, temp_table AS t2;
ERROR 1137: Can't reopen table: 'temp_table'
```

- The optimizer may handle `DISTINCT` differently when you are using "hidden" columns in a join than when you are not. In a join, hidden columns are counted as part of the result (even if they are not shown), whereas in normal queries, hidden columns do not participate in the `DISTINCT` comparison.

  An example of this is:

```
SELECT DISTINCT mp3id FROM band_downloads
       WHERE userid = 9 ORDER BY id DESC;
```

  and

```
SELECT DISTINCT band_downloads.mp3id
       FROM band_downloads,band_mp3
       WHERE band_downloads.userid = 9
       AND band_mp3.id = band_downloads.mp3id
       ORDER BY band_downloads.id DESC;
```

  In the second case, using MySQL Server 3.23.x, you may get two identical rows in the result set (because the values in the hidden `id` column may differ).

  Note that this happens only for queries that do not have the `ORDER BY` columns in the result.

- If you execute a `PROCEDURE` on a query that returns an empty set, in some cases the `PROCEDURE` does not transform the columns.

- Creation of a table of type `MERGE` does not check whether the underlying tables are compatible types.

- If you use `ALTER TABLE` to add a `UNIQUE` index to a table used in a `MERGE` table and then add a normal index on the `MERGE` table, the key order is different for the tables if there was an old, non-`UNIQUE` key in the table. This is because `ALTER TABLE` puts `UNIQUE` indexes before normal indexes to be able to detect duplicate keys as early as possible.

Appendix C Restrictions and Limits

Table of Contents

The discussion here describes restrictions that apply to the use of MySQL features such as subqueries or views.

C.1 Restrictions on Stored Programs

These restrictions apply to the features described in Chapter 19, *Stored Programs and Views*.

Some of the restrictions noted here apply to all stored routines; that is, both to stored procedures and stored functions. There are also some restrictions specific to stored functions but not to stored procedures.

The restrictions for stored functions also apply to triggers. There are also some restrictions specific to triggers.

The restrictions for stored procedures also apply to the `DO` clause of Event Scheduler event definitions. There are also some restrictions specific to events.

SQL Statements Not Permitted in Stored Routines

Stored routines cannot contain arbitrary SQL statements. The following statements are not permitted:

- The locking statements `LOCK TABLES` and `UNLOCK TABLES`.

- `ALTER VIEW`. (Before MySQL 5.1.21, this restriction is enforced only for stored functions.)

- `LOAD DATA` and `LOAD TABLE`.

- SQL prepared statements (`PREPARE`, `EXECUTE`, `DEALLOCATE PREPARE`) can be used in stored procedures, but not stored functions or triggers. Thus, stored functions and triggers cannot use dynamic SQL (where you construct statements as strings and then execute them).

- Generally, statements not permitted in SQL prepared statements are also not permitted in stored programs. For a list of statements supported as prepared statements, see Section 13.5, "SQL Syntax for Prepared Statements".

- Because local variables are in scope only during stored program execution, references to them are not permitted in prepared statements created within a stored program. Prepared statement scope is the

current session, not the stored program, so the statement could be executed after the program ends, at which point the variables would no longer be in scope. For example, `SELECT ... INTO` *`local_var`* cannot be used as a prepared statement. This restriction also applies to stored procedure and function parameters. See Section 13.5.1, "PREPARE Syntax".

- Inserts cannot be delayed. `INSERT DELAYED` syntax is accepted, but the statement is handled as a normal `INSERT`.

- Within all stored programs (stored procedures and functions, triggers, and events), the parser treats `BEGIN [WORK]` as the beginning of a `BEGIN ... END` block. To begin a transaction in this context, use `START TRANSACTION` instead.

Restrictions for Stored Functions

The following additional statements or operations are not permitted within stored functions. They are permitted within stored procedures, except stored procedures that are invoked from within a stored function or trigger. For example, if you use `FLUSH` in a stored procedure, that stored procedure cannot be called from a stored function or trigger.

- Statements that perform explicit or implicit commit or rollback. Support for these statements is not required by the SQL standard, which states that each DBMS vendor may decide whether to permit them.

- Statements that return a result set. This includes `SELECT` statements that do not have an `INTO` *`var_list`* clause and other statements such as `SHOW`, `EXPLAIN`, and `CHECK TABLE`. A function can process a result set either with `SELECT ... INTO` *`var_list`* or by using a cursor and `FETCH` statements. See Section 13.2.8.1, "SELECT ... INTO Syntax", and Section 13.6.6, "Cursors".

- `FLUSH` statements.

- Stored functions cannot be used recursively.

- A stored function or trigger cannot modify a table that is already being used (for reading or writing) by the statement that invoked the function or trigger.

- If you refer to a temporary table multiple times in a stored function under different aliases, a `Can't reopen table:` *`'tbl_name'`* error occurs, even if the references occur in different statements within the function.

Restrictions for Triggers

For triggers, the following additional restrictions apply:

- Triggers are not activated by foreign key actions.

- When using row-based replication, triggers on the slave are not activated by statements originating on the master. The triggers on the slave are activated when using statement-based replication. For more information, see Section 16.4.1.36, "Replication and Triggers".

- The `RETURN` statement is not permitted in triggers, which cannot return a value. To exit a trigger immediately, use the `LEAVE` statement.

- Triggers are not permitted on tables in the `mysql` database.

- The trigger cache does not detect when metadata of the underlying objects has changed. If a trigger uses a table and the table has changed since the trigger was loaded into the cache, the trigger operates using the outdated metadata.

Restrictions on Calling Stored Procedures

Before MySQL 5.1.4, `CALL` statements cannot be prepared, meaning that stored procedures cannot be called from dynamic SQL. This is true both for server-side prepared statements and for SQL prepared statements.

Name Conflicts within Stored Routines

The same identifier might be used for a routine parameter, a local variable, and a table column. Also, the same local variable name can be used in nested blocks. For example:

```
CREATE PROCEDURE p (i INT)
BEGIN
  DECLARE i INT DEFAULT 0;
  SELECT i FROM t;
  BEGIN
    DECLARE i INT DEFAULT 1;
    SELECT i FROM t;
  END;
END;
```

In such cases, the identifier is ambiguous and the following precedence rules apply:

• A local variable takes precedence over a routine parameter or table column.

• A routine parameter takes precedence over a table column.

• A local variable in an inner block takes precedence over a local variable in an outer block.

The behavior that variables take precedence over table columns is nonstandard.

Replication Considerations

Use of stored routines can cause replication problems. This issue is discussed further in Section 19.7, "Binary Logging of Stored Programs".

The `--replicate-wild-do-table=`*`db_name.tbl_name`* option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the `--replicate-*-db` options.

Introspection Considerations

`INFORMATION_SCHEMA` does not have a `PARAMETERS` table until MySQL 5.5; this table enables stored routines or client applications to determine the names, types, and default values of parameters for stored routines. For releases without this `INFORMATION_SCHEMA.PARAMETERS` table, to examine these types of metadata, you must use workarounds such as parsing the output of `SHOW CREATE` statements or the `param_list` column of the `mysql.proc` table. `param_list` contents can be processed from within a stored routine, unlike the output from `SHOW`.

Debugging Considerations

There are no stored routine debugging facilities.

Unsupported Syntax from the SQL:2003 Standard

The MySQL stored routine syntax is based on the SQL:2003 standard. The following items from that standard are not currently supported:

- `UNDO` handlers

- `FOR` loops

Concurrency Considerations

To prevent problems of interaction between sessions, when a client issues a statement, the server uses a snapshot of routines and triggers available for execution of the statement. That is, the server calculates a list of procedures, functions, and triggers that may be used during execution of the statement, loads them, and then proceeds to execute the statement. While the statement executes, it does not see changes to routines performed by other sessions.

For maximum concurrency, stored functions should minimize their side-effects; in particular, updating a table within a stored function can reduce concurrent operations on that table. A stored function acquires table locks before executing, to avoid inconsistency in the binary log due to mismatch of the order in which statements execute and when they appear in the log. When statement-based binary logging is used, statements that invoke a function are recorded rather than the statements executed within the function. Consequently, stored functions that update the same underlying tables do not execute in parallel. In contrast, stored procedures do not acquire table-level locks. All statements executed within stored procedures are written to the binary log, even for statement-based binary logging. See Section 19.7, "Binary Logging of Stored Programs".

Event Scheduler Restrictions

The following limitations are specific to the Event Scheduler:

- In MySQL 5.1.6 only, any table referenced in an event's action statement must be fully qualified with the name of the schema in which it occurs (that is, as `schema_name.table_name`).

- Beginning with MySQL 5.1.8, event names are handled in case-insensitive fashion. For example, this means that you cannot have two events in the same database (and—prior to MySQL 5.1.12—with the same definer) with the names `anEvent` and `AnEvent`.

  > **Important**
  >
  > If you have events created in MySQL 5.1.7 or earlier which are assigned to the same database and have the same definer, and whose names differ only with respect to lettercase, then you must rename these events to respect case-sensitive handling before upgrading to MySQL 5.1.8 or later.

- An event may not be created, altered, or dropped by a stored routine, trigger, or another event. An event also may not create, alter, or drop stored routines or triggers. (Bug #16409, Bug #18896)

- Event timings using the intervals `YEAR`, `QUARTER`, `MONTH`, and `YEAR_MONTH` are resolved in months; those using any other interval are resolved in seconds. There is no way to cause events scheduled to occur at the same second to execute in a given order. In addition—due to rounding, the nature of threaded applications, and the fact that a nonzero length of time is required to create events and to signal their execution—events may be delayed by as much as 1 or 2 seconds. However, the time shown in the `INFORMATION_SCHEMA.EVENTS` table's `LAST_EXECUTED` column or the `mysql.event` table's `last_executed` column is always accurate to within one second of the actual event execution time. (See also Bug #16522.)

- Each execution of the statements contained in the body of an event takes place in a new connection; thus, these statements has no effect in a given user session on the server's statement counts such as `Com_select` and `Com_insert` that are displayed by `SHOW STATUS`. However, such counts *are* updated in the global scope. (Bug #16422)

- Prior to MySQL 5.1.12, you could not view another user's events in the `INFORMATION_SCHEMA.EVENTS` table. In other words, any query made against this table was treated as though it contained the condition `DEFINER = CURRENT_USER()` in the `WHERE` clause.

- Events do not support times later than the end of the Unix Epoch; this is approximately the beginning of the year 2038. Prior to MySQL 5.1.8, handling in scheduled events of dates later than this was buggy; starting with MySQL 5.1.8, such dates are specifically not permitted by the Event Scheduler. (Bug #16396)

- In MySQL 5.1.6, `INFORMATION_SCHEMA.EVENTS` shows `NULL` in the `SQL_MODE` column. Beginning with MySQL 5.1.7, the `SQL_MODE` displayed is that in effect when the event was created.

- In MySQL 5.1.6, the only way to drop or alter an event created by a user who was not the definer of that event was by manipulation of the `mysql.event` system table by the MySQL `root` user or by another user with privileges on this table. Beginning with MySQL 5.1.7, `DROP USER` drops all events for which that user was the definer; also beginning with MySQL 5.1.7 `DROP SCHEMA` drops all events associated with the dropped schema.

- References to stored functions, user-defined functions, and tables in the `ON SCHEDULE` clauses of `CREATE EVENT` and `ALTER EVENT` statements are not supported. Beginning with MySQL 5.1.13, these sorts of references are not permitted. (See Bug #22830 for more information.)

- Generally speaking, statements that are not permitted in stored routines or in SQL prepared statements are also not permitted in the body of an event. For more information, see Section 13.5, "SQL Syntax for Prepared Statements".

- When upgrading to MySQL 5.1.18 or 5.1.19 from a previous MySQL version where scheduled events were in use, the upgrade utilities `mysql_upgrade` and `mysql_fix_privilege_tables` do not accommodate changes in system tables relating to the Event Scheduler. This issue was fixed in MySQL 5.1.20 (see Bug #28521).

Stored routines and triggers in MySQL Cluster. Stored procedures, stored functions, and triggers are all supported by tables using the `NDB` storage engine; however, it is important to keep in mind that they do *not* propagate automatically between MySQL Servers acting as Cluster SQL nodes. This is because of the following:

- Stored routine definitions are kept in tables in the `mysql` system database using the `MyISAM` storage engine, and so do not participate in clustering.

- The `.TRN` and `.TRG` files containing trigger definitions are not read by the `NDB` storage engine, and are not copied between Cluster nodes.

Any stored routine or trigger that interacts with MySQL Cluster tables must be re-created by running the appropriate `CREATE PROCEDURE`, `CREATE FUNCTION`, or `CREATE TRIGGER` statements on each MySQL Server that participates in the cluster where you wish to use the stored routine or trigger. Similarly, any changes to existing stored routines or triggers must be carried out explicitly on all Cluster SQL nodes, using the appropriate `ALTER` or `DROP` statements on each MySQL Server accessing the cluster.

> **Warning**
>
> Do *not* attempt to work around the issue described in the first item mentioned previously by converting any `mysql` database tables to use the `NDB` storage engine. *Altering the system tables in the `mysql` database is not supported* and is very likely to produce undesirable results.

C.2 Restrictions on Server-Side Cursors

Server-side cursors are implemented in the C API using the `mysql_stmt_attr_set()` function. The same implementation is used for cursors in stored routines. A server-side cursor enables a result set to be generated on the server side, but not transferred to the client except for those rows that the client requests. For example, if a client executes a query but is only interested in the first row, the remaining rows are not transferred.

In MySQL, a server-side cursor is materialized into an internal temporary table. Initially, this is a `MEMORY` table, but is converted to a `MyISAM` table when its size exceeds the minimum value of the `max_heap_table_size` and `tmp_table_size` system variables. The same restrictions apply to internal temporary tables created to hold the result set for a cursor as for other uses of internal temporary tables. See Section 8.4.4, "Internal Temporary Table Use in MySQL". One limitation of the implementation is that for a large result set, retrieving its rows through a cursor might be slow.

Cursors are read only; you cannot use a cursor to update rows.

`UPDATE WHERE CURRENT OF` and `DELETE WHERE CURRENT OF` are not implemented, because updatable cursors are not supported.

Cursors are nonholdable (not held open after a commit).

Cursors are asensitive.

Cursors are nonscrollable.

Cursors are not named. The statement handler acts as the cursor ID.

You can have open only a single cursor per prepared statement. If you need several cursors, you must prepare several statements.

You cannot use a cursor for a statement that generates a result set if the statement is not supported in prepared mode. This includes statements such as `CHECK TABLE`, `HANDLER READ`, and `SHOW BINLOG EVENTS`.

C.3 Restrictions on Subqueries

- In MySQL 5.1 before 5.1.16, if you compare a `NULL` value to a subquery using `ALL`, `ANY`, or `SOME`, and the subquery returns an empty result, the comparison might evaluate to the nonstandard result of `NULL` rather than to `TRUE` or `FALSE`. As of 5.1.16, the comparison evaluates to `TRUE` or `FALSE` except for subqueries inside `IS NULL`, such as this:

```
SELECT ... WHERE NULL IN (SELECT ...) IS NULL
```

  As of 5.1.32, the `IS NULL` limitation is removed and the comparison evaluates to `TRUE` or `FALSE`.

- Subquery optimization for `IN` is not as effective as for the `=` operator or for the `IN(value_list)` operator.

  A typical case for poor `IN` subquery performance is when the subquery returns a small number of rows but the outer query returns a large number of rows to be compared to the subquery result.

  The problem is that, for a statement that uses an `IN` subquery, the optimizer rewrites it as a correlated subquery. Consider the following statement that uses an uncorrelated subquery:

```
SELECT ... FROM t1 WHERE t1.a IN (SELECT b FROM t2);
```

  The optimizer rewrites the statement to a correlated subquery:

```
SELECT ... FROM t1 WHERE EXISTS (SELECT 1 FROM t2 WHERE t2.b = t1.a);
```

If the inner and outer queries return M and N rows, respectively, the execution time becomes on the order of O(M×N), rather than O(M+N) as it would be for an uncorrelated subquery.

An implication is that an `IN` subquery can be much slower than a query written using an `IN(value_list)` operator that lists the same values that the subquery would return.

• In general, you cannot modify a table and select from the same table in a subquery. For example, this limitation applies to statements of the following forms:

```
DELETE FROM t WHERE ... (SELECT ... FROM t ...);
UPDATE t ... WHERE col = (SELECT ... FROM t ...);
{INSERT|REPLACE} INTO t (SELECT ... FROM t ...);
```

Exception: The preceding prohibition does not apply if you are using a subquery for the modified table in the `FROM` clause. Example:

```
UPDATE t ... WHERE col = (SELECT * FROM (SELECT ... FROM t...) AS _t ...);
```

Here the result from the subquery in the `FROM` clause is stored as a temporary table, so the relevant rows in `t` have already been selected by the time the update to `t` takes place.

• Row comparison operations are only partially supported:

• For `expr [NOT] IN subquery`, `expr` can be an n-tuple (specified using row constructor syntax) and the subquery can return rows of n-tuples. The permitted syntax is therefore more specifically expressed as `row_constructor [NOT] IN table_subquery`

• For `expr op {ALL|ANY|SOME} subquery`, `expr` must be a scalar value and the subquery must be a column subquery; it cannot return multiple-column rows.

In other words, for a subquery that returns rows of n-tuples, this is supported:

```
(expr_1, ..., expr_n) [NOT] IN table_subquery
```

But this is not supported:

```
(expr_1, ..., expr_n) op {ALL|ANY|SOME} subquery
```

The reason for supporting row comparisons for `IN` but not for the others is that `IN` is implemented by rewriting it as a sequence of `=` comparisons and `AND` operations. This approach cannot be used for `ALL`, `ANY`, or `SOME`.

• Prior to MySQL 5.1.12, row constructors were not well optimized; of the following two equivalent expressions, only the second could be optimized:

```
(col1, col2, ...) = (val1, val2, ...)
col1 = val1 AND col2 = val2 AND ...
```

In MySQL 5.1.12 and later, all row equalities are converted into conjunctions of equalities between row elements, and handled by the optimizer in the same way. (Bug #16081)

- Subqueries in the `FROM` clause cannot be correlated subqueries. They are materialized in whole (evaluated to produce a result set) before evaluating the outer query, so they cannot be evaluated per row of the outer query.

- MySQL does not support `LIMIT` in subqueries for certain subquery operators:

```
mysql> SELECT * FROM t1
    ->    WHERE s1 IN (SELECT s2 FROM t2 ORDER BY s1 LIMIT 1);
ERROR 1235 (42000): This version of MySQL doesn't yet support
 'LIMIT & IN/ALL/ANY/SOME subquery'
```

- The optimizer is more mature for joins than for subqueries, so in many cases a statement that uses a subquery can be executed more efficiently if you rewrite it as a join.

  An exception occurs for the case where an `IN` subquery can be rewritten as a `SELECT DISTINCT` join. Example:

```
SELECT col FROM t1 WHERE id_col IN (SELECT id_col2 FROM t2 WHERE condition);
```

  That statement can be rewritten as follows:

```
SELECT DISTINCT col FROM t1, t2 WHERE t1.id_col = t2.id_col AND condition;
```

  But in this case, the join requires an extra `DISTINCT` operation and is not more efficient than the subquery.

- MySQL permits a subquery to refer to a stored function that has data-modifying side effects such as inserting rows into a table. For example, if `f()` inserts rows, the following query can modify data:

```
SELECT ... WHERE x IN (SELECT f() ...);
```

  This behavior is an extension to the SQL standard. In MySQL, it can produce indeterminate results because `f()` might be executed a different number of times for different executions of a given query depending on how the optimizer chooses to handle it.

  For statement-based or mixed-format replication, one implication of this indeterminism is that such a query can produce different results on the master and its slaves.

C.4 Restrictions on Views

View processing is not optimized:

- It is not possible to create an index on a view.

- Indexes can be used for views processed using the merge algorithm. However, a view that is processed with the temptable algorithm is unable to take advantage of indexes on its underlying tables (although indexes can be used during generation of the temporary tables).

Subqueries cannot be used in the `FROM` clause of a view.

There is a general principle that you cannot modify a table and select from the same table in a subquery. See Section C.3, "Restrictions on Subqueries".

The same principle also applies if you select from a view that selects from the table, if the view selects from the table in a subquery and the view is evaluated using the merge algorithm. Example:

```
CREATE VIEW v1 AS
SELECT * FROM t2 WHERE EXISTS (SELECT 1 FROM t1 WHERE t1.a = t2.a);

UPDATE t1, v2 SET t1.a = 1 WHERE t1.b = v2.b;
```

If the view is evaluated using a temporary table, you *can* select from the table in the view subquery and still modify that table in the outer query. In this case the view will be stored in a temporary table and thus you are not really selecting from the table in a subquery and modifying it "at the same time." (This is another reason you might wish to force MySQL to use the temptable algorithm by specifying ALGORITHM = TEMPTABLE in the view definition.)

You can use DROP TABLE or ALTER TABLE to drop or alter a table that is used in a view definition. No warning results from the DROP or ALTER operation, even though this invalidates the view. Instead, an error occurs later, when the view is used. CHECK TABLE can be used to check for views that have been invalidated by DROP or ALTER operations.

A view definition is "frozen" by certain statements:

- If a statement prepared by PREPARE refers to a view, the view definition seen each time the statement is executed later will be the definition of the view at the time it was prepared. This is true even if the view definition is changed after the statement is prepared and before it is executed. Example:

  ```
  CREATE VIEW v AS SELECT RAND();
  PREPARE s FROM 'SELECT * FROM v';
  ALTER VIEW v AS SELECT NOW();
  EXECUTE s;
  ```

  The result returned by the EXECUTE statement is a random number, not the current date and time.

- If a statement in a stored routine refers to a view, the view definition seen by the statement are its definition the first time that statement is executed. For example, this means that if the statement is executed in a loop, further iterations of the statement see the same view definition, even if the definition is changed later in the loop. Example:

  ```
  CREATE VIEW v AS SELECT 1;
  delimiter //
  CREATE PROCEDURE p ()
  BEGIN
    DECLARE i INT DEFAULT 0;
    WHILE i < 5 DO
      SELECT * FROM v;
      SET i = i + 1;
      ALTER VIEW v AS SELECT 2;
    END WHILE;
  END;
  //
  delimiter ;
  CALL p();
  ```

  When the procedure p() is called, the SELECT returns 1 each time through the loop, even though the view definition is changed within the loop.

  As of MySQL 5.1.21, ALTER VIEW is prohibited within stored routines, so this restriction does not apply.

With regard to view updatability, the overall goal for views is that if any view is theoretically updatable, it should be updatable in practice. This includes views that have UNION in their definition. Not all views that are theoretically updatable can be updated. The initial view implementation was deliberately written this way to get usable, updatable views into MySQL as quickly as possible. Many theoretically updatable views can be updated now, but limitations still exist:

- Updatable views with subqueries anywhere other than in the `WHERE` clause. Some views that have subqueries in the `SELECT` list may be updatable.

- You cannot use `UPDATE` to update more than one underlying table of a view that is defined as a join.

- You cannot use `DELETE` to update a view that is defined as a join.

There exists a shortcoming with the current implementation of views. If a user is granted the basic privileges necessary to create a view (the `CREATE VIEW` and `SELECT` privileges), that user will be unable to call `SHOW CREATE VIEW` on that object unless the user is also granted the `SHOW VIEW` privilege.

That shortcoming can lead to problems backing up a database with `mysqldump`, which may fail due to insufficient privileges. This problem is described in Bug #22062.

The workaround to the problem is for the administrator to manually grant the `SHOW VIEW` privilege to users who are granted `CREATE VIEW`, since MySQL doesn't grant it implicitly when views are created.

Views do not have indexes, so index hints do not apply. Use of index hints when selecting from a view is not permitted.

`SHOW CREATE VIEW` displays view definitions using an `AS alias_name` clause for each column. If a column is created from an expression, the default alias is the expression text, which can be quite long. As of MySQL 5.1.23, aliases for column names in `CREATE VIEW` statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters). As a result, views created from the output of `SHOW CREATE VIEW` fail if any column alias exceeds 64 characters. This can cause problems in the following circumstances for views with too-long aliases:

- View definitions fail to replicate to newer slaves that enforce the column-length restriction.

- Dump files created with `mysqldump` cannot be loaded into servers that enforce the column-length restriction.

A workaround for either problem is to modify each problematic view definition to use aliases that provide shorter column names. Then the view will replicate properly, and can be dumped and reloaded without causing an error. To modify the definition, drop and create the view again with `DROP VIEW` and `CREATE VIEW`, or replace the definition with `CREATE OR REPLACE VIEW`.

For problems that occur when reloading view definitions in dump files, another workaround is to edit the dump file to modify its `CREATE VIEW` statements. However, this does not change the original view definitions, which may cause problems for subsequent dump operations.

C.5 Restrictions on XA Transactions

XA transaction support is limited to the `InnoDB` storage engine.

For "external XA," a MySQL server acts as a Resource Manager and client programs act as Transaction Managers. For "Internal XA", storage engines within a MySQL server act as RMs, and the server itself acts as a TM. Internal XA support is limited by the capabilities of individual storage engines. Internal XA is required for handling XA transactions that involve more than one storage engine. The implementation of internal XA requires that a storage engine support two-phase commit at the table handler level, and currently this is true only for `InnoDB`.

For `XA START`, the `JOIN` and `RESUME` clauses are not supported.

For `XA END`, the `SUSPEND [FOR MIGRATE]` clause is not supported.

The requirement that the `bqual` part of the `xid` value be different for each XA transaction within a global transaction is a limitation of the current MySQL XA implementation. It is not part of the XA specification.

If an XA transaction has reached the `PREPARED` state and the MySQL server is killed (for example, with `kill -9` on Unix) or shuts down abnormally, the transaction can be continued after the server restarts. However, if the client reconnects and commits the transaction, the transaction will be absent from the binary log even though it has been committed. This means the data and the binary log have gone out of synchrony. An implication is that XA cannot be used safely together with replication.

It is possible that the server will roll back a pending XA transaction, even one that has reached the `PREPARED` state. This happens if a client connection terminates and the server continues to run, or if clients are connected and the server shuts down gracefully. (In the latter case, the server marks each connection to be terminated, and then rolls back the `PREPARED` XA transaction associated with it.) It should be possible to commit or roll back a `PREPARED` XA transaction, but this cannot be done without changes to the binary logging mechanism.

C.6 Restrictions on Character Sets

- Identifiers are stored in `mysql` database tables (`user`, `db`, and so forth) using `utf8`, but identifiers can contain only characters in the Basic Multilingual Plane (BMP). Supplementary characters are not permitted in identifiers.

- The `ucs2` character sets has the following restrictions:

  - It cannot be used as a client character set, which means that it does not work for `SET NAMES` or `SET CHARACTER SET`. (See Section 10.1.4, "Connection Character Sets and Collations".)

  - It is currently not possible to use `LOAD DATA INFILE` to load data files that use this character set.

  - `FULLTEXT` indexes cannot be created on a column that this character set. However, you can perform `IN BOOLEAN MODE` searches on the column without an index.

  - The use of `ENCRYPT()` with this character set is not recommended because the underlying system call expects a string terminated by a zero byte.

- The `REGEXP` and `RLIKE` operators work in byte-wise fashion, so they are not multibyte safe and may produce unexpected results with multibyte character sets. In addition, these operators compare characters by their byte values and accented characters may not compare as equal even if a given collation treats them as equal.

C.7 Limits in MySQL

This section lists current limits in MySQL 5.1.

C.7.1 Limits on Joins

The maximum number of tables that can be referenced in a single join is 61. This also applies to the number of tables that can be referenced in the definition of a view.

C.7.2 Limits on Number of Databases and Tables

MySQL has no limit on the number of databases. The underlying file system may have a limit on the number of directories.

MySQL has no limit on the number of tables. The underlying file system may have a limit on the number of files that represent tables. Individual storage engines may impose engine-specific constraints. `InnoDB` permits up to 4 billion tables.

C.7.3 Limits on Table Size

The effective maximum table size for MySQL databases is usually determined by operating system constraints on file sizes, not by MySQL internal limits. The following table lists some examples of operating system file-size limits. This is only a rough guide and is not intended to be definitive. For the most up-to-date information, be sure to check the documentation specific to your operating system.

Operating System	File-size Limit
Win32 w/ FAT/FAT32	2GB/4GB
Win32 w/ NTFS	2TB (possibly larger)
Linux 2.2-Intel 32-bit	2GB (LFS: 4GB)
Linux 2.4+	(using ext3 file system) 4TB
Solaris 9/10	16TB
OS X w/ HFS+	2TB
NetWare w/NSS file system	8TB

Windows users, please note that FAT and VFAT (FAT32) are *not* considered suitable for production use with MySQL. Use NTFS instead.

On Linux 2.2, you can get `MyISAM` tables larger than 2GB in size by using the Large File Support (LFS) patch for the ext2 file system. Most current Linux distributions are based on kernel 2.4 or higher and include all the required LFS patches. On Linux 2.4, patches also exist for ReiserFS to get support for big files (up to 2TB). With JFS and XFS, petabyte and larger files are possible on Linux.

For a detailed overview about LFS in Linux, have a look at Andreas Jaeger's *Large File Support in Linux* page at http://www.suse.de/~aj/linux_lfs.html.

If you do encounter a full-table error, there are several reasons why it might have occurred:

- The disk might be full.

- The `InnoDB` storage engine maintains `InnoDB` tables within a tablespace that can be created from several files. This enables a table to exceed the maximum individual file size. The tablespace can include raw disk partitions, which permits extremely large tables. The maximum tablespace size is 64TB.

  If you are using `InnoDB` tables and run out of room in the `InnoDB` tablespace. In this case, the solution is to extend the `InnoDB` tablespace. See Section 14.6.5.2, "Changing the Number or Size of InnoDB Redo Log Files".

- You are using `MyISAM` tables on an operating system that supports files only up to 2GB in size and you have hit this limit for the data file or index file.

- You are using a `MyISAM` table and the space required for the table exceeds what is permitted by the internal pointer size. `MyISAM` permits data and index files to grow up to 256TB by default, but this limit can be changed up to the maximum permissible size of 65,536TB ($256^7 - 1$ bytes).

  If you need a `MyISAM` table that is larger than the default limit and your operating system supports large files, the `CREATE TABLE` statement supports `AVG_ROW_LENGTH` and `MAX_ROWS` options. See Section 13.1.17, "CREATE TABLE Syntax". The server uses these options to determine how large a table to permit.

  If the pointer size is too small for an existing table, you can change the options with `ALTER TABLE` to increase a table's maximum permissible size. See Section 13.1.7, "ALTER TABLE Syntax".

```
ALTER TABLE tbl_name MAX_ROWS=1000000000 AVG_ROW_LENGTH=nnn;
```

You have to specify `AVG_ROW_LENGTH` only for tables with `BLOB` or `TEXT` columns; in this case, MySQL can't optimize the space required based only on the number of rows.

To change the default size limit for `MyISAM` tables, set the `myisam_data_pointer_size`, which sets the number of bytes used for internal row pointers. The value is used to set the pointer size for new tables if you do not specify the `MAX_ROWS` option. The value of `myisam_data_pointer_size` can be from 2 to 7. A value of 4 permits tables up to 4GB; a value of 6 permits tables up to 256TB.

You can check the maximum data and index sizes by using this statement:

```
SHOW TABLE STATUS FROM db_name LIKE 'tbl_name';
```

You also can use `myisamchk -dv /path/to/table-index-file`. See Section 13.7.5, "SHOW Syntax", or Section 4.6.3, "`myisamchk` — MyISAM Table-Maintenance Utility".

Other ways to work around file-size limits for `MyISAM` tables are as follows:

- If your large table is read only, you can use `myisampack` to compress it. `myisampack` usually compresses a table by at least 50%, so you can have, in effect, much bigger tables. `myisampack` also can merge multiple tables into a single table. See Section 4.6.5, "`myisampack` — Generate Compressed, Read-Only MyISAM Tables".

- MySQL includes a `MERGE` library that enables you to handle a collection of `MyISAM` tables that have identical structure as a single `MERGE` table. See Section 14.8, "The MERGE Storage Engine".

- You are using the `NDB` storage engine, in which case you need to increase the values for the `DataMemory` and `IndexMemory` configuration parameters in your `config.ini` file. See Section 17.3.2.1, "MySQL Cluster Data Node Configuration Parameters".

- You are using the `MEMORY` (`HEAP`) storage engine; in this case you need to increase the value of the `max_heap_table_size` system variable. See Section 5.1.4, "Server System Variables".

C.7.4 Limits on Table Column Count and Row Size

There is a hard limit of 4096 columns per table, but the effective maximum may be less for a given table. The exact limit depends on several interacting factors.

- Every table (regardless of storage engine) has a maximum row size of 65,535 bytes. Storage engines may place additional constraints on this limit, reducing the effective maximum row size.

  The maximum row size constrains the number (and possibly size) of columns because the total length of all columns cannot exceed this size. For example, `utf8` characters require up to three bytes per character, so for a `CHAR(255) CHARACTER SET utf8` column, the server must allocate 255 × 3 = 765 bytes per value. Consequently, a table cannot contain more than 65,535 / 765 = 85 such columns.

  Storage for variable-length columns includes length bytes, which are assessed against the row size. For example, a `VARCHAR(255) CHARACTER SET utf8` column takes two bytes to store the length of the value, so each value can take up to 767 bytes.

  `BLOB` and `TEXT` columns count from one to four plus eight bytes each toward the row-size limit because their contents are stored separately from the rest of the row.

  Declaring columns `NULL` can reduce the maximum number of columns permitted. For `MyISAM` tables, `NULL` columns require additional space in the row to record whether their values are `NULL`. Each `NULL`

column takes one bit extra, rounded up to the nearest byte. The maximum row length in bytes can be calculated as follows:

```
row length = 1
             + (sum of column lengths)
             + (number of NULL columns + delete_flag + 7)/8
             + (number of variable-length columns)
```

delete_flag is 1 for tables with static row format. Static tables use a bit in the row record for a flag that indicates whether the row has been deleted. *delete_flag* is 0 for dynamic tables because the flag is stored in the dynamic row header. For information about `MyISAM` table formats, see Section 14.5.3, "MyISAM Table Storage Formats".

For `InnoDB` tables, storage size is the same for `NULL` and `NOT NULL` columns, so the preceding calculations do not apply.

The following statement to create table `t1` succeeds because the columns require 32,765 + 2 bytes and 32,766 + 2 bytes, which falls within the maximum row size of 65,535 bytes:

```
mysql> CREATE TABLE t1
    -> (c1 VARCHAR(32765) NOT NULL, c2 VARCHAR(32766) NOT NULL)
    -> ENGINE = MyISAM CHARACTER SET latin1;
Query OK, 0 rows affected (0.02 sec)
```

The following statement to create table `t2` fails because the columns are `NULL` and `MyISAM` requires additional space that causes the row size to exceed 65,535 bytes:

```
mysql> CREATE TABLE t2
    -> (c1 VARCHAR(32765) NULL, c2 VARCHAR(32766) NULL)
    -> ENGINE = MyISAM CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the
used table type, not counting BLOBs, is 65535. You have to change some
columns to TEXT or BLOBs
```

The following statement to create table `t3` fails because, although the column length is within the maximum length of 65,535 bytes, two additional bytes are required to record the length, which causes the row size to exceed 65,535 bytes:

```
mysql> CREATE TABLE t3
    -> (c1 VARCHAR(65535) NOT NULL)
    -> ENGINE = MyISAM CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the
used table type, not counting BLOBs, is 65535. You have to change some
columns to TEXT or BLOBs
```

Reducing the column length to 65,533 or less permits the statement to succeed.

- Individual storage engines might impose additional restrictions that limit table column count. Examples:

  - `InnoDB` permits up to 1000 columns.

  - `InnoDB` restricts row size to something less than half a database page (approximately 8000 bytes), not including `VARBINARY`, `VARCHAR`, `BLOB`, or `TEXT` columns. For more information, see Section 14.6.6.7, "Limits on InnoDB Tables".

  - Different `InnoDB` storage formats (`COMPRESSED`, `REDUNDANT`) use different amounts of page header and trailer data, which affects the amount of storage available for rows.

- Each table has an `.frm` file that contains the table definition. The definition affects the content of this file in ways that may affect the number of columns permitted in the table. For more information, see Section C.7.5, "Limits Imposed by .frm File Structure".

C.7.5 Limits Imposed by .frm File Structure

Each table has an `.frm` file that contains the table definition. The server uses the following expression to check some of the table information stored in the file against an upper limit of 64KB:

```
if (info_length+(ulong) create_fields.elements*FCOMP+288+
    n_length+int_length+com_length > 65535L || int_count > 255)
```

The portion of the information stored in the `.frm` file that is checked against the expression cannot grow beyond the 64KB limit, so if the table definition reaches this size, no more columns can be added.

The relevant factors in the expression are:

- `info_length` is space needed for "screens." This is related to MySQL's Unireg heritage.

- `create_fields.elements` is the number of columns.

- `FCOMP` is 17.

- `n_length` is the total length of all column names, including one byte per name as a separator.

- `int_length` is related to the list of values for `ENUM` and `SET` columns. In this context, "int" does not mean "integer." It means "interval," a term that refers collectively to `ENUM` and `SET` columns.

- `int_count` is the number of unique `ENUM` and `SET` definitions.

- `com_length` is the total length of column comments.

The expression just described has several implications for permitted table definitions:

- Using long column names can reduce the maximum number of columns, as can the inclusion of `ENUM` or `SET` columns, or use of column comments.

- A table can have no more than 255 unique `ENUM` and `SET` definitions. Columns with identical element lists are considered the same against this limt. For example, if a table contains these two columns, they count as one (not two) toward this limit because the definitions are identical:

```
e1 ENUM('a','b','c')
e2 ENUM('a','b','c')
```

- The sum of the length of element names in the unique `ENUM` and `SET` definitions counts toward the 64KB limit, so although the theoretical limit on number of elements in a given `ENUM` column is 65,535, the practical limit is less than 3000.

C.7.6 Windows Platform Limitations

The following limitations apply to use of MySQL on the Windows platform:

- **Number of file descriptors**

  The number of open file descriptors on Windows is limited to a maximum of 2048, which may limit the ability to open a large number of tables simultaneously. This limit is due not to Windows but to C runtime library compatibility functions used to open files on Windows that use the POSIX compatibility layer.

This limitation will also cause problems if you try to set `open_files_limit` to a value greater than the 2048 file limit.

- **Process memory**

  On Windows 32-bit platforms it is not possible by default to use more than 2GB of RAM within a single process, including MySQL. This is because the physical address limit on Windows 32-bit is 4GB and the default setting within Windows is to split the virtual address space between kernel (2GB) and user/ applications (2GB).

  Some versions of Windows have a boot time setting to enable larger applications by reducing the kernel application. Alternatively, to use more than 2GB, use a 64-bit version of Windows.

- **File system aliases**

  When using `MyISAM` tables, you cannot use aliases within Windows link to the data files on another volume and then link back to the main MySQL `datadir` location.

  This facility is often used to move the data and index files to a RAID or other fast solution, while retaining the main `.frm` files in the default data directory configured with the `datadir` option.

- **Limited number of ports**

  Windows systems have about 4,000 ports available for client connections, and after a connection on a port closes, it takes two to four minutes before the port can be reused. In situations where clients connect to and disconnect from the server at a high rate, it is possible for all available ports to be used up before closed ports become available again. If this happens, the MySQL server appears to be unresponsive even though it is running. Ports may be used by other applications running on the machine as well, in which case the number of ports available to MySQL is lower.

  For more information about this problem, see http://support.microsoft.com/default.aspx?scid=kb;en- us;196271.

- **Concurrent reads**

  MySQL depends on the `pread()` and `pwrite()` system calls to be able to mix `INSERT` and `SELECT`. We use mutexes to emulate `pread()` and `pwrite()`. We intend to replace the file level interface with a virtual interface in the future so that we can use the `readfile()`/`writefile()` interface to get more speed. The current implementation limits the number of open files that MySQL 5.1 can use to 2,048, which means that you cannot run as many concurrent threads on Windows as on Unix.

  This problem is fixed in MySQL 5.5.

- **Blocking read**

  Before MySQL 5.1.41, MySQL uses a blocking read for each connection. That has the following implications if named-pipe connections are enabled:

  - A connection is not disconnected automatically after eight hours, as happens with the Unix version of MySQL.

  - If a connection hangs, it is not possible to break it without killing MySQL.

  - `mysqladmin kill` does not work on a sleeping connection.

  - `mysqladmin shutdown` cannot abort as long as there are sleeping connections.

- **DROP DATABASE**

  You cannot drop a database that is in use by another session.

- **Case-insensitive names**

  File names are not case sensitive on Windows, so MySQL database and table names are also not case sensitive on Windows. The only restriction is that database and table names must be specified using the same case throughout a given statement. See Section 9.2.2, "Identifier Case Sensitivity".

- **Directory and file names**

  On Windows, MySQL Server supports only directory and file names that are compatible with the current ANSI code pages. For example, the following Japanese directory name will not work in the Western locale (code page 1252):

  ```
  datadir="C:/私たちのプロジェクトのデータ"
  ```

  The same limitation applies to directory and file names referred to in SQL statements, such as the data file path name in LOAD DATA INFILE.

- **The "\" path name separator character**

  Path name components in Windows are separated by the "\" character, which is also the escape character in MySQL. If you are using LOAD DATA INFILE or SELECT ... INTO OUTFILE, use Unix-style file names with "/" characters:

  ```
  mysql> LOAD DATA INFILE 'C:/tmp/skr.txt' INTO TABLE skr;
  mysql> SELECT * INTO OUTFILE 'C:/tmp/skr.txt' FROM skr;
  ```

  Alternatively, you must double the "\" character:

  ```
  mysql> LOAD DATA INFILE 'C:\\tmp\\skr.txt' INTO TABLE skr;
  mysql> SELECT * INTO OUTFILE 'C:\\tmp\\skr.txt' FROM skr;
  ```

- **Problems with pipes**

  Pipes do not work reliably from the Windows command-line prompt. If the pipe includes the character ^Z / CHAR(24), Windows thinks that it has encountered end-of-file and aborts the program.

  This is mainly a problem when you try to apply a binary log as follows:

  ```
  C:\> mysqlbinlog binary_log_file | mysql --user=root
  ```

  If you have a problem applying the log and suspect that it is because of a ^Z / CHAR(24) character, you can use the following workaround:

  ```
  C:\> mysqlbinlog binary_log_file --result-file=/tmp/bin.sql
  C:\> mysql --user=root --execute "source /tmp/bin.sql"
  ```

  The latter command also can be used to reliably read in any SQL file that may contain binary data.

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